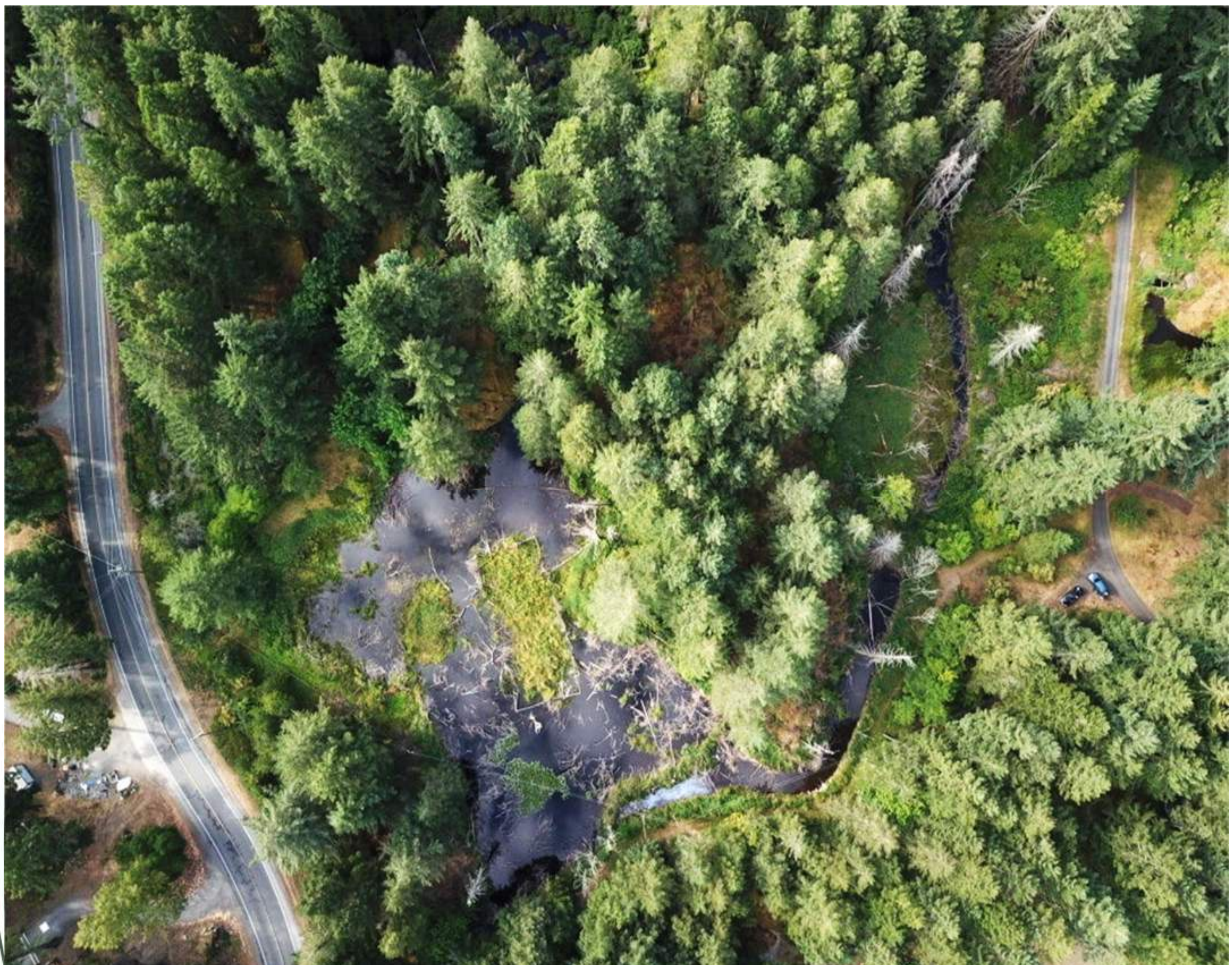
2023 Research Project

Beaver Wetland Assessment

A Mary Lake Nature Sanctuary Project



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Executive Summary

Mary Lake Nature Sanctuary is located approximately 25 kilometers northeast from Victoria, British Columbia and sits on 17 hectares of land. The sanctuary lies within the traditional territory of the WSÁNEC (Saanich) Coast Salish First Nations, as well as the Highlands District of the Capital Region District (CRD) of Vancouver Island (GVGS, n.d.). Wild Riparian Conservation (WRC) was retained by Greater Victoria Greenbelt Society (GVGS) to conduct baseline studies and to generate a report outlining the health and current state of Mary Lake and the attached Beaver Wetland located on the eastern side of the property adjacent to Millstream Road.

Wild Riparian Conservation continued the overview assessment of the water quality of Mary Lake, with the addition of the Beaver Wetland along the property lines this year. Mary Lake Nature Sanctuary has had a multi-year monitoring program since 2019 focusing on water quality monitoring for Mary Lake on a bi-weekly basis for *in situ* water parameters for pH, conductivity, total dissolved solids (TDS), and dissolved oxygen (DO), as well, quarterly *ex situ* sampling involving alkalinity, nitrogen, phosphorus, and fecal coliform bacteria. During the 2023 sampling year, five sites in the Beaver Wetland were also added to the monitoring program for water quality monitoring with the same parameters and timelines as Mary Lake. A riparian vegetation assessment recorded plant and animal species that were observed in the area. The assessment identified wildlife trees in and around the Wetland, vegetation species, as well as areas of disturbance caused by other animals, invasive species, or anthropogenic activities (such as the road or subdivision along the perimeter of the property). Soil samples were taken adjacent to Millstream Road and the Beaver Wetland and analyzed for heavy metal contamination from road runoff pollution into the wetland. Gee trapping for aquatic species present was conducted to target invertebrates before water levels dropped during the summer months.

Preliminary field work was conducted at Mary Lake and Beaver Wetland with *in situ* water quality samples taken bi-weekly and sample site locations chosen. A small section of the riparian zone was assessed at Beaver Wetland as well. The results concluded the Beaver Wetland is a marsh, and overall is healthy; however, there were elevated heavy metal concentrations found in the sediment samples.

Acknowledgements

Wild Riparian Conservation would like to acknowledge the land on which Mary Lake Nature Sanctuary resides. The property is located on the traditional and ancestral lands of the WSÁNEC Coast Salish Peoples. We recognize the important role the WSÁNEC Peoples have played within the protection and stewardship of Mary Lake Nature Sanctuary as well as the Highlands area.

We also want to acknowledge our faculty advisors, Dr. Jonathan Moran, Sharon McMillan, and Dr. Mickie Noble who provided much guidance on the research and data collection methods regarding the project. A special thanks to our sponsors, the Greater Victoria Greenbelt Society, specifically Eric Bonham, Bob McMinn, and Emma Ross for their support throughout the project and knowledge given about the site.

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Acronyms and Abbreviations

CCME: Canadian Council of Ministers of the Environment
DO: Dissolved Oxygen
DBH: Diameter at Breast Height, standard = 1.37m
GVGS: Greater Victoria Greenbelt Society
MF: Membrane Filtration
MLNS: Mary Lake Nature Sanctuary
RRU: Royal Roads University
RRUEC: RRU Environmental Consulting
TDS: Total Dissolved Solids
WRC: Wild Riparian Conservation
XRF: X-Ray Fluorescence
MF: Membrane Filtration
MPN: Most Probable Number
EIEC: East Island Environmental Consulting
VIEC: Van Isle Eco Consulting

Glossary of Terms

Alkalinity: Measure of buffering capacity of pH to remain at a relatively stable level within water.

Conductivity: The ability for water to pass electrical current relating to ion concentration within the water (Fondriest Environmental, 2014).

Deionized Water: Water which does not contain an ion concentration, also referred to as “pure water” (Fondriest Environmental Inc, 2014).

Dissolved Oxygen: Presence of free non-compound (not bonded) oxygen within a body of water (Fondriest Environmental Inc, 2013).

Fecal Coliforms: Group of bacteria typically present within human and animal waste (e.g., *E.coli*) used to indicate the possible presence of disease-causing organisms.

Lake: Slow moving water that occupies a depression and is surrounded by land; size and volume vary depending on the land depressions; this definition includes ponds (Government of New Brunswick, 2012).

Nitrates: Naturally-occurring chemical compounds containing nitrogen and oxygen atoms.

pH: Negative logarithm of the molecular concentration of hydrogen ions to determine acid or base level of a substance.

Phosphates: Naturally-occurring chemical compounds containing phosphorus and oxygen atoms.

Riparian Area: Vegetation zone around a waterbody that houses a variety of plant and animal life (BC Ministry of Agriculture and Food, 2023).

Stream: Flowing waterway where gravity carries water from high elevation to a lower elevation, changing characteristics as flow rate slows. Streams, rivers, and creeks are all under this definition, differing in size; creeks are smallest, rivers are largest (Forest Preserve District Will County, 2023).

Total Dissolved Solids: Total amount of substances dissolved in the water.

Wetland: Land that is covered by water either seasonally or permanently that functions as its own ecosystem, designated as a swamp (Ws), marsh (Wm), shallow water (aquatic) (Wa), bog (Wb), or a fen (Wf) (MacKenzie, W. H., & Moran, J. R. 2004).

> **Swamp (Ws):** Nutrient-rich wetland with significant groundwater inflow, with elevated areas allowing the growth of large trees or tall shrubs; swamp gas is characteristic (MacKenzie, W. H., & Moran, J. R. 2004).
>
> **Marsh (Wm):** Permanent or seasonal flooded area of a mineral wetland, dominated by emergent grass-like vegetation, often found at the edge of streams or lakes (MacKenzie, W. H., & Moran, J. R. 2004).
>
> **Shallow-water (aquatic) (Wa):** Shallow-water wetland that is permanently flooded, dominated by rooted submerged and floating plants, while supporting aquatic life (MacKenzie, W. H., & Moran, J. R. 2004).
>
> **Bog (Wb):** Nutrient-poor, acidic peat moss ecosystem, isolated from groundwater. The ground is spongy, consisting of decaying plant matter (MacKenzie, W. H., & Moran, J. R. 2004).
>
> **Fen (Wf):** Nutrient-medium peat moss ecosystem, dominated by sedges and moss. Fens are fed by groundwater (MacKenzie, W. H., & Moran, J. R. 2004).

1.0 Introduction

1.1 Project Overview

In conjunction with Royal Roads University, four undergraduate students in the Bachelor of Science in Environmental Science program have undertaken the 2023 Mary Lake Nature Sanctuary Major Project. The students Harrison Craig, Kimberly Groome, Jaeden Jones, and Kyla Macilroy make up the Wild Riparian Conservation (WRC) research group.

For the fourth consecutive year of monitoring on the Mary Lake Nature Sanctuary (MLNS) property, the sponsor and client Greater Victoria Greenbelt Society (GVGS) have collaborated with the Royal Roads University research project to assess the health of the area through various monitoring and reporting efforts. Initiated in January 2023, WRC and GVGS have agreed the 2023 MLNS project would entail (1) expansion of databases from previous research groups, (2) creation of baselines of new concerns of heavy metal contamination, lower water quality, and ecosystem health through qualitative and quantitative assessment, (3) provision of analytical methodologies of survey and laboratory techniques, and (4) development of future recommendations for the continuation the MLNS research project.

After deliberation with GVGS, it was determined that WRC would develop an ecological report encompassing various components to assess the health of the ecosystem and buffer zone of the large wetland habitat residing on the east side of the property. Located along the border of Millstream Road, the wetland, given the name Beaver Wetland, is an ecosystem of concern within MLNS as it entails a rich history of past and current human interaction with a high potential for contamination. Millstream Creek directly flows through Beaver Wetland providing essential habitat and pathways for various organisms throughout the area. Optimum monitoring protocols were created based on literature review, and sampling points within Beaver Wetland were implemented. The ecological report encompassed vegetation assessment of the wetland perimeter including wildlife trees, sediment heavy metal testing, both *in situ* and *ex situ* water quality evaluation, gee trapping for the presence of crayfish, and incidental observations, particularly mammalian presence. Assessment of all these components allowed the team to create a baseline report reviewing the overall health of Beaver Wetland. This baseline ecological report will benefit future researchers by providing a point of comparison for future environmental and anthropogenic activities prevalent in the area.

Similar to past MLNS reports (VIEC, 2019; RRUEC, 2020; EIEC, 2022), the continuation of water quality monitoring of past sites was conducted by WRC. GVGS requested the addition of a new lake site to the sampling. Continual water quality monitoring allows for the properties of water bodies to be compared over time to track chemical or physical differences within water quality of the sampled sites.

1.2 Scope of Project

As stated by the sponsor, the goal of this major project is to assess the water quality of Mary Lake and complete field studies at the Beaver Wetland on the MLNS property. The timeframe to complete field and laboratory analysis to then compile findings into a written ecological report for this project was January to August 2023. Information gathered showcases the overall health of the ecosystems within MLNS and highlights possible changes that occur over time. The sections below outline the major requirements of the project.

1.2.1 Beaver Wetland Riparian Assessment

I. Assess the wetland perimeter marking areas of interest for sampling measures.
II. Facilitate and organize riparian assessment methodologies, including vegetation and wildlife tree surveys, sediment collection, water quality measures, gee trapping, and overall surveillance of incidentals via media observations.
III. Develop sampling protocol for all riparian assessments to occur over the duration of the project, including *in situ* procedures, table creation, and time management through the allocation of sampling days.
IV. Divide the outer perimeter of the wetland into polygons identifying specific locations of assessment as well as creation of set sampling points used in riparian assessment.
V. Analysis of all data collected and presentation in a clear effective way for easy comprehension of material and results.
VI. Compile findings, methodologies, and final format protocols into a report for use in future projects.

1.2.2 Continued Water Quality Monitoring

I. Review water quality protocols from past projects (VIEC, 2019; RRUEC, 2020; EIEC, 2022) and implement past recommendations for continuing MLNS water quality monitoring.

II. Create an organized schedule for sampling and laboratory analysis by implementing a large laboratory procedure encompassing the entirety of the 2023 MLNS project (incorporating wetland sampling sites).
III. Perform bi-weekly *in situ* water quality measurements consisting of temperature, pH, dissolved oxygen, conductivity, and total dissolved solids.
IV. Perform at minimum two *ex situ* laboratory assessments of water quality measurements consisting of separate alkalinity, nitrates, phosphates, and fecal coliform testing.
V. Present all results clearly and comprehensively through the creation of tables and figures. State seasonal changes and/or similarities in all parameters, and if applicable, compare findings to past water quality measurements from MLNS.
VI. Compile findings, methodologies, and final format protocols into an ecological report suitable for use in future projects.

2.0 History and Background

2.1 Site History

Mary Lake is located in the Highlands district of British Columbia on the traditional territory of the W̱SÁNEĆ (Saanich) Coast Salish First Nations. This area was traditionally lived on by the Pauquachin, Tsartlip, Tsawout, Tseycum, Esquimalt, and W̱MÍYEŦEN (Songhees) peoples who were and continue to be stewards of the land.

The property was first taken over as private property in 1887. The property was owned by Albert Reginald Manzer from 1935 to 1947. Manzer installed an earthen dam, flooding the hardhack swamp and creating the lake. In addition to the dam installation, most of the old growth trees on the property were logged. Gertrude Mabel Snider, a local artist, bought the property in 1947 and shifted the focus of the area to conservation. Snider conserved the area until 1963 when she sold the property to fellow conservationists Peter and Hazel Brotherston. The Brotherstons installed a concrete dam which led to the lake looking as it does presently as well as a fishpond and ladder in South Earsman creek. The land was purchased again in 2016 and is currently owned by the Greater Victoria Greenbelt Society, who continue to conserve the land (GVGSa). During the spring of 2023, MLNS underwent a name change to W̱MÍEŦEN Nature Sanctuary; in this report we will refer to the site as MLNS.

2.2 Background Information on Mary Lake Nature Sanctuary

Mary Lake Nature Sanctuary is located in the Highlands District of British Columbia, Canada. The address is 1772 Millstream Rd, Victoria, BC, V9B 6E3. The sanctuary consists of 42 acres, 7 of which comprise Mary Lake. There are several streams that flow into and out of the lake including Dead Deer Creek, Millstream Creek, and North Earsman Creek as well as multiple wetlands (see Figure 1.1). These are all part of the larger Millstream Creek Watershed which begins in the Gowlland Tod range and flows through to Esquimalt Harbour (GVGSb).

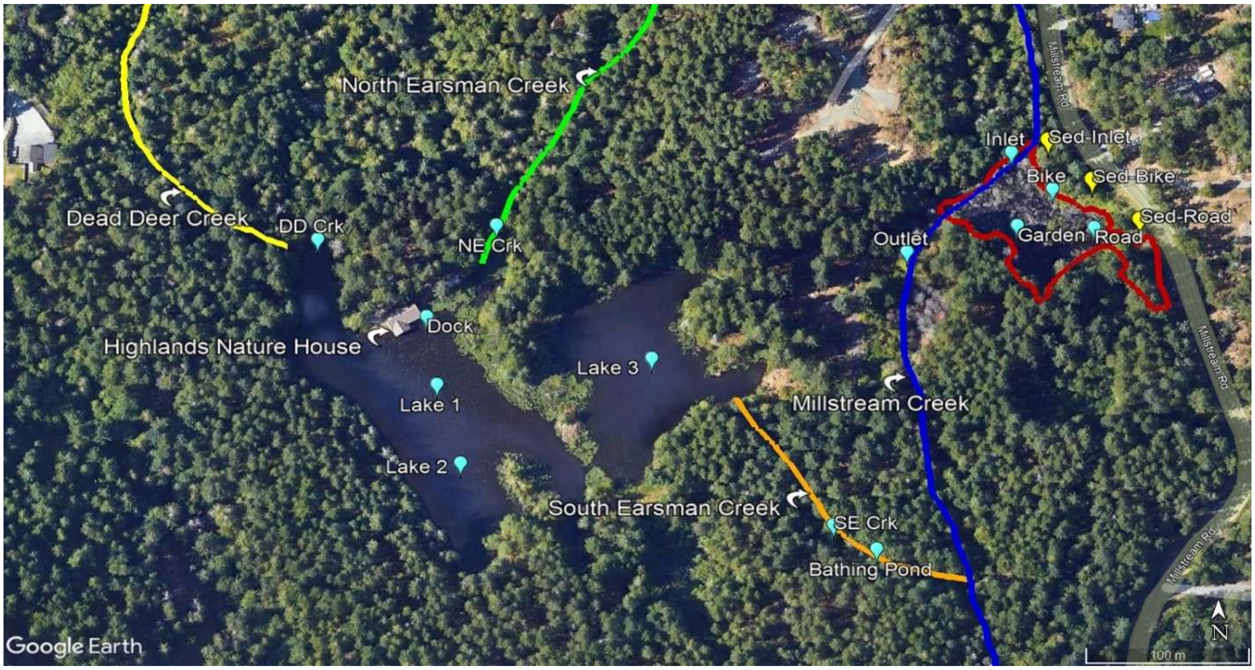

Figure 1.1. Map of water quality and sediment sampling sites at Mary Lake Nature Sanctuary and the Beaver Wetland in relation to the creeks; Map made in Google Earth Pro by Kimberly Groome; July 23rd, 2023, NAD 83 WSGS U10.

2.3 Background Information on Water Quality

The long-term water quality study began with the creation of surface water sampling sites including sites near the outflow of Dead Deer Creek and South Earsman as well as near the inflow of North Earsman Creek and a collection off the dock at Mary Lake Nature House (Van Isle Eco Consulting, 2019). Other surface water sampling sites include three lake sites with a 2m depth collection associated with them. The established water quality monitoring by previous RRU students includes *in situ* and *ex situ* protocols. The *in-situ* water quality testing has included dissolved oxygen, pH, water temperature, conductivity, and total dissolved solids. The *ex-situ* quality testing has included alkalinity, nitrates, phosphates, and fecal coliforms (VIEC, 2019; RRUEC, 2020; EIEC, 2022).

Wild Riparian Conservation (WRC) introduced five new water quality sampling sites in the Beaver Wetland as a part of the goal of gaining an understanding of the Beaver Wetland. The sites were spread throughout the wetland area including sampling sites at the inlet and outlet creeks. The other three sites of interest were chosen due to their proximity to areas of interest. These include near the historic garden by Millstream Road, as well as an area with submerged bicycles and metal fencing (see Figure 1.1). These sites were measured at the surface as water quality was anticipated to change as the wetland water levels dropped in the summer.

2.4 Background Information on Riparian Assessment

Riparian areas are transition zones between aquatic and dry upland habitat, creating bio productive zones of lush moisture-loving vegetation surrounding a wetland, lake, stream, or river (BC Ministry of Agriculture and Food, 2023). Riparian areas have many ecological functions including filtering of nutrients or contaminants from water, sequestering carbon, providing shade, and reducing solar heat gain, as well as maintaining stream banks and biodiversity (BC Ministry of Agriculture and Food, 2023). Managing a riparian area encompasses soil and water quality analysis, as well as documentation of plant growth, wildlife evidence and their corresponding habitats throughout the seasons. The vegetation survey was conducted in the riparian zone of the Beaver Wetland. The wetland was broken into 23 polygons, each 15m in length following provincial standards (Fletcher, et al. 2021). Plants were identified by species or genus, categorized based on type, then assessed for % cover, vegetation stage, and species vigor. Lichen and moss were assigned a “Lichen/moss abundance code” (Table A.23). Trees that have not been identified as wildlife trees were also counted in the vegetation survey. The vegetation survey did not include the wildlife trees as they had their own assessment.

A wildlife tree is a standing dead or decaying tree, with a minimum height of 15m and a minimum DBH of 30cm, preferably up to 70cm on the coast, with a tree class between two and six (BC Ministry of Environment, 2012). For deciduous trees, classes range from one to six, with one and two being stages of life, while three, four, and five are stages of dead trees; “hard”, “spongy”, and “soft”, respectively. Class six is past wildlife tree status and is a “dead fallen tree” (BC Ministry of Environment, 2012). For conifers tree classes range from one to nine, with one and two being “alive”, three to five different “hard” stages, six is “spongy”, seven and eight are “soft”, and nine is a “dead fallen tree” (BC Ministry of Environment, 2012). Other wildlife tree characteristics include sloughing bark, broken tops, tree leans greater than 15°, with excavations, cavities, and/or stem damage (BC Ministry of Environment, 2012). These characteristics provide different assets to different species, for example sloughing bark provides roosting habitat for bats, and broken tops and dead limbs provide perching and nesting areas for large birds. Excavation by primary nesters provides important habitat for secondary nesters, who move in once the tree has been abandoned. Trees species with the highest wildlife tree value are 1. Douglas-fir *(Pseudotsuga menziesii)* and Western larch *(Larix occidentalis)*, 2. Ponderosa pine *(Pinus ponderosa)*, 3. Trembling aspen *(Populus tremuloides)* and cottonwood *(Populus trichocarpa)*, 4. Cedars *(Thuja* sp.*)* with large cavities, and 5. Hemlocks *(Tsuga* sp.*)* and true firs *(Abies* sp.*)* (BC Ministry of Environment, 2012). Each tree is identified by species, and classed based on its life stage, and measured for height, and diameter at breast height

(DBH). The trees could be classed further as “Danger Trees” if this were a work site where excavation or building were happening. Since this is only a survey site for ecosystem health, all trees are classed as wildlife trees and are thereby inherently safe under the Level of Disturbance (LOD) section (Fletcher, et al. 2021).

3.0 Materials and Methods

3.1 Water quality methods

3.1.1 *In situ*

In situ water quality sampling occurred bi-weekly starting February 7, 2023, ending June 2023. One surface water sample was taken from each of seven sampling sites within the lake as well as one deep water sample (~2m) from three of the seven sites (lake 1, 2, & 3). Five surface water samples were taken from different locations throughout the wetland. Collection of samples was undertaken via canoe or walking/wadding dependent on site location. Water quality information was collected with handheld meters assessing pH, DO, TDS, Conductivity, and Temperature. Deep samples were obtained with a Van-Dorn bottle dropped to the desired depth then placed into a 500ml plastic bottle.

- pH meter
- Conductivity, DO, TDS, Temperature meter
- Van-Dorn Bottle
- 500ml plastic bottle
- Canoe
- Lifejackets

3.1.2 *Ex situ*

Sampling occurred once a quarter, in the months of March and June. Collected water samples were be taken from the same sites as the *in-situ* water quality samples during the bi-weekly water sampling. Labeled water samples were transported to the Royal Roads University Laboratory to be analyzed for nitrate, phosphate, alkalinity, and fecal coliform levels. See 2023 Mary Lake Laboratory Procedure.docx for detailed laboratory procedures.

- 15 x 1L plastic bottles
- Tape and marker
- Van-Dorn bottle
- Canoe and lifejackets
- Graduated cylinder
- 250ml beakers
- Distilled water
- 1.0M NaOH and 1.0M HCl
- KHP Standards
- pH meter
- pH Standards
- Burette, magnetic stir bar, stir plate.
- 50 ppm nitrate stock solution
- 125ml Erlenmeyer flask
- 1.0ml (1:4 diluted) HCl, 1.0ml Sulfuric acid reagent, 1.0ml Zn/NaCl

- 1.0ml naphthylamine hydrochloride
- Spectrophotometer
- 100 ppm phosphate stock solution
- 2.0ml ammonium molybdate solution
- Stannous chloride solution
- Test tubes, loop, Bunsen burner
- m-FC plates (2 per sample)
- Membrane filter apparatus
- Forceps
- Incubator

3.2 Sediment Sampling

3.2.1 *In situ*

In situ sediment sampling was undertaken at three sites; five samples from each (total 15) were collected with a hand trowel and returned to the lab for weighing and drying for further analysis. For the sediment collection, a 1m-by-1m plot was created at the inlet and bike sites and divided into four quadrants. The five samples were collected in the following order: middle, top left, top right, bottom left, bottom right. For the road site, the five sediment samples were collected in a straight line along the road with 2m in between each sample.

- Hand trowel
- Ziploc bags
- Tape and marker
- Wash bin and soap
- Deionized water

Sediment was collected using a trowel and placed in labelled Ziploc bags. To avoid cross contamination, the trowel was cleaned with detergent between uses. Pictures were taken of each plot.

3.2.2 *Ex situ*

Sediment wet weight was measured in the lab then the samples were left in weigh boats to dry in the fume hood. Once the sediment samples were dry, the dry weight was recorded. The samples were sifted, with the sieves being cleaned between each use and approximately 10g was used for X-Ray Fluorescence (XRF) analysis. Duplicates were made every five samples. Aliquots of each were rehydrated and analyzed for pH and conductivity.

- Scale and weigh boats
- pH meter and standards
- Conductivity meter

- XRF meter and 15x sample cups w/ rings and prolene liners
- Glass stir rod
- 25mL graduated cylinder
- 3x 100mL beakers

From the results from the XRF analysis, the data were examined for the presence of metals that are of environmental concern including arsenic, cadmium, chromium, lead, mercury, nickel, and copper as well as metals that are found to be in high concentrations.

Table 3.1. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health for arsenic, cadmium, total chromium, lead, mercury, nickel, vanadium, zinc, and copper.

Chemical Name	CAS RN	Concentration (mg/kg dry weight)
Arsenic (CCME, 1997a)	7440-38-2	17
Cadmium (CCME, 1999a)	7440-43-9	10
Chromium (total) (CCME, 1999b)	7440-47-3	64
Lead (CCME, 1999c)	7439-92-1	140
Mercury (CCME, 1999d)	7439-97-6	6.6
Nickel (CCME, 2015)	7440-02-0	45
Vanadium (CMME, 1997b)	7440-62-2	130
Zinc (CCME, 2018)	7440-66-6	250
Copper (CCME, 1999e)	7440-50-8	63

3.3 Wetland Assessment

3.3.1 *In situ: Vegetation Survey and Wildlife Trees*

In situ wetland assessment included gathering data on plants in the riparian zone, such as scientific names, stages of growth throughout the spring and summer seasons , as well as species vigor and abundance. Shrubs, herbs/dwarf shrubs, lichen/moss, aquatics, coniferous and deciduous trees, and wildlife trees were assessed. The polygons were mapped using a handheld GPS device to record the coordinates, and flagging tape and a sharpie were used to mark the polygon boundaries. The GPS was also used to get the coordinates for the wildlife trees. All GPS data were mapped for the Final Report.

- Wildlife tree assessment form (digital)
- Riparian assessment form (digital)
- Meter tape measure
- Flagging tape
- Sharpie
- Garmin GPS
- Labeled photos (digital)
- Langford, View Royal, Highlands, and Colwood, BC Map

3.3.2 *Ex situ: Wetland Overview and Map*

The wetland was classed based on literature reviews and field assessments of the plants. Heads-up-digitizing was done for the wetland polygons to get a rough idea of the wetland's layout. Ground truthing was then done to measure the wetland perimeter using Avensa Maps, and the GPS unit. All water quality and sediment sampling sites were compiled onto one map, and the wildlife trees were compiled onto another.

- Avensa Maps
- Google Earth Pro

4.0 Results

4.1 Water Quality

WRC gathered both *in situ* and *ex situ* water quality data from Mary Lake and the Beaver Wetland. *In situ* testing occurred biweekly starting on February 7th, 2023, and was ongoing until June 28, 2023, to collect data regarding temperature, pH, conductivity, total dissolved solids, percent oxygen, and concentration of oxygen from each site. Three *ex situ* quality tests were performed on April 5th, May 17th, and June 28th, 2023, to analyze the alkalinity, nitrates, phosphates, and fecal coliforms of each site. On April 5th, 2023, fecal coliform tests were not conducted as laboratory procedures needed to be finalized. The first fecal coliform tests occurred on May 17th, 2023, where both the membrane filtration and most probable number test methods were performed. The final *ex situ* laboratory analysis performed on June 28th, 2023, included fecal coliform testing as well as the same water quality parameters from April and May sampling.

4.1.1 Alkalinity

Figure 4.1 showcases alkalinity concentrations in milligrams per liter of each lake and wetland water sample taken on April 5th, May 17th, and June 28th. The addition of the Bathing Pond sampling site was added after the first analysis as per the sponsor's request. On April 5th, sites within the lake and creeks had similar alkalinity results ranging from 35 to 38 mg/L, whereas wetland sites had decreased alkalinity concentrations, relative to the lake, ranging from 27 to 37.4 mg/L. The second sampling day (May 17th) observed similar results in comparison with the first *ex situ* sampling day (April 5th), with concentrations slightly increased and decreased. Alkalinity concentrations of all creek sites remained constant in comparison to each other on their sampling dates. The dock site on June 28 had a slight increase of 50mg/l comparative to the April and May sampling dates with concentrations at about 35 mg/L. On May 17th, all wetland sites increased in concentration by approximately 10 mg/L from the April sampling date, with a maximum of 45 mg/L of the road site. The third sampling date showed overall higher concentrations comparative to the April and May sampling dates, ranging from approximately 38 mg/L to 50 mg/L. All sampling days found the lowest concentrations at the wetland garden site. The wetland sites showed more variability than the Mary Lake sites.

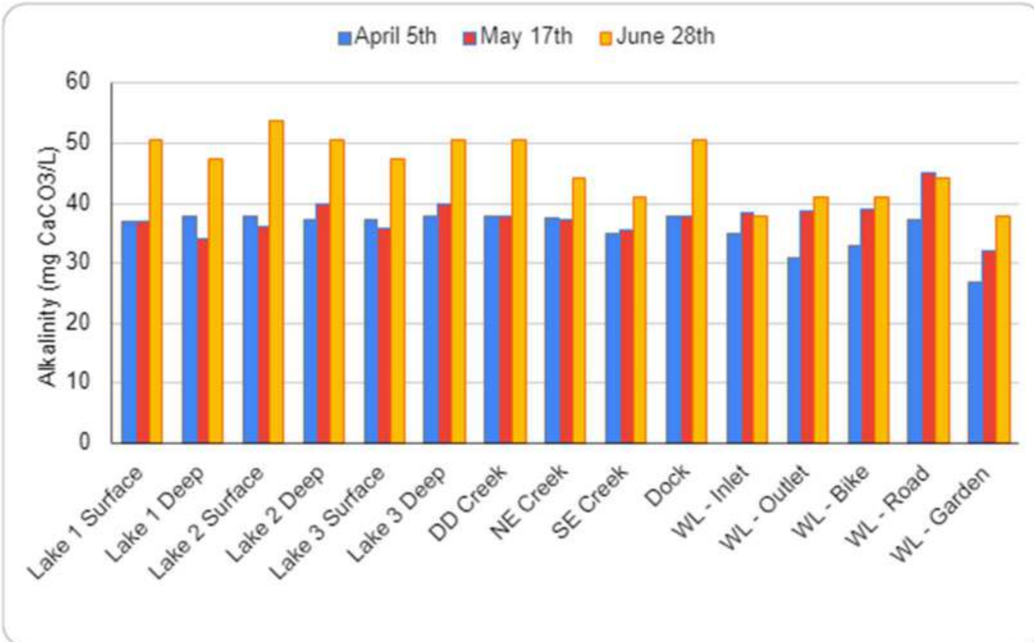

Figure 4.1. Alkalinity results from April 5th, May 17th and June 28th, 2023, of each site location of both the wetland and lake on Mary Lake property. Results found from laboratory analysis of a potentiometric titration of 0.04M HCl and site sample.

4.1.2 Nitrates & Phosphates

Figure 4.2 displays the nitrate concentration in parts per million in the water samples at each of the lake and wetland sites. The figure displays data for both the April 5th analysis, the May 17th analysis, and the June 28th analysis with the inclusion of the bathing pond site in the later second lab date. Phosphates were tested for on April 5th, May 17th, and June 28th; however, every sample concentration was below the detection limit 0.01mg/L) for this method of testing. The samples had very little variation between sites on each date; however, the concentrations varied between sample dates. The concentrations increased on average 0.01ppm between the first and second sampling date. The concentrations increased on average 0.03ppm between the second and third sampling dates.

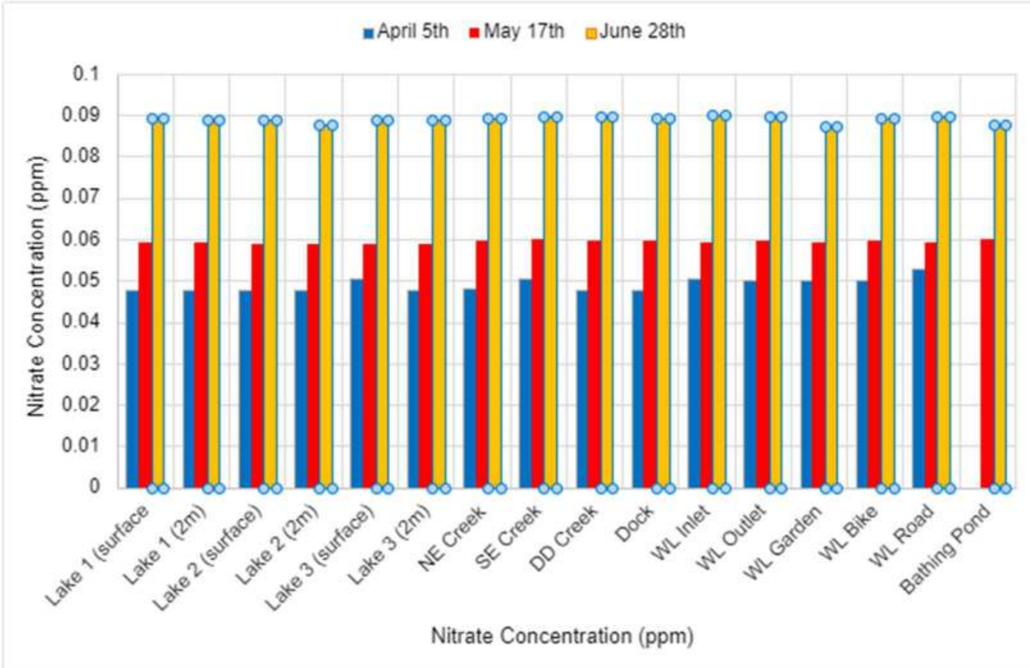

Figure 4.2. Nitrate results from April 5th, May 17th, and June 28th 2023, of each site location of both the wetland and lake on Mary Lake property. Results found from laboratory analysis of absorbance using a spectrometer to determine concentration via colorimetric assay.

4.1.3 Fecal Coliform Testing

4.1.3.1 Membrane Filtration (MF)

The membrane filtration testing for fecal coliform performed May17th and June 28th, 2023, found the highest concentrations for fecal coliforms were present in South Earsman Creek (57 fecal coliform/100ml in June), Wetland Inlet (32 fecal coliform/100ml in May), and Wetland Outlet (48 fecal coliform/100ml in May), all of which were above the Canadian Drinking Water Quality Standards (1 coliform/100ml) but below the Recreational Water Quality Standards (<200 coliforms/100ml) (Government of British Columbia, 2021). During May sampling, Lake 2, Lake 3, Dead Deer Creek, and the Swim sites had colony counts less than one per 100 ml indicating that they were below the Canadian Drinking Water Quality standards, the rest of the sites being above the standard. Lake 1 site was the only location within the Canadian Drinking Water Quality standards during the second sampling period in June. Higher levels of coliforms were present in the second set of sampling results except for Lake 1, Wetland Inlet, Wetland Bike, and Wetland Road sites.

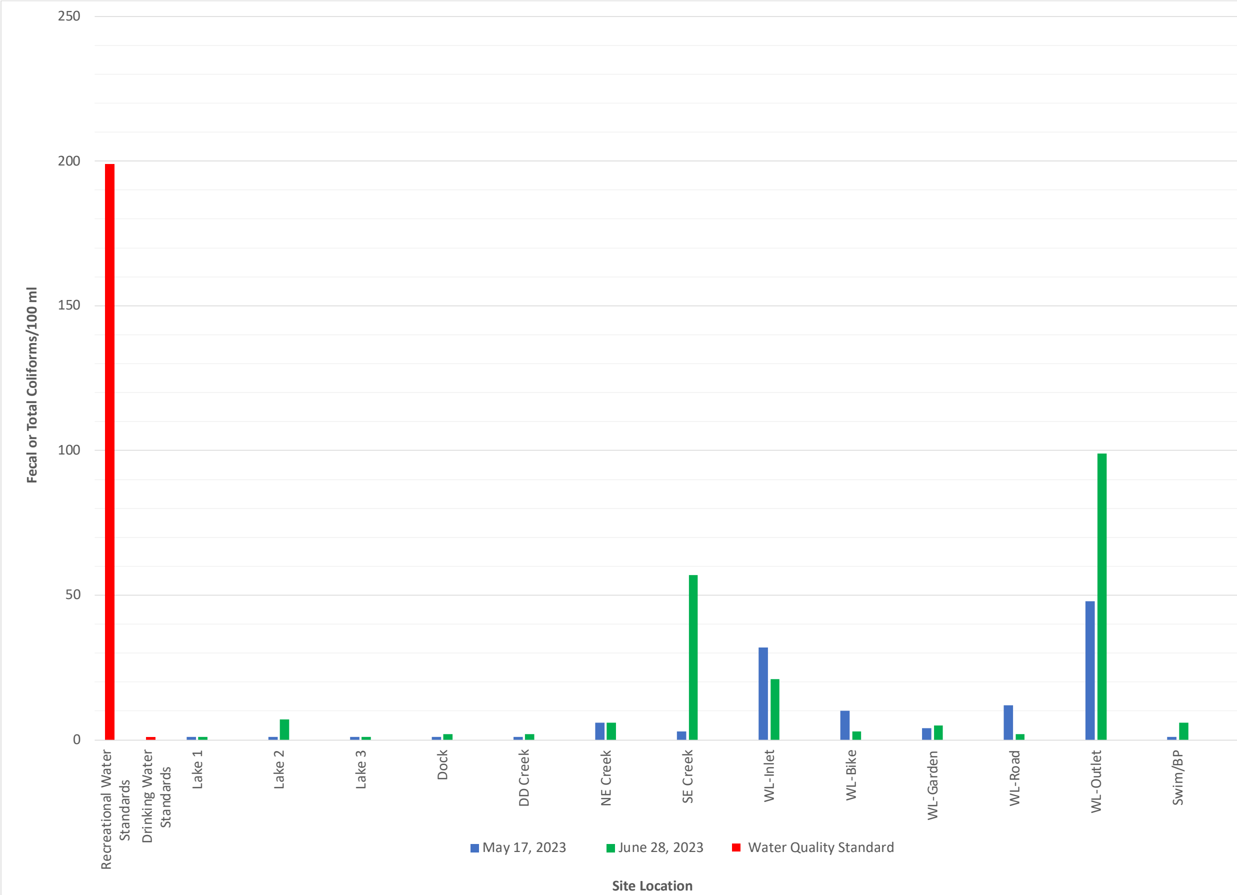

Figure 4.3. Membrane filtration test results for fecal/total coliforms per 100ml water sample from Mary Lake and Wetland water sampling sites during May 17th, 2023, and June 28th, 2023. Water samples collected by Harrison Craig and Jaeden Jones, laboratory analysis conducted by Kyla Macilroy and Kimberly Groome.

4.1.3.2 Most Probable Number (MPN)

Results from the confirmed total coliform MPN tests in figure 4.4, found high levels of coliforms in North Earsman Creek (>2,400 total coliforms/100ml) in July and Wetland Outlet (1,100 total coliforms/100ml) in May, both results were not within the recreational water quality standards. Wetland Inlet and Wetland Road sites remained constant with total coliform levels, being 93 total coliforms/100ml and 43 total coliforms/100ml respectively. All other sampling sites had slightly higher concentrations of total coliforms during the second set of sampling when compared to the first set of MPN results. The Lake 1, 2, 3, and Dock sites during May sampling were the only sites within Drinking Water Quality Standards for total coliforms being 10 total coliforms/100ml (Government of British Columbia, 2021), with all lake sites containing 9 total coliforms/100ml and the dock site having the lowest concentration of 7 total coliforms/100ml.

Figure 4.5 showcases the confirmed fecal coliform MPN test indicating the highest concentrations were found in South Earsman Creek (240 fecal coliforms/100ml in June), Wetland Outlet (460 fecal coliforms/100ml in May), and Wetland Inlet (93 fecal coliforms/100ml in both May and June) sites. The lowest concentrations of fecal coliforms were present within Lake 1 (<3 fecal coliforms/100ml in May and 4 fecal coliforms/100ml in June), Lake 3 (<3 fecal coliforms/100ml in May and 4 fecal coliforms/100ml in June), Dock (3 fecal coliforms/100ml in May and 4 coliforms/100ml in June), and North Earsman Creek (4 coliforms/100ml in June) sites throughout both sampling dates. The second set of sampling occurring in June found higher concentrations of fecal coliforms except for the Wetland Outlet (93 coliforms/100ml) site which had the highest concentration overall with >2,400 fecal coliforms/100ml present on the first sample set in May. The Wetland Inlet site had no change in fecal coliform concentrations, remaining constant with 93 fecal coliforms/100ml. All sample sites were within the Canadian Recreational Water Quality Guidelines of 200 fecal coliforms per 100 ml (Government of British Columbia, 2021), except for South Earsman Creek (240 coliforms/100ml) in June and Wetland Outlet (460 coliforms/100ml) in May 2023, and no site was within Canadian Drinking Water Quality Guidelines of 1 coliform/100ml (Government of British Columbia, 2021) over the duration of testing.

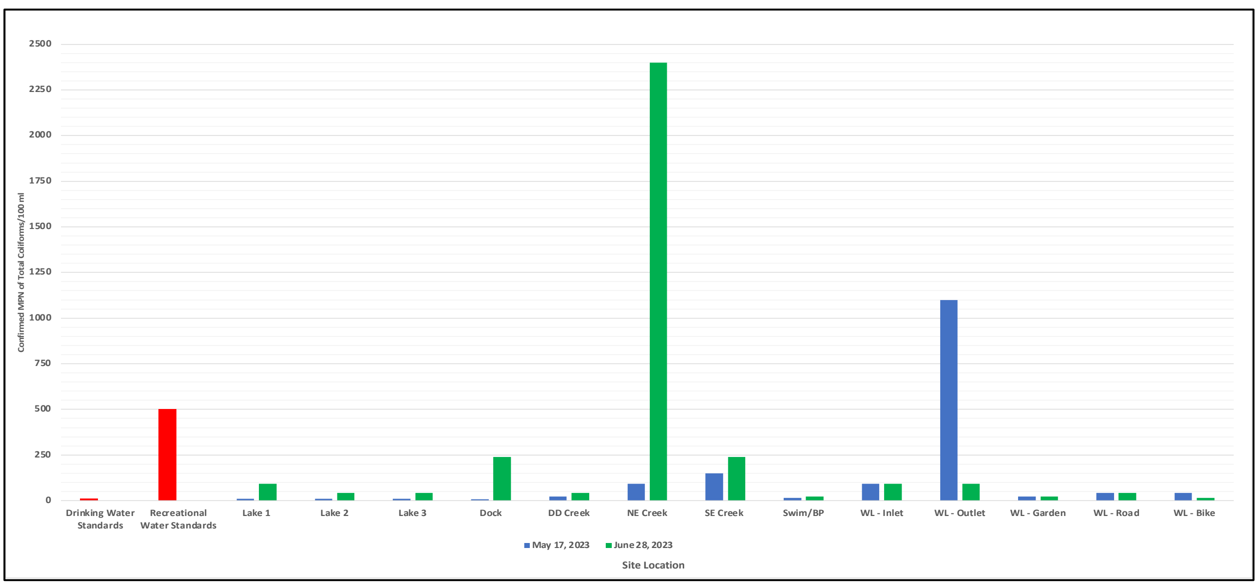

Figure 4.4. Most probable number test results of confirmed total coliforms per 100ml water sample from Mary Lake and Wetland water sampling sites during May 17th, 2023, and June 28th, 2023. Water samples collected by Harrison Craig and Jaeden Jones, laboratory analysis conducted by Kyla Macilroy and Kimberly Groome.

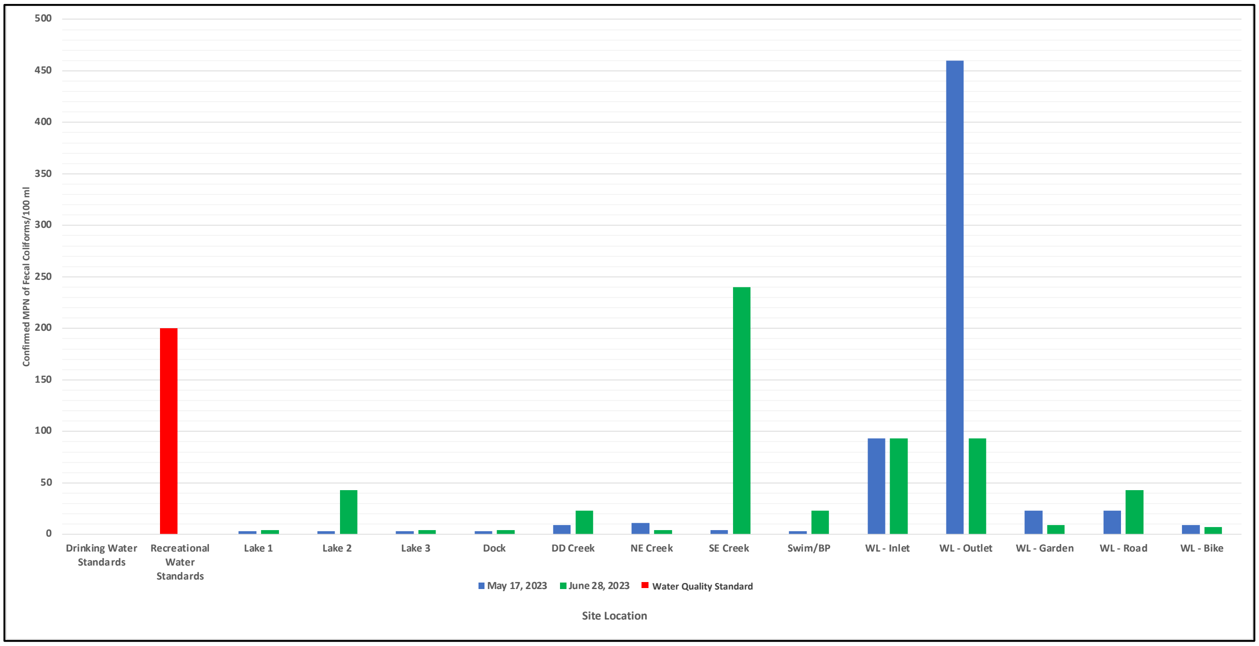

Figure 4.5. Most probable number test results of confirmed fecal coliforms per 100ml water sample from Mary Lake and Wetland water sampling sites during May 17th, 2023, and June 28th, 2023. Water samples collected by Harrison Craig and Jaeden Jones, laboratory analysis conducted by Kyla Macilroy and Kimberly Groome.

4.1.4 Temperature (*In situ*)

The temperature of Mary Lake ranged from 5.5 °C to 21.9 °C, while the wetland temperatures ranged from 5.5 °C to 21.2 °C. The temperature of Mary Lake sites and the creek sites increased as warmer months continued with a large increase in temperature in the month of June (Figure 4.6). Ambient air temperatures are shown in Figure 4.7 which shows the relationship between air temperature and lake/wetland temperature. The coldest water temperatures were sites Lake 1 & 2 at 2-meter depth with an average temperature of both at 11.7 °C. The water samples at the surface of the lake were warmer compared to the 2-meter depth samples (see Figure 4.6). Mary Lake showed that generally colder water was at the Inlet and Outlet sites where moving water was present, and deeper locations whereas higher temperatures were seen at the still water locations (see Figure 4.6).

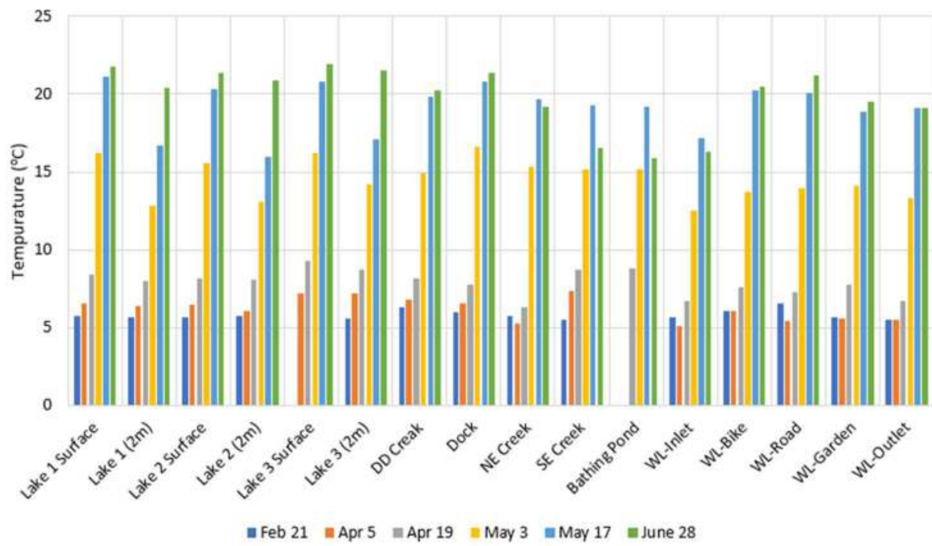

Figure 4.6. Temperature results from February 21 to June 28 from Mary Lake and Wetland sites. Field water quality parameter collected with Oakton PCTSTestr 50 Probe.

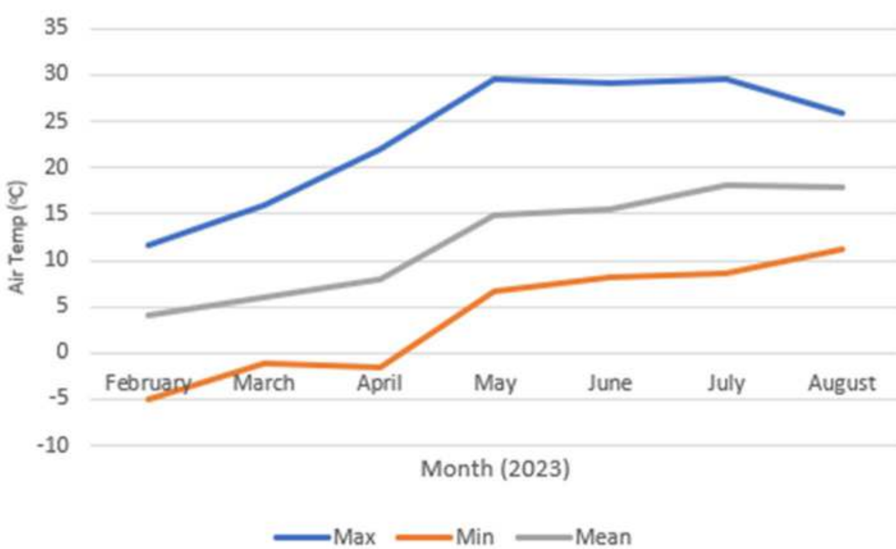

Figure 4.7 Ambient air temperature showing maximum, minimum and mean average from February – August, 2023 in Victoria BC.

4.1.5 Conductivity (*In situ*)

Conductivity increased with time at Mary Lake sites, whereas the wetland sites had an increase towards the end of April but a decrease towards the end of June (Figure 4.8). The WL-Road site had an abnormal increase compared to the rest of the sites from the wetland. The Mary Lake sites measured between 126 μS/cm and 196.9 μS/cm and the creek samples ranged from 149.9 μS/cm to 218 μS/cm. The wetland conductivity results ranged from 96.3 μS/cm at the Outlet site to 197.6 μS/cm at the Road site.

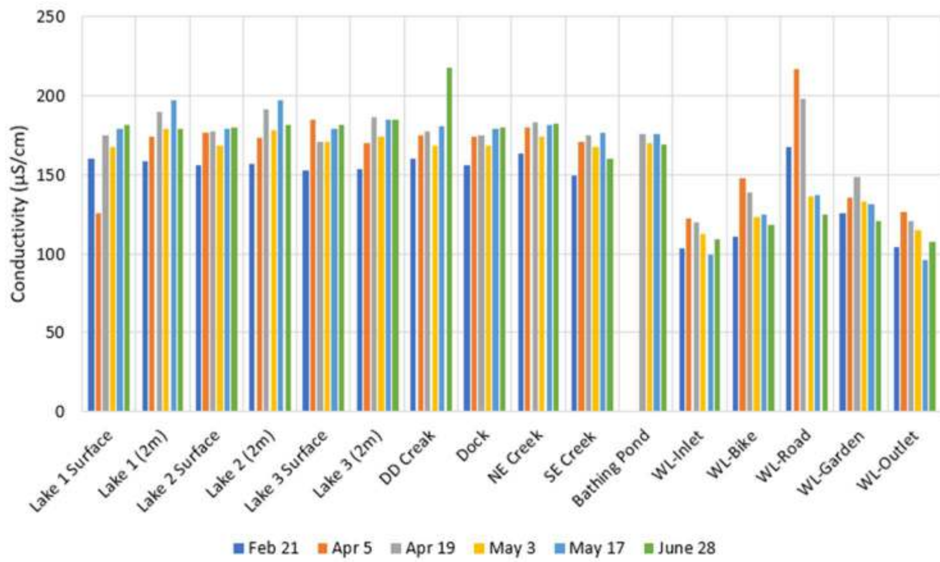

Figure 4.8. Conductivity results from February 21 to June 28 from Mary Lake and Wetland sites. Field water quality parameter collected with Oakton PCTSTestr 50 Probe.

4.1.6 pH (*In situ*)

The pH results from Mary Lake ranged from 7.6 to 8.23 and the creeks around the lake ranged from 7.64 to 8.41. The wetland results show a range from 5.7 to 7.78. The most acidic result was observed at South Earsman Creek site on April 19. Overall, pH ranges stayed similar and did not fluctuate drastically at any of the sampled sites (Figure 4.9).

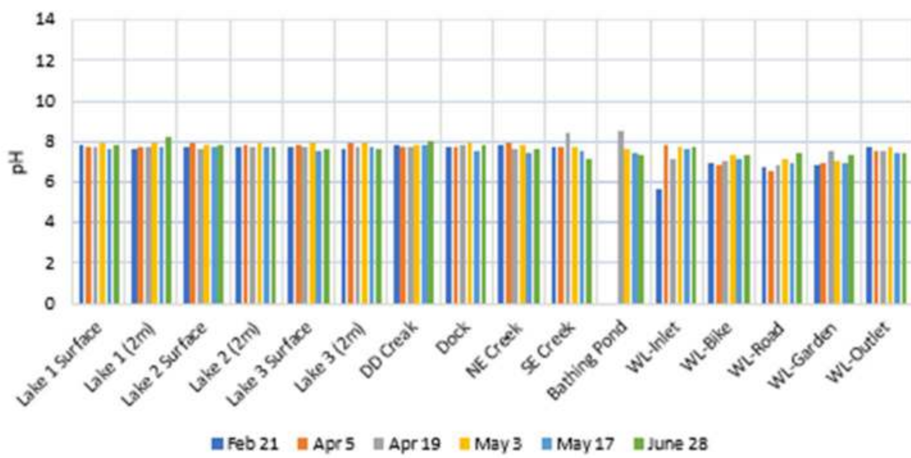

Figure 4.9. pH results from February 21 June 28 from Mary Lake and Wetland sites. Field water quality parameter collected with Oakton PCTSTestr 50 Probe.

4.1.7 Total Dissolved Solids (*In situ*)

The total dissolved solids measured showed an overall increase at Mary Lake and the surrounding creeks from February to June (Figure 4.10). The measurements ranged from 123mg/L to 159mg/L at Mary Lake while the surrounding creeks ranged from 121mg/L to 148mg/L. The wetland sites had an increase in April but dropped again when measures continued into May and June. The Wetland Road Site showed a large increase in ppm compared to the rest of the wetland sites. The total dissolved solids ranged from 76.6mg/L to 176mg/L at Beaver Wetland.

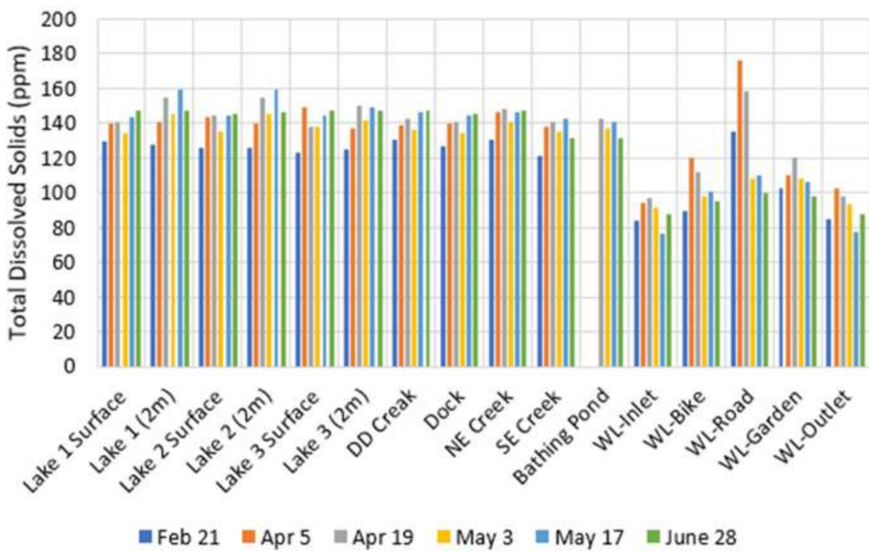

Figure 4.10. Total dissolved solid results from February 21 to June 28 from Mary Lake and Wetland sites. Field water quality parameter collected with Oakton PCTSTestr 50 Probe.

4.1.8 Dissolved Oxygen (*In situ*)

Dissolved oxygen (DO) from Mary Lake ranged from 5.1mg/L to 11.8mg/L with a sharp decrease over the sampling period. The surrounding creeks showed a similar trend ranging from 4.8mg/L to 11.8mg/L. The wetland had similar trends and ranged from 3.6mg/L to 11.6mg/L. Each water quality collection site had a large decrease in dissolved oxygen as the warmer months progressed (Figure 4.11).

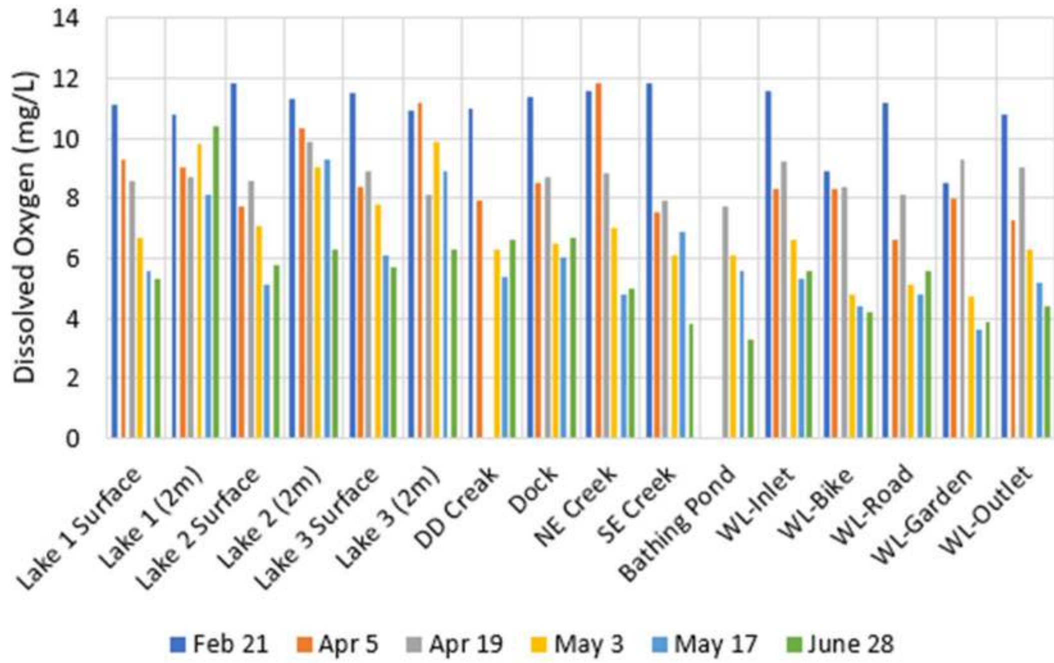

Figure 4.11. Dissolved oxygen results from February 21 to June 28 from Mary Lake and Wetland sites. Field water quality parameter collected with Cole-Parmer DO Probe.

4.2 Sediment Sampling

The pilot sediment sampling was completed on February 7th, 2023, with one sample from each location taken and analyzed on February 21st, 2023. It was realized that more samples were needed in order to acquire useful data. The form was updated to reflect the increase in sample number; no other adjustments were made (Table 4.1). The second sediment collection was completed on April 12th, 2023, where five samples were taken from each location. The samples were analyzed using the XRF machine on May 10th, 2023, as can be seen in table 4.1. All of the metals of interest exceeded CCME guidelines in at least two of the five samples. The average metal concentration at each site is displayed in table 4.2. When concentrations at each site were compared to the CCME guidelines, there were no guidelines exceeded at the inlet site; however, the road and bike sites exceeded the guidelines for several metals. Figure 4.12 displays the average metal concentrations per site from table 4.2.

Table 4.3 displays the metal concentrations found in each sample on July 5th. It is of note that all the metals at the bike site exceeded the CCME guidelines for environmental protection. Only three samples from the inlet site of the 15 samples collected did not exceed the guidelines for any metals. Table 4.4 displays the average concentrations per site and all of the metal's concentration guidelines were exceeded in one of the three sites unlike the May 10th samples, where five of the eight metals concentrations guidelines were exceeded. Figure 4.13 displays all metal concentrations at all sites within the wetland. Figure 4.14 displays the concentrations of metals in the road site samples including a duplicate sample. Figure 4.15 displays the concentrations of metals at the inlet site with a duplicate, present are spikes in lead concentrations. Figure 4.16 displays the concentrations of metals at the bike site including spikes of zinc and arsenic concentrations.

Table 4.1. Metal concentrations (ppm) in sediment by site through XRF analysis of sediments collected at the inlet, bike, and road sites by Jaeden Jones and Kyla Macilroy on April 12th and analyzed by Jaeden Jones and Harrison Craig on May 10th.

Mary Lake Nature Sanctuary XRF Sediment Data Date: May 10th, 2023 Assessors: Jaeden and Harrison					WILD RIPARIAN CONSERVATION			
Sample	As	Cd	Cr	Cu	Pb	V	Zn	Ni
Inlet 5	<2.7882	**13.5802**	21.9841	37.1941	128.0773	96.7356	173.4556	<9.1046
Inlet 4	<2.0276	**15.4679**	14.023	38.954	56.0897	83.34	235.3192	<8.9784
Inlet 3	<2.5721	8.1229	43.1965	28.4611	104.8588	120.0906	116.7461	<9.1653
Inlet 2	<2.6694	**10.4949**	18.7349	31.1553	103.7246	111.2769	91.7482	<9.2266
Inlet 1	<2.7236	**12.4159**	29.3383	35.1797	111.8332	93.6561	198.5094	14.27
Road 5	<2.7375	<3.5303	**133.3741**	**106.6426**	82.0952	**226.1553**	146.2052	**144.2033**
Road 4	<2.249	<3.571	**143.6672**	**125.501**	39.3837	**261.6096**	172.6839	**177.5665**
Road 3	<1.7986	<3.1965	**95.7632**	**73.5281**	24.0106	**171.0359**	89.6681	**49.2856**
Road 2	<1.7684	<3.3455	**111.1631**	**96.8523**	17.9391	**200.0681**	118.2903	**72.5406**
Road 1	<1.6431	<3.4779	**88.3395**	**112.279**	9.4097	**195.9218**	138.6823	**97.992**
Bike 5	5.0954	<3.0006	**83.4862**	60.2745	**422.6293**	**148.2188**	183.524	40.2788
Bike 4	<3.3843	<3.0085	**74.9574**	52.961	**149.2581**	**158.3732**	142.5329	33.3111
Bike 3	15.7305	<3.0304	**129.0242**	**108.6112**	**412.4409**	**140.0883**	**408.3868**	28.7002
Bike 2	6.1532	<2.9591	**66.0122**	58.7354	**331.0844**	**150.7508**	150.7543	27.0532
Bike 1	15.1461	<3.131	**81.9134**	**127.7483**	**440.2007**	**140.996**	**341.8574**	38.0171
CCME Guidelines	17	10	64	63	140	130	250	45

Note: the **bold** values are above the current CCME sediment guidelines.

Table 4.2. Average metal concentrations (ppm) in sediment by site through XRF analysis of sediments collected at the inlet, bike, and road sites by Jaeden Jones and Kyla Macilroy on April 12th and analyzed by Jaeden Jones and Harrison Craig on May 10th.

Mary Lake Nature Sanctuary XRF Summary Data Date: May 10th, 2023 Assessors: Jaeden and Harrison					WILD RIPARIAN CONSERVATION			
Sample	As	Cd	Cr	Cu	Pb	V	Zn	Ni
Inlet	BDL	12.01636	25.45536	34.18884	100.9167	101.0198	163.1557	BDL
Road	BDL	BDL	**114.4614**	**102.9606**	34.56766	**210.9581**	133.106	**108.3176**
Bike	BDL	BDL	**87.07868**	**81.66608**	**351.1227**	**147.6854**	245.4111	33.47208
CCME Guidelines	17	10	64	63	140	130	250	45

Note: average concentrations of contaminants at certain sites could not be calculated due to one or more of the samples being below the detection limit.
Note: the **bold** values are above the current CCME sediment guidelines.

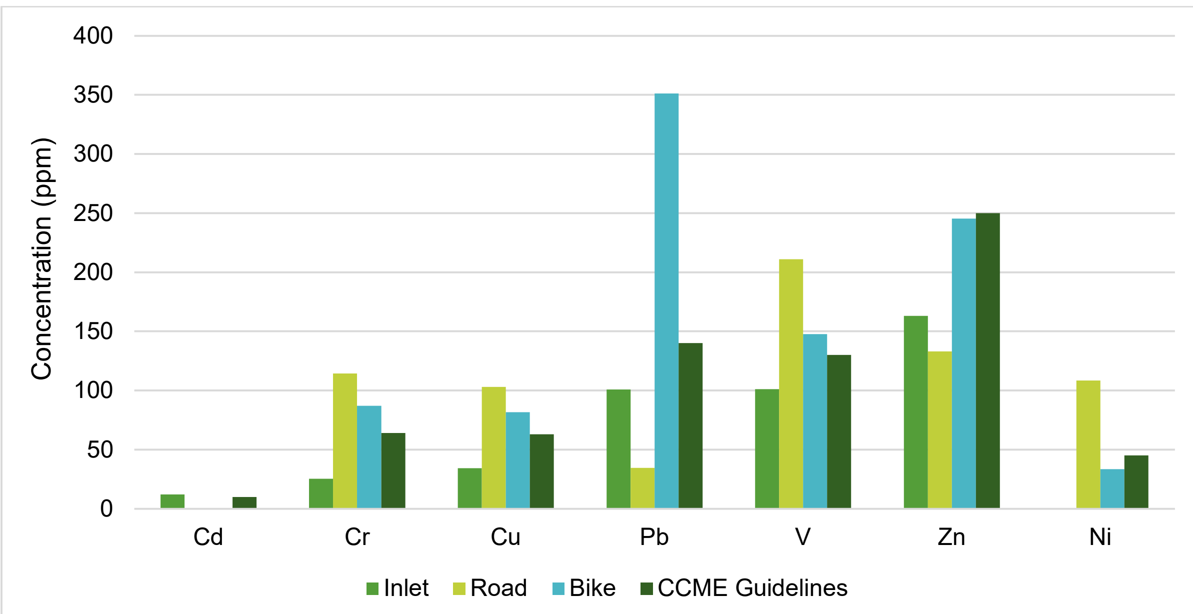

Figure 4.12. Average metal concentrations (ppm) in sediment by site through XRF analysis of sediments collected at the inlet, bike, and road sites by Jaeden Jones and Kyla Macilroy on April 12th and analyzed by Jaeden Jones and Harrison Craig on May 10th.

Table 4.3. Metal concentrations (ppm) in sediment by site through XRF analysis of sediments collected at the inlet, bike, and road sites by Jaeden Jones on June 21st and analyzed by Jaeden Jones and Harrison Craig on July 5th.

Mary Lake Nature Sanctuary XRF Sediment Data
Date: July 5th, 2023
Assessors: Jaeden and Harrison

Sample	As	Cd	Cr	Cu	Ni	Pb	V	Zn
Bike 1	**171.1896**	**26.2422**	**375.5569**	**724.5592**	**72.869**	**1961.438**	**135.3728**	**13754.1**
Bike 2	**333.9798**	**23.6984**	**348.1971**	**8777.483**	**172.9838**	**3797.985**	107.1534	**9647.186**
Bike 3	**18.7486**	6.6863	**123.9378**	**195.6817**	**79.5627**	**775.5095**	111.8781	**3693.648**
Bike 4	<9.404	7.1724	**102.4748**	**132.6415**	25.2681	**574.3847**	**133.0222**	**1548.082**
Bike 5	**19.3727**	**10.087**	**86.5397**	**340.7098**	<20.572	**712.1755**	117.3946	**4149.491**
Road 1	<2.2585	<3.5625	**115.034**	**102.7036**	**118.562**	37.9858	**227.1485**	163.6887
Road 2	<2.2947	<3.4616	**111.2069**	**99.8336**	**104.9154**	36.4421	**208.9175**	182.2859
Road 2d	<2.1704	<3.3873	**113.7957**	**96.0558**	**137.459**	37.532	**239.5225**	173.4822
Road 3	<2.2689	<3.4752	**133.0698**	**101.318**	**109.1761**	46.8083	**209.5218**	203.5255
Road 4	<2.1827	<3.4713	**91.9155**	**97.2416**	**73.2908**	40.5056	**230.3449**	149.4174
Road 5	<2.0663	<3.46	**158.7901**	**116.2168**	**162.9614**	27.3351	**235.2842**	173.5881
Inlet 1	<4.4369	8.8712	23.9922	41.0092	11.06	120.1916	97.4857	204.39
Inlet 2	<2.9152	7.1652	27.3697	33.382	<9.615	99.6643	110.6902	149.7665
Inlet 3	<5.0744	9.1546	30.6297	34.288	19.0635	**474.2155**	112.2494	170.4456
Inlet 4	<2.0464	**11.7305**	38.6943	37.2149	<12.9388	59.0902	113.565	219.6916
Inlet 4d	<4.6646	8.9404	44.5052	32.7795	28.9027	**412.3931**	109.0336	165.1757
Inlet 5	<2.2282	8.3291	32.3635	34.3576	<9.2524	70.2343	111.165	200.8131
CCME	17	10	64	63	45	140	130	250

Note: the **bold** values are above the current CCME sediment guidelines.

Table 4.4. Average metal concentrations(ppm) in sediment by site through XRF analysis of sediments collected at the inlet, bike, and road sites by Jaeden on June 21st and analyzed by Jaeden Jones and Harrison Craig on July 5th.

Mary Lake Nature Sanctuary XRF Sediment Data
Date: July 5th, 2023
Assessors: Jaeden and Harrison

Sample	As	Cd	Cr	Cu	Ni	Pb	V	Zn
Bike	**135.8227**	**14.77726**	**207.3413**	**2034.215**	BDL	**1564.298**	120.9642	**6558.502**
Road	BDL	BDL	**120.6353**	**102.2282**	**117.7275**	37.76815	**225.1232**	174.3313
Inlet	BDL	9.031833	32.92577	35.5052	BDL	**205.9648**	109.0315	185.0471
CCME	17	10	64	63	45	140	130	250

Note: average concentrations of contaminants at certain sites could not be calculated due to one or more of the samples being below the detection limit.

Note: the **bold** values are above the current CCME sediment guidelines.

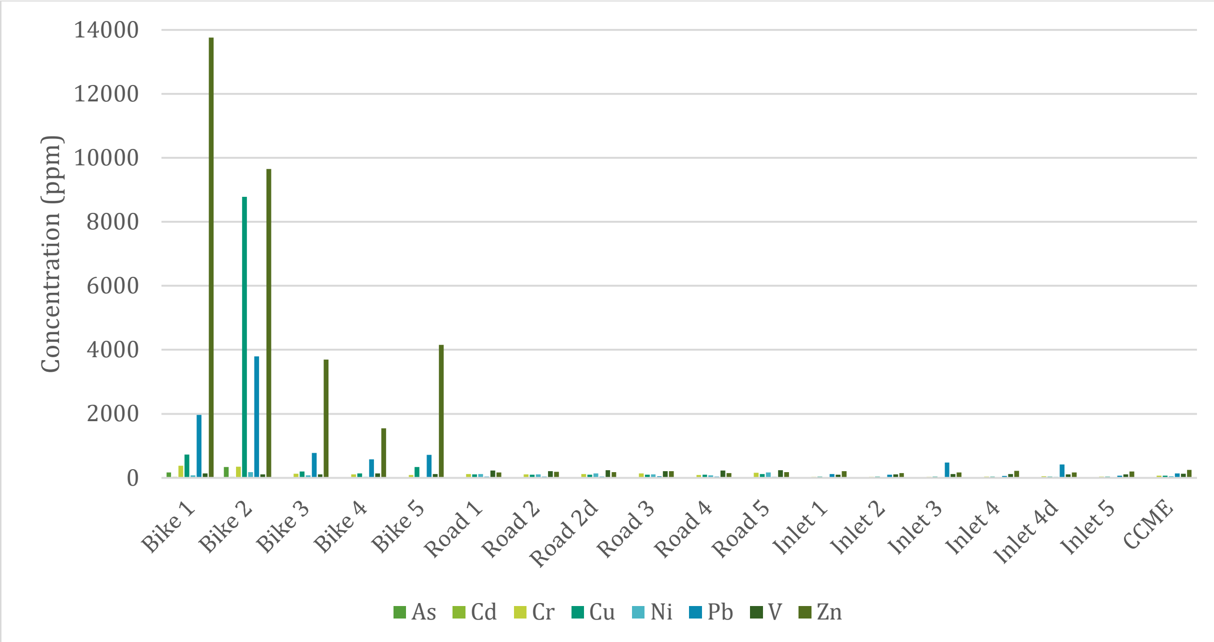

Figure 4.13. Metal concentrations (ppm) in sediment by site through XRF analysis of sediments collected at the inlet, bike, and road sites by Jaeden Jones on June 21st and analyzed by Jaeden Jones and Harrison Craig on July 5th.

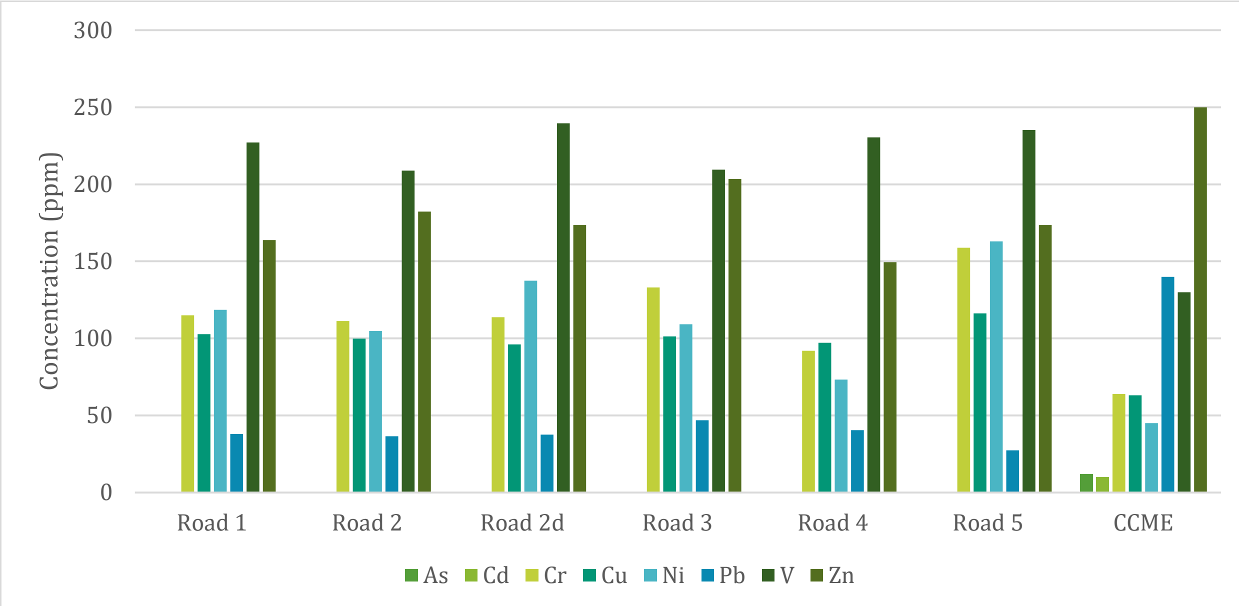

Figure 4.14. Metal concentrations (ppm) in sediment samples at the road site through XRF analysis of sediments collected by Jaeden Jones on June 21st and analyzed by Jaeden Jones and Harrison Craig on July 5th.

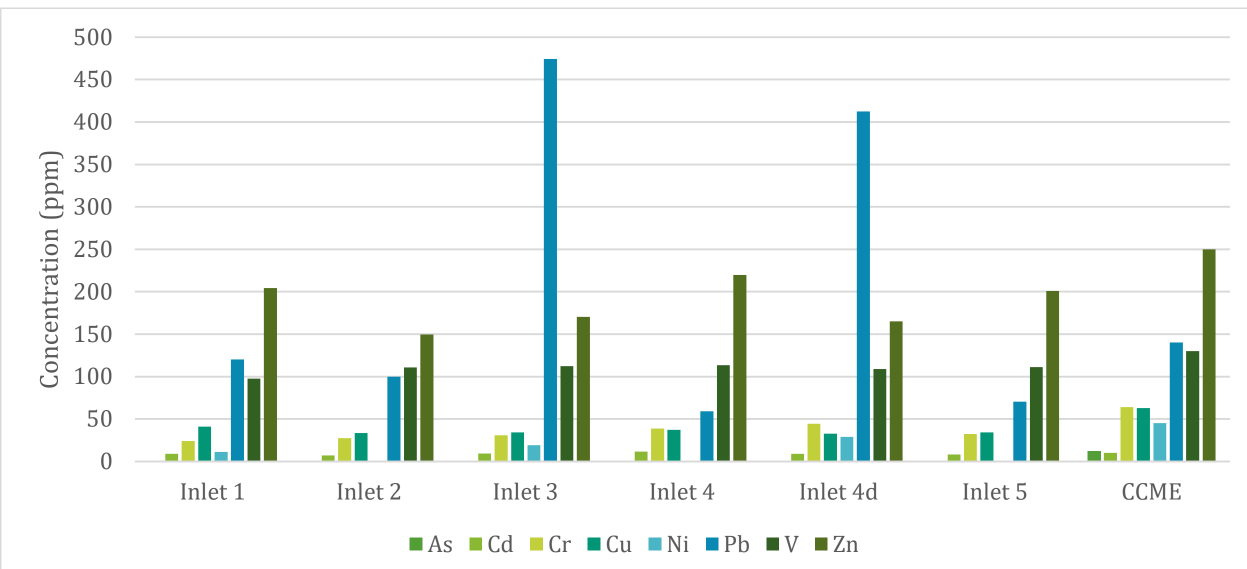

Figure 4.15. Metal concentrations (ppm) in sediment samples at the inlet site through XRF analysis of sediments collected by Jaeden Jones on June 21st and analyzed by Jaeden Jones and Harrison Craig on July 5th.

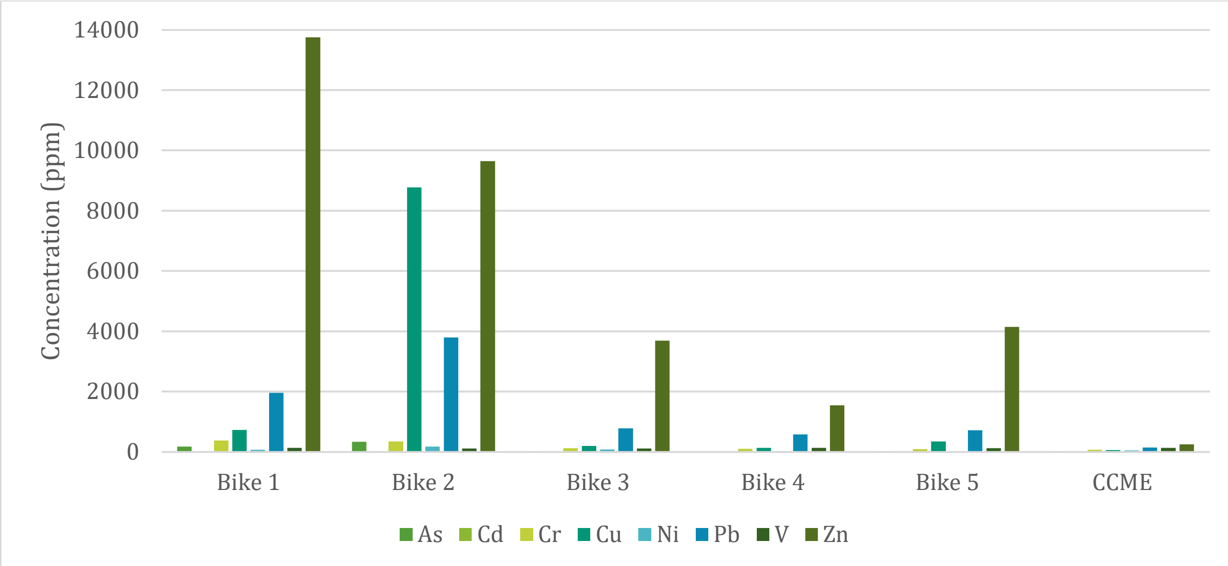

Figure 4.16. Metal concentrations (ppm) in sediment samples at the bike site through XRF analysis of sediments collected by Jaeden Jones on June 21st and analyzed by Jaeden Jones and Harrison Craig on July 5th.

4.3 Wetland Assessment

4.3.1 Wetland Overview

Millstream Creek flows southwest through polygons 1-6, it then curves fully south, where it meets up with South Earsman Creek (Figure 4.17). Other than precipitation, Millstream Creek is the source of water for the wetland. The Beaver Wetland can be broken into four distinct polygon groups based on the characteristics of the wetland and amount of sun throughout the day. Polygons 1-8 are next to an old overgrown road closest to the inlet and outlet that is Millstream Creek; they are dominated by shrubs <2m tall, and grass (Figure 4.18). These polygons have the greatest number of all the plant species in the wetland comparatively (Figure 4.18) and receive a lot of sun. Polygons 9-12 are dominated by grass: the area here sees the most change throughout the spring, the land is flatter, and the water has large surface area rather than depth (Figure 4.19). Due to the amount of grass cover, there were no observed aquatic plants in these polygons (Figure 4.19). Polygons 13-15 are an interesting ecosystem; there are more ferns and some taller shrubs, as the wetland transitions into more tree cover (Figure 4.20). Polygons 16-23 are predominantly shade covered (Figure 4.21); however, the species distribution is similar to polygons 13-15 (Figure 4.20).

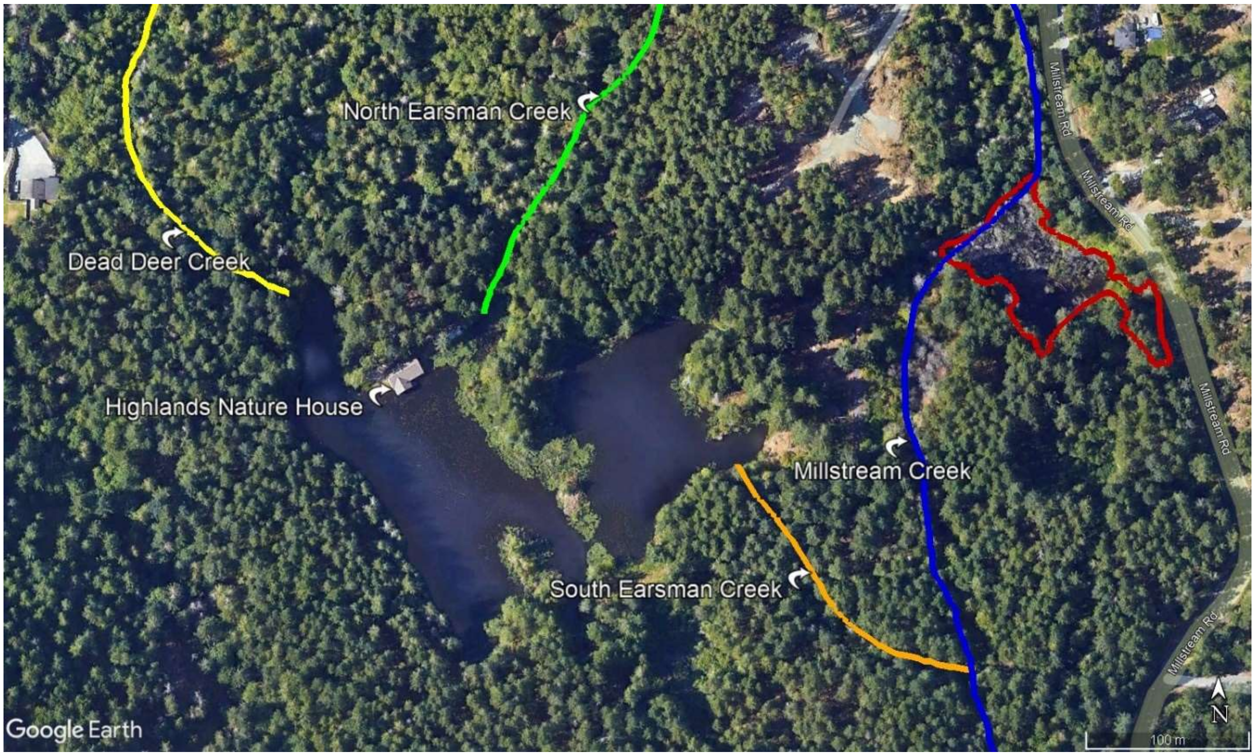

Figure 4.17. Map of Millstream Creek (dark blue), North Earsman Creek (green) and South Earsman Creek (Orange), and Dead Deer Creek (yellow) present at the MLNS, and their joining downstream of; red outline is the wetland; Map made in Google Earth Pro by Kimberly Groome; May 29, 2023, NAD 83 WSGS U10.

Figure 4.18. Image showing the open sun polygons 1-8, with deep water close to the shore; photo: Kimberly Groome.

Figure 4.19. Image showing polygons 9-12 dominated by grass and shallow water, photo: Kimberly Groome.

Figure 4.20. Image showing polygons 13-15 distinct ecosystem from the rest of the Beaver Wetland, photo: Kimberly Groome.

Figure 4.21. Image showing polygons 16-23 ecosystem compared to the rest of the Beaver Wetland, this site is predominantly shade covered compared to the sun covered polygons 1-8 in the background, photo: Kimberly Groome.

4.3.2 Riparian Vegetation

The total number of species found around the Beaver Wetland at MLNS was 109, of those species six were shrubs 2-10m tall, 68 were shrubs <2m, 14 were species of moss and lichen, seven were aquatic species, and 14 were grass species found during the summer assessment (Table 4.5). A full list of these species can be found in the Appendix tables A.27 to A.30. Shrubs <2m had the most diversity out of any of the other plant categories. In spring there were 69 species, and in summer there were 63 species in polygons 1-8 (Table 4.6, Figure 4.22). Polygons 16-23 had the next highest species diversity of shrubs 2-10m with 58 species in the spring and 30 species in the summer, which is also the biggest change in diversity out of any polygon group (Table 4.6). For the shrubs 2-10m, all polygons had ten or less different plants, which was fairly consistent for polygons 1-8, 9-12, and 13-15 (Table 4.6, Figure 4.23). For polygons 16-23 the number of different species dropped from ten to three from spring to summer (Table 4.6). This was also the case for moss and lichen species, while all polygons experienced a loss of species, the first three polygon groups had relatively stable numbers while polygons 16-23 went from ten species in the spring to zero in the summer (Table 4.6, Figure 4.24). The grass species found at the Beaver Wetland all saw an increase from spring to summer in species diversity in all polygon groups except, again group 16-23 (Table 4.6, Figure 4.25). The aquatic species were not abundant around the wetland, and in all polygons, there was a drop to almost none being present in the summer (Table 4.6, Figure 4.26). Trees were observed in all polygons except 9-12; polygons 1-8 saw an increase in the number of trees present, while polygons 13-15 saw a loss of two trees, and polygons 16-23 observed one additional tree (Figure 4.27).

The average % cover for shrubs 2-10m and shrubs <2m was relatively consistent in all polygons from spring to summer, all within 4% of each other over the seasons (Table 4.7, Figure 4.28). The <2m shrubs were consistent between the spring and summer assessments (Figure 4.29). The moss and lichen had a drastic drop in average % cover for polygons 1-8, from 42% to 24%, and in polygons 16-23 dropping from 18% to 0% (Table 4.7, Figure 4.30). Both polygons 9-12 and 13-15 had an increase in moss and lichen cover, rising from 14% to 20% in polygons 9-12 and 39% to 43% in polygons 13-15 (Table 4.7, Figure 4.30). Grass was an abundant cover with only a slight drop in cover in polygons 16-23 from 33% to 31% (Table 4.7, Figure 4.31). All polygons saw a drop in aquatic species, polygons 13-15 saw the largest decrease in %cover from 9% to 0% (Figure 4.32).

There was a total of 11 invasive species identified around the Beaver Wetland. Polygons 1-8 had the greatest number of invasive species with 20 and 18 identified in spring and summer respectively (Table 4.6). However, polygons 9-12 had the highest average % cover with 30% in spring and 22% in summer (Table 4.7).

Table 4.5. Total number of species present and the average % cover around the Beaver Wetland at Mary Lake Nature Sanctuary by species group, Moss/lichen, Aquatics, Grass, Shrubs <2m, Shrubs 2-10m, during spring (April 26th and May 3rd, 2023), and summer (June 21st and July 12th, 2023), data collected by Wild Riparian Conservation.

Species Group	Number of Species Present	Number of Invasives Present
Shrubs (2-10m)	6	0
Shrubs (<2m)	68	11
Moss/lichen	14	0
Grass	14	4
Aquatics	7	0
Total Species	109	15

Table 4.6. The number of species present in each polygon group, 1-8, 9-12, 13-15, and 16-23; Categories: Shrubs 2-10m, Shrubs <2m, Moss/lichen, Grass, Aquatics, and Trees found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

Season	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
Polygons	1--8	1--8	9--12	9--12	13--15	13--15	16--23	16--23
Shrubs 2-10m	6	6	3	1	5	3	10	3
Shrubs <2m	69	63	19	8	27	22	58	30
Moss/lichen	12	7	4	3	10	4	10	0
Grass	18	18	4	9	3	5	12	8
Aquatics	7	1	2	0	3	0	13	3
Trees	17	23	0	0	8	6	23	24
Invasives	20	18	2	2	7	4	8	5

Table 4.7. The % cover average of species present in each polygon group, 1-8, 9-12, 13-15, and 16-23; Categories: Shrubs 2-10m, Shrubs <2m, Moss/lichen, Grass, Aquatics, and Trees found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

Season	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
Polygons	1--8	1--8	9--12	9--12	13--15	13--15	16--23	16--23
Shrubs 2-10m	7%	6%	33%	40%	28%	31%	10%	6%
Shrubs <2m	10%	11%	16%	15%	16%	18%	9%	9%
Moss/lichen	42%	24%	14%	20%	39%	43%	18%	0%
Grass	37%	36%	50%	50%	50%	50%	33%	31%
Aquatics	4%	1%	2%	0%	9%	0%	3%	1%
Invasives	4%	11%	30%	22%	7%	20%	10%	2%

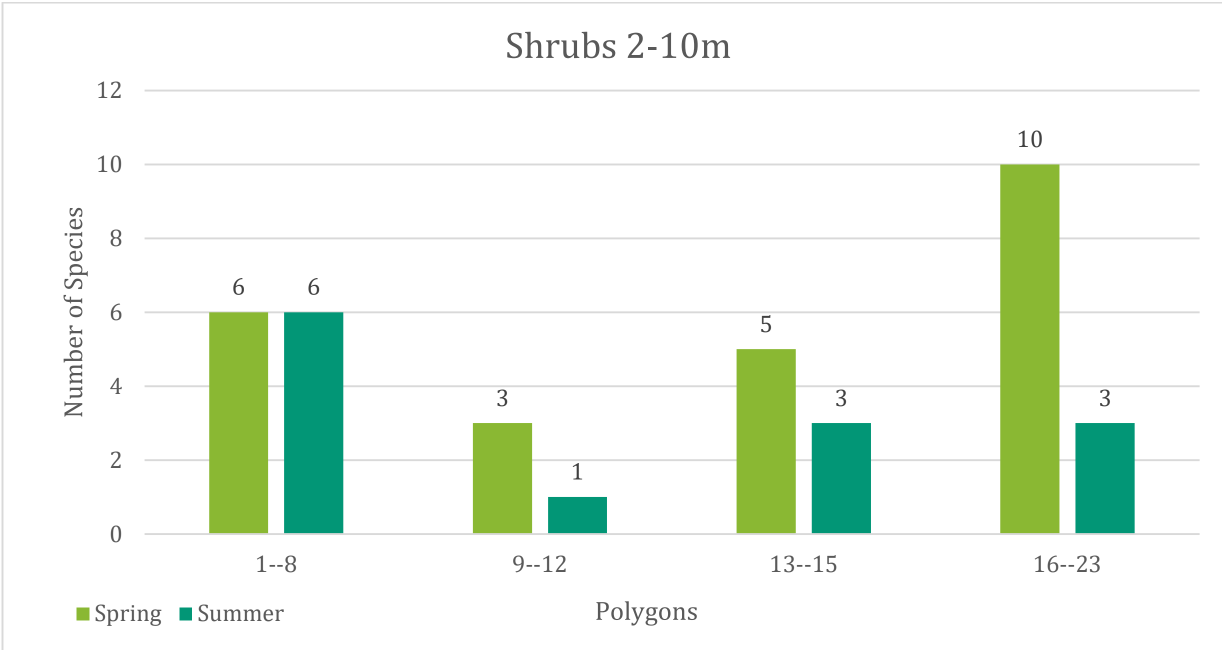

Figure 4.22. The number of shrubs 2-10m species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

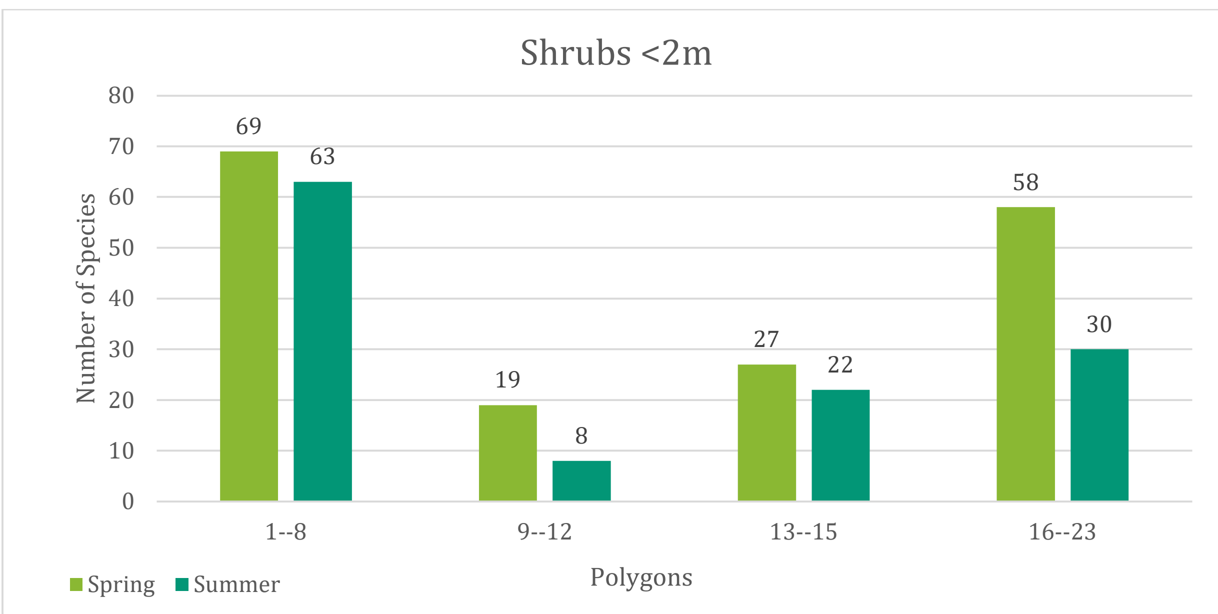

Figure 4.23. The number of shrubs <2m species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

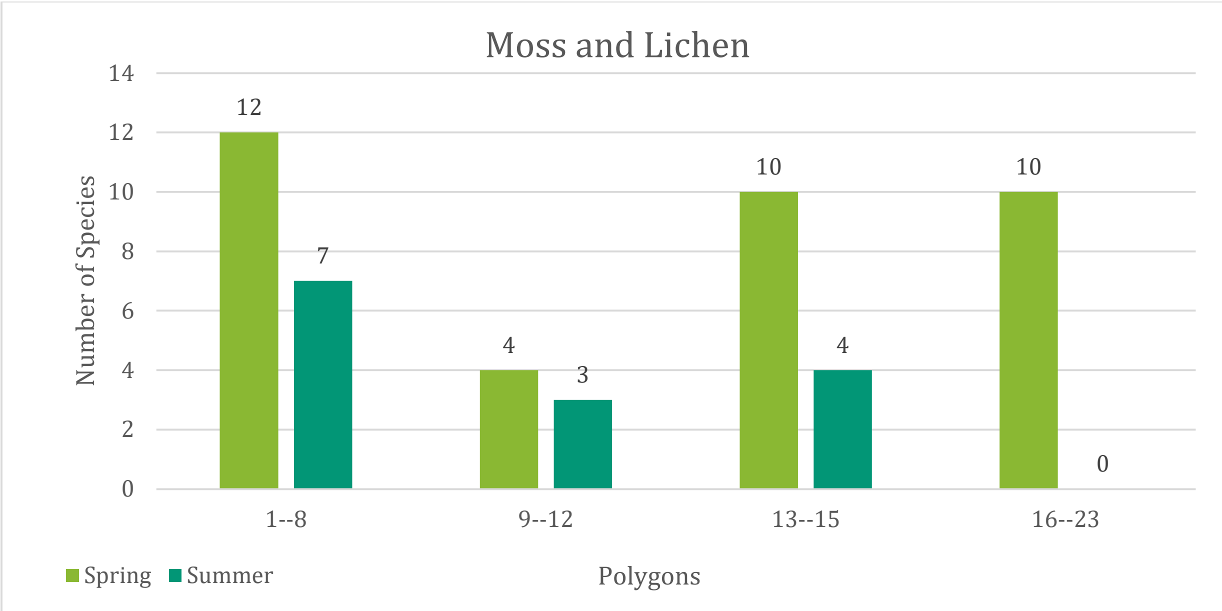

Figure 2.24. The number of moss and lichen species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

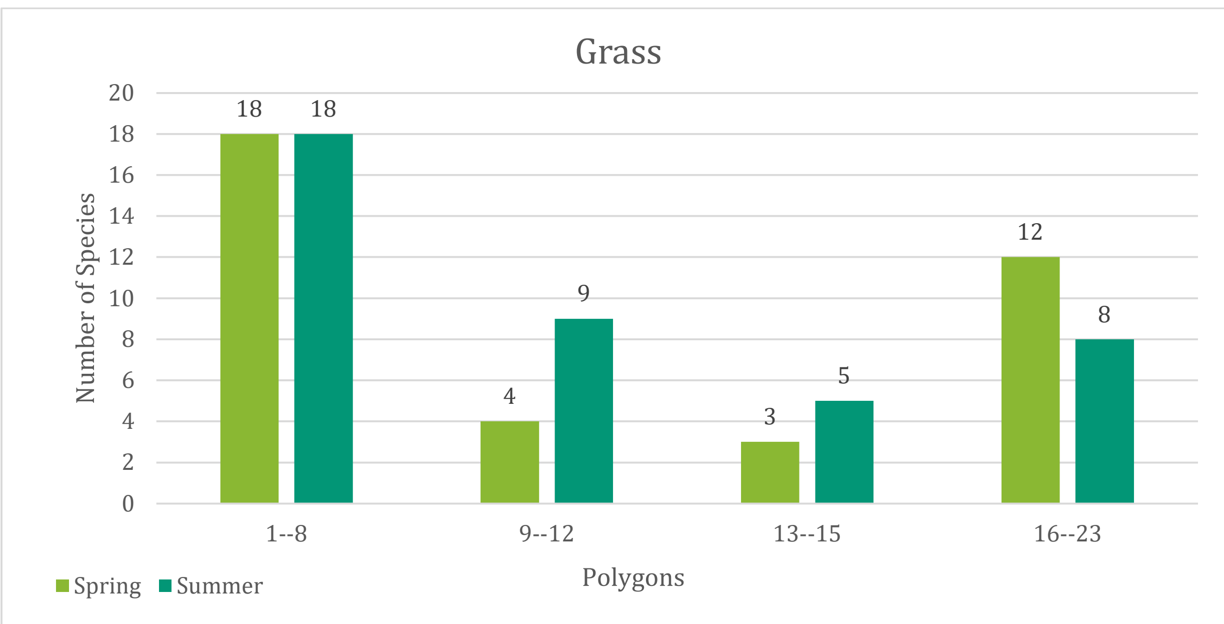

Figure 4.25. The number of grass species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

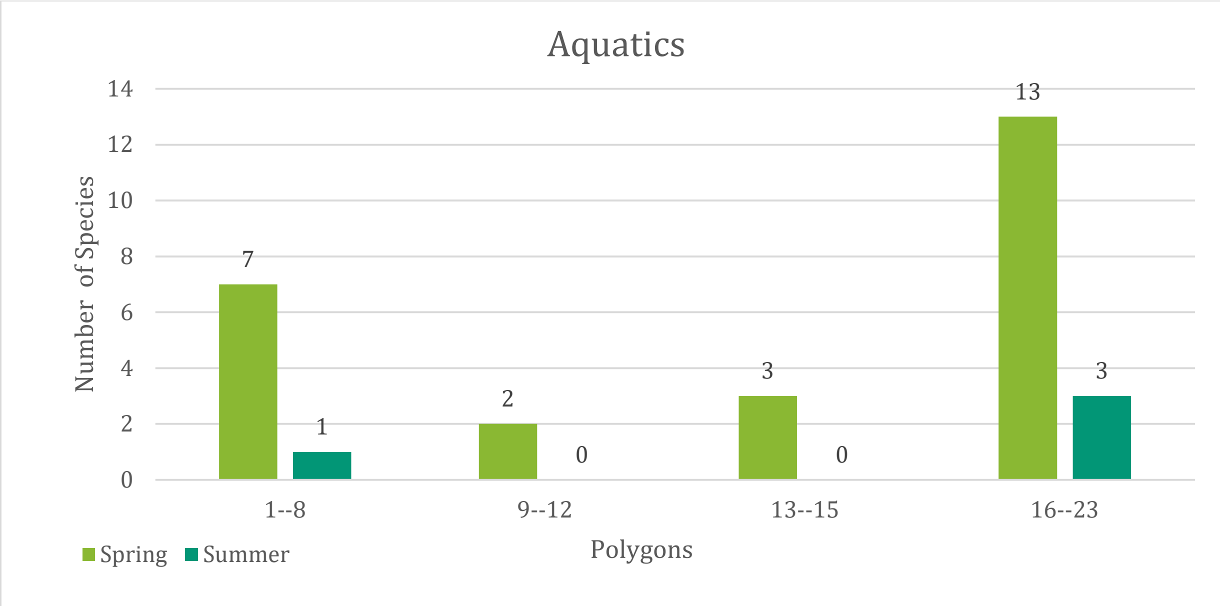

Figure 4.26. The number of aquatic species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

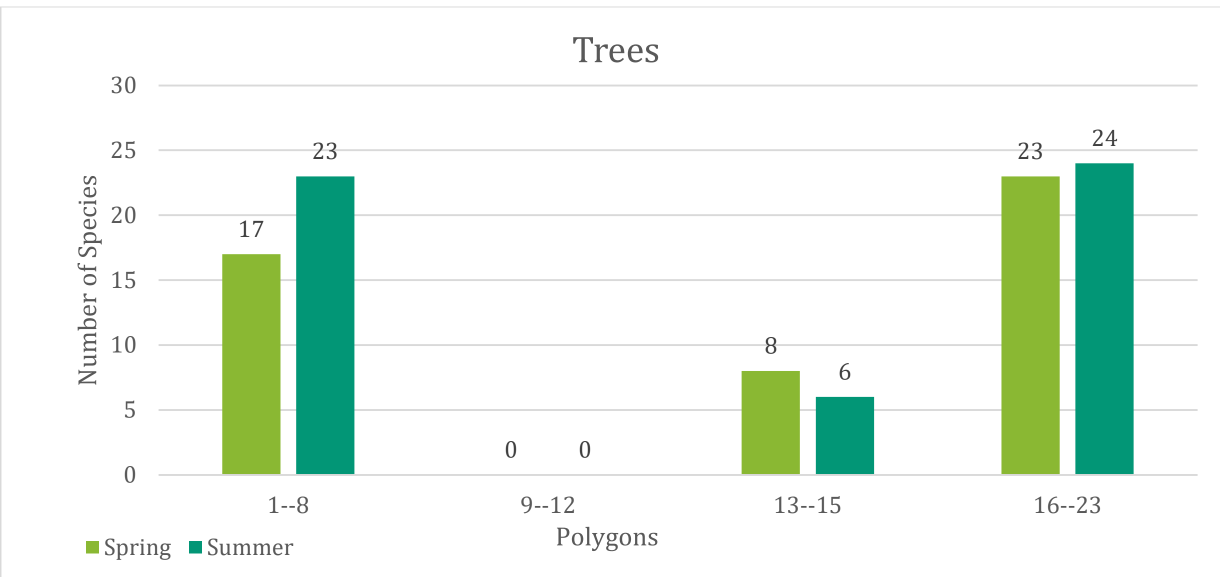

Figure 4.27. The number of tree species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st, July 12th, and August 2nd, 2023) assessments.

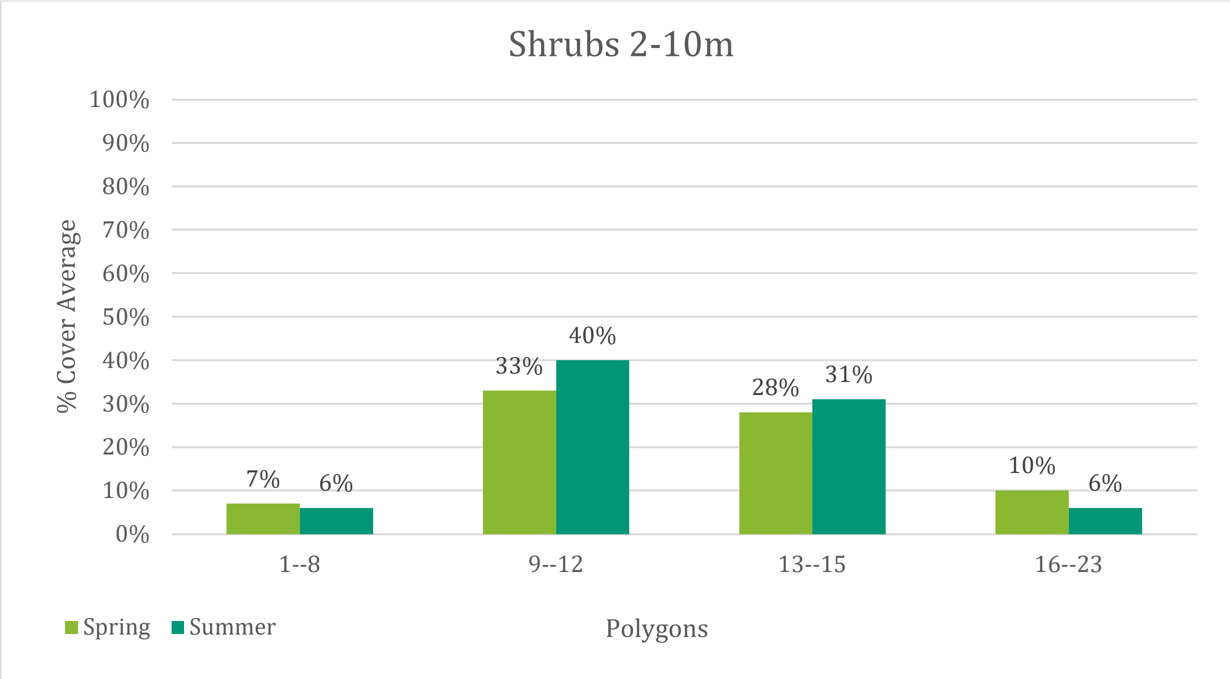

Figure 4.28. The % cover average of shrubs 2-10m species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

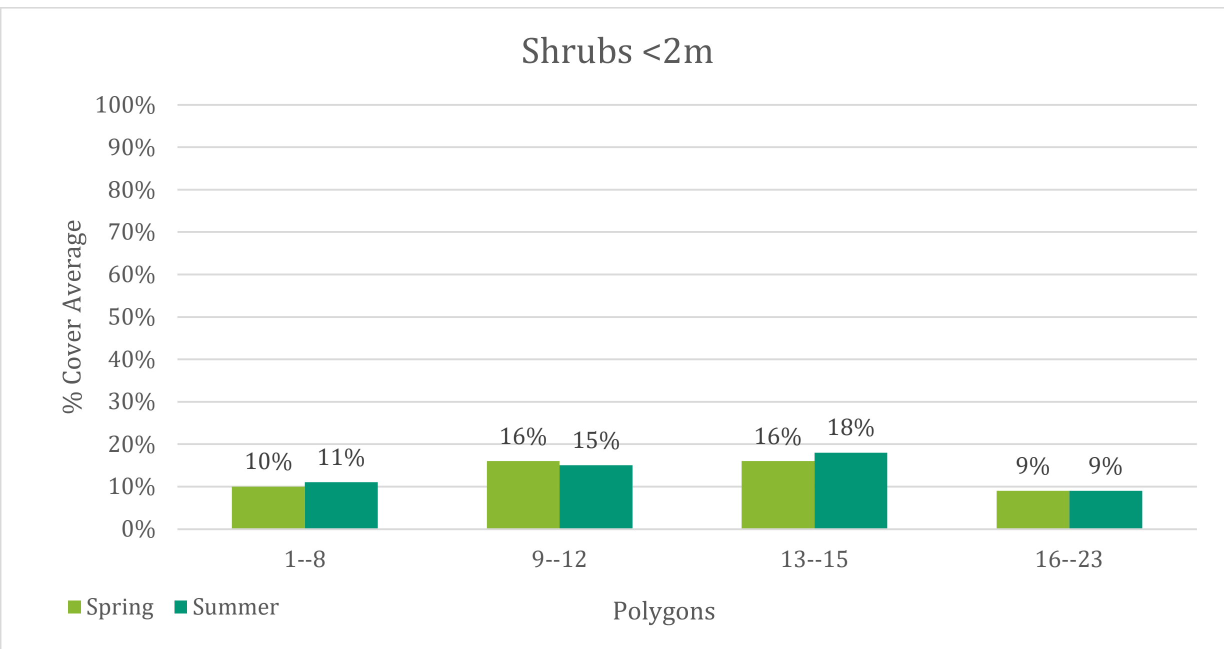

Figure 4.29. The % cover average of shrubs <2m species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

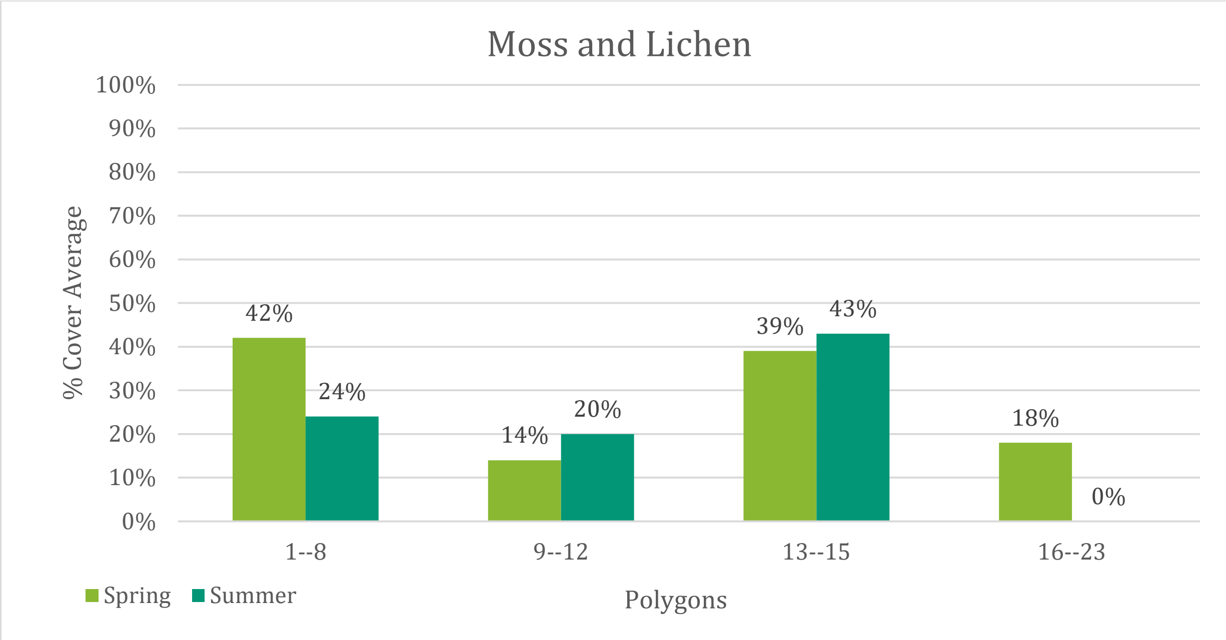

Figure 4.30. The % cover average of moss and lichen species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

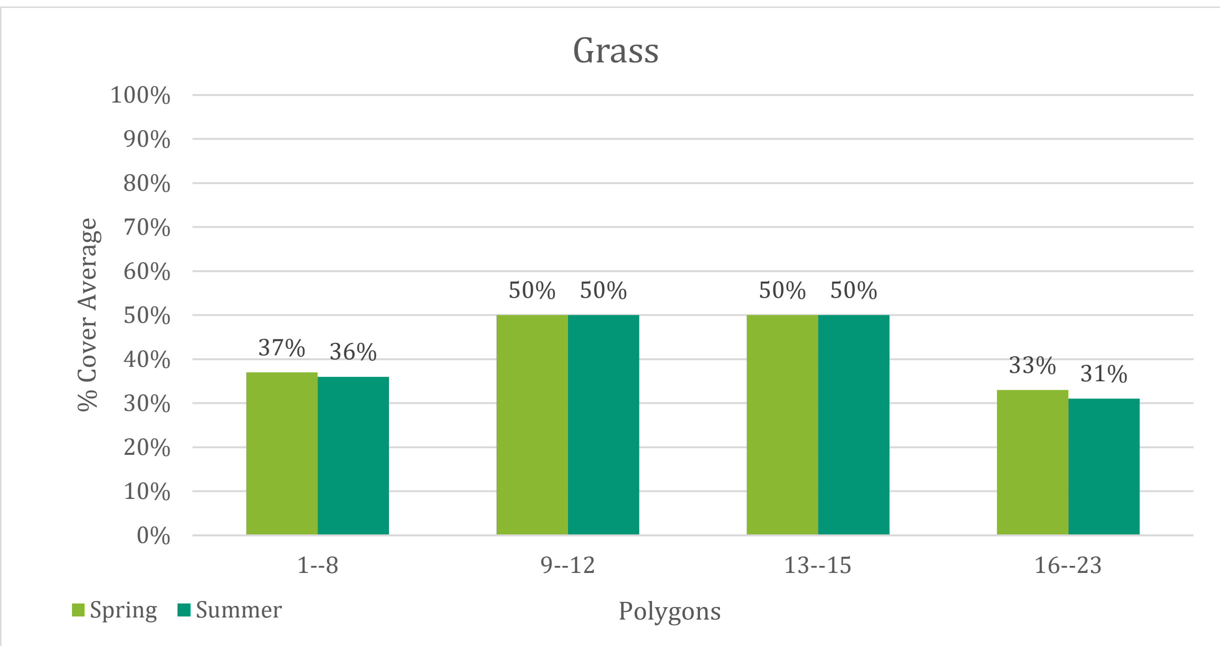

Figure 4.31. The % cover average of grass species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

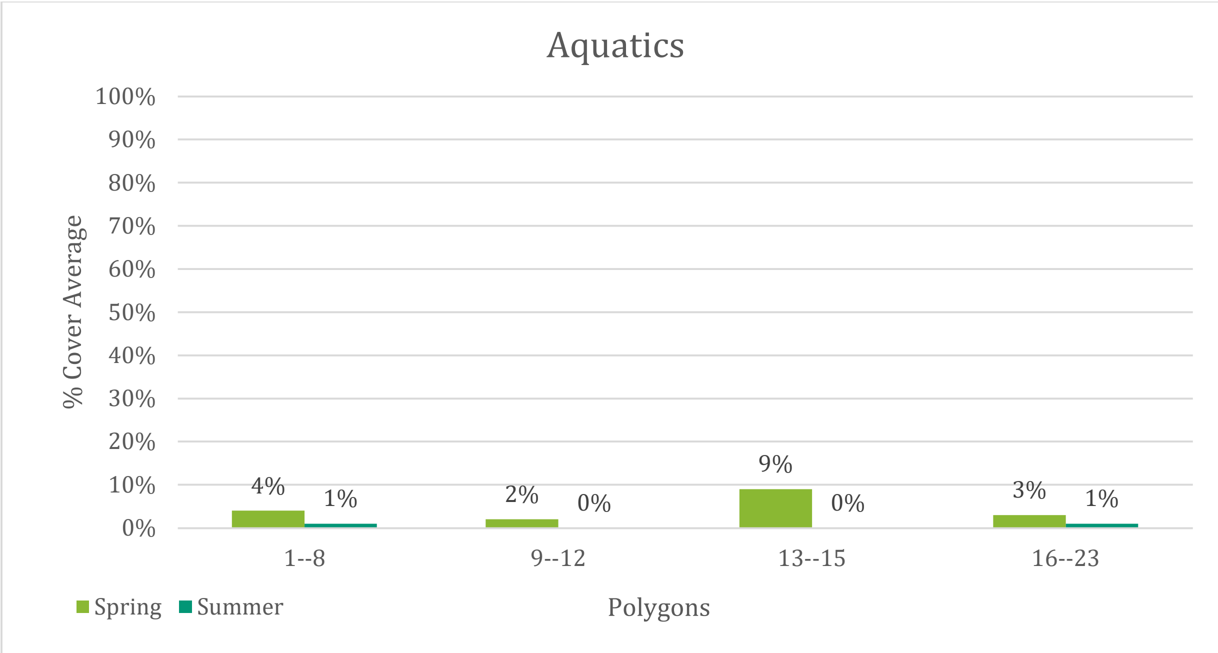

Figure 4.32. The % cover average of aquatic species present in each polygon group, 1-8, 9-12, 13-15, and 16-23 found during the spring (April 26th and May 3rd, 2023) and summer (June 21st and July 12th, 2023) assessments.

4.3.3 Wildlife Trees

Twenty-four wildlife trees of three different species were identified around the wetland during the spring assessment. Sixteen were Douglas-fir, seven were red alder *(Alnus rubra)*, and one was western redcedar *(Thuja plicata)* (Pojar and MacKinnon, 2016). Figure 4.33 shows the location of the wildlife trees around the wetland. The alders were all tree class three; the heartwood was still intact, but the sapwood was starting to decay, and the bark was beginning to slough (Table 4.8). Most if not all the limbs were dead on all trees, and half of the trees (1, 2, 22) had developed a tree lean greater than 15° (Table 4.8). Trees 2, 3, and 4 all had DBH greater than 30cm, with tree 3 having the largest at 45cm (Table 4.8). Trees 2, 3, 4, 22, 23, and 24 all have heights greater than 15m, with tree 22 being the tallest at 25m (Table 4.8). Tree 1 was the only tree to have a broken top, and stem damage (Table 4.8). Trees 2 and 3 had signs of new excavation, and tree 3 had evidence of beaver activity. The single western redcedar, tree 21, was tree class three, 14m tall with a DBH of 30cm. This tree was fully dead, had no cavities or excavations, but did have a broken top (Table 4.8). The Douglas-fir trees had a wide range in heights and DBH. Trees 5, 6, and 12 all have heights shorter than 15m but have DBH greater than 30cm; tree 5 is 14m tall and 48cm wide, tree 6 is 14m tall and 33cm wide, and tree 12 is 8m tall and 47cm wide (Table 4.8). All three of these trees had broken tops, dead limbs, and conks; trees 5 and 12 had a tree lean >15°, and all three had lots of new excavation (Table 4.8). Trees 7, 17, 18, and 20 all had heights and DBH greater than the standards; tree 7 was 20m tall and 83cm wide, tree 17 was 20m tall and 40cm wide, tree 18 was 20m tall and 30cm wide, and tree 20 was 22m tall and 90cm wide (Table 4.8). Only tree 17 and 18 had broken tops, but all four had dead limbs, and trees 17, 18, and 20 had conks growing, as well as lichen and moss (Table 4.8). Trees 17 and 20 had evidence of new excavation. Trees 8, 16, and 19 had both heights and DBH under the standards, tree 8 was 8m tall and 27cm wide, tree 16 was 7.5m tall and 25cm wide, and tree 19 was 5m tall and 18cm wide (Table 4.8). All three trees had broken tops, tree 8 had sloughing bark and a tree lean greater than 15° (Table 4.8). Based on all these characteristics the wildlife trees were ranked from low to high value for the ecosystem. Of the Douglas-fir 53% were high, 6% medium, and 41% low value (Figure 4.34); while for the deciduous trees 43% were high, 0% were medium, and 57% had a low value (Figure 4.35). Overall, 71% of the wildlife trees were coniferous and 29% were deciduous (Figure 4.36). The wildlife trees did not change much from spring to summer, although tree 7 had new excavation holes and tree 8 had newly broken branches (Table 4.8).

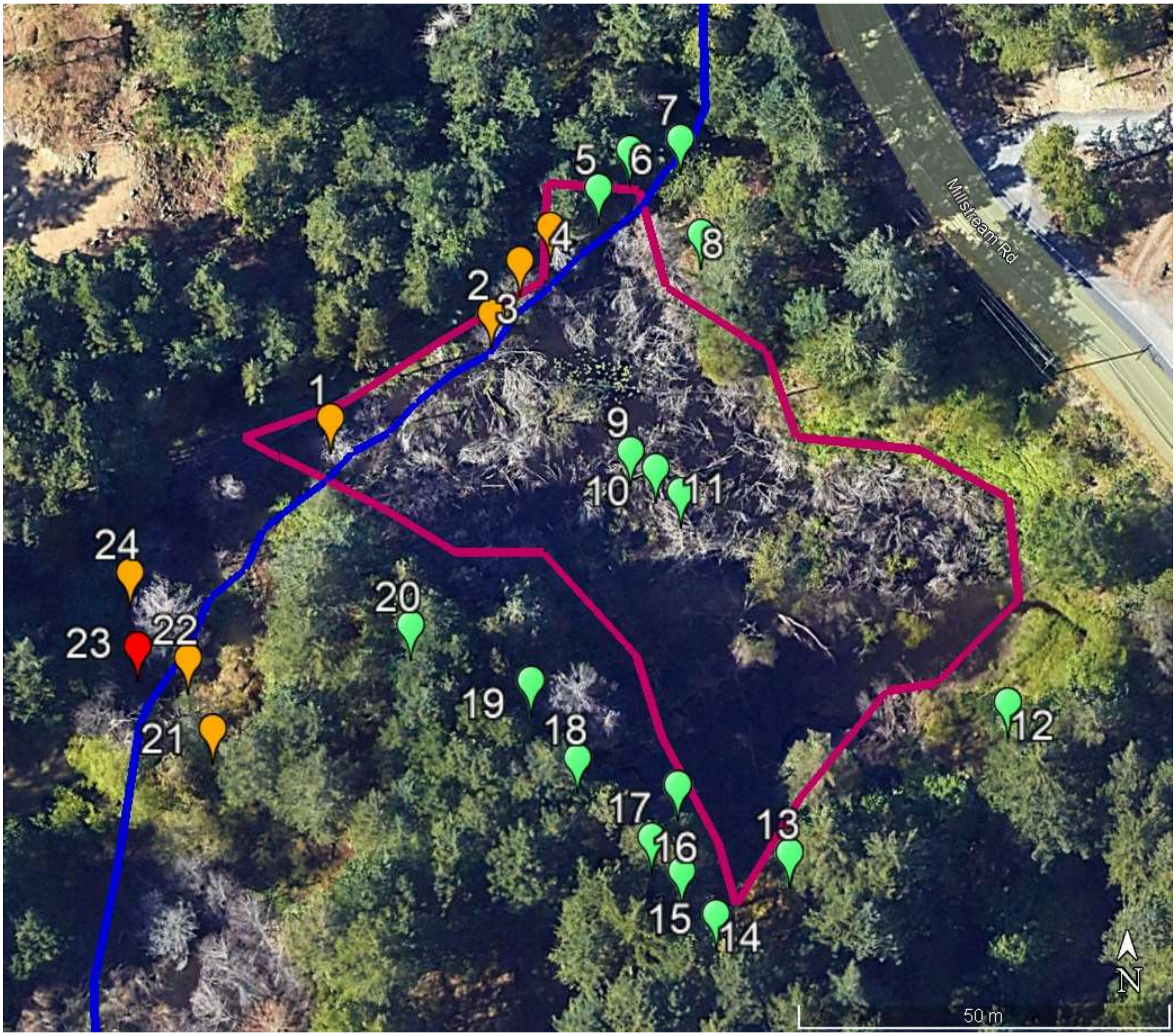

Figure 4.33. Map of the wildlife trees found around the Beaver Wetland, orange indicates alder, red indicates western red cedar, and green indicates Douglas-fir; pink outline is the wetland perimeter, and the blue line is Millstream Creek; Map made in Google Earth Pro by Kimberly Groome; May 29, 2023, NAD 83 WSGS U10.

Table 4.8. Wildlife tree assessment form filled out for the Beaver Wetland around Mary lake Nature Sanctuary, indicating species (Sp.), tree class, wildlife value, height (m), diameter at breast height (DBH cm), the level of danger (LOD), and characteristics: broken top (HT), dead limbs (DL), Witch's broom (WB), split trunk (ST), sloughing bark (SB), conks/cankers (CA), tree lean (TL), and stem damage (SD); all blank cells are intentional and indicate an absence of that quality; adapted from the BC MoE Wildlife/Danger Tree Assessor's Course Workbook.

Wildlife Tree Assessment: Mary Lake Nature Sanctuary - Wetland East - Wild Riparian Conservation																	WILD RIPARIAN CONSERVATION	
Date: April 12, 2023 and May 10, 2023 Location: Beaver Wetland Assessors: Kimberly and Kyla						LOD 1 = Table 3 S = safe D = dangerous			Y = characteristic present Blank = characteristic absent LOD 2 or 3 = Table 3, 3a									
Tree ID	Sp.	Tree Class	Wildlife Value	Height (m)	DBH (cm)	A	B	C	HT	DL	WB	ST	SB	CA	TL	SD	Spring Wildlife Evidence/Notes	Summer Wildlife Evidence/Notes
WIT1	Alder	C-3	Low	13	28			S	Y	Y		Y	Y		Y			
WIT2	Alder	D-3	High	15	35			S		Y			Y		Y		Excavation holes	
WIT3	Alder	D-3	High	15	45			S		Y			Y				Beaver marks, excavation holes, lots of moss	
WIT4	Alder	D-3	High	15	32			S		Y			Y					
WIT5	Df	C-5	High	14	48			S	Y	Y				Y	Y		Lots of excavation holes	
WIT6	Df	C-5	High	14	33			S	Y	Y				Y			Lots of excavation holes	
WIT7	Df	C-4	High	20	83			S		Y							Lichen and moss	New excavation holes
WIT8	Df	C-3	High	8	27			S	Y	Y			Y		Y			New broken branches
WIT9	Df	C-6	Low	9	26			S	Y	Y		Y	Y	Y		Y		

WIT10	Df	C-6	Low	11	28			S	Y	Y				Y				
WIT11	Df	C-6	Low	10	25			S	Y	Y				Y				
WIT12	Df	C-4	High	8	47			S	Y	Y			Y	Y	Y		Lots of excavation holes	
WIT13	Df	C-4	Low	18	44			S	Y	Y				Y	Y			
WIT14	Df	C-4	Low	20	52			S	Y	Y				Y				Large excavation hole
WIT15	Df	C-4	Low	22	46			S	Y	Y				Y				
WIT16	Df	C-4	Med	7.5	25			S	Y	Y				Y				
WIT17	Df	C-4	High	20	40			S	Y	Y				Y			Tiny conks growing, new excavation	
WIT18	Df	C-4	High	20	30			S	Y	Y				Y				
WIT19	Df	C-5	High	5	18			S	Y	Y				Y			New excavation, newly broken top	
WIT20	Df	C-3	High	28	90			S		Y				Y			New excavation	
WIT21	RC	C-3	Low	14	30			S	Y	Y				Y			Moss on branches	
WIT22	Alder	D-3	Low	22	17			S		Y			Y		Y			
WIT23	Alder	D-3	Low	20	16			S		Y			Y					
WIT24	Alder	D-3	Low	18	16			S		Y			Y					

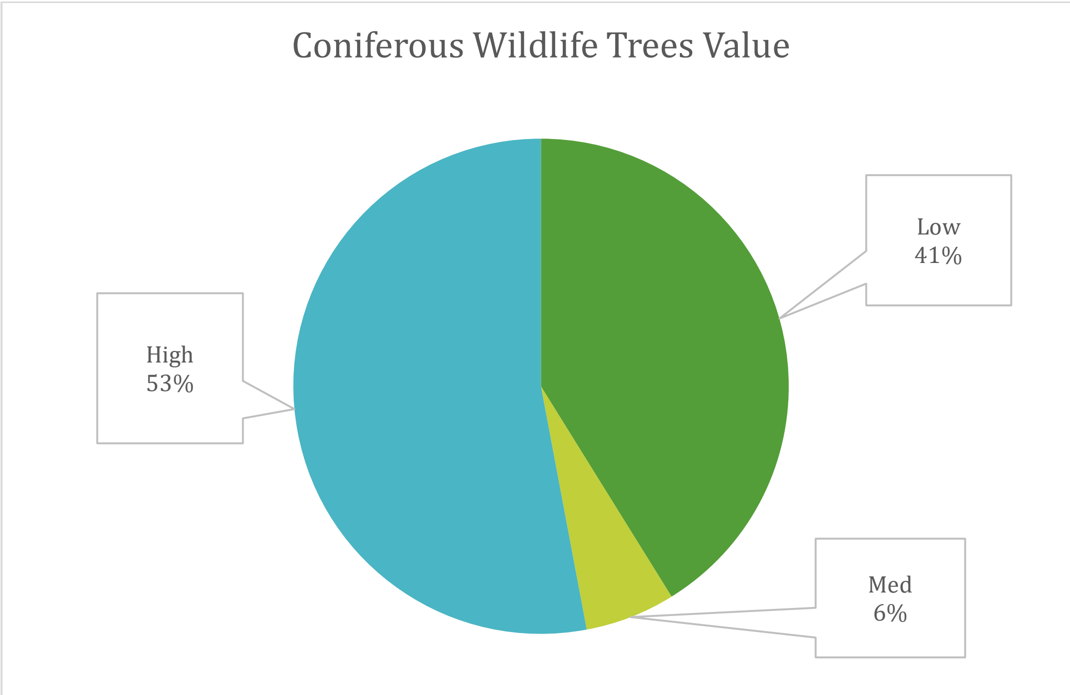

Figure 4.34. Coniferous wildlife trees around the Beaver wetland based on value, 53% high, 6% medium, and 41% low value.

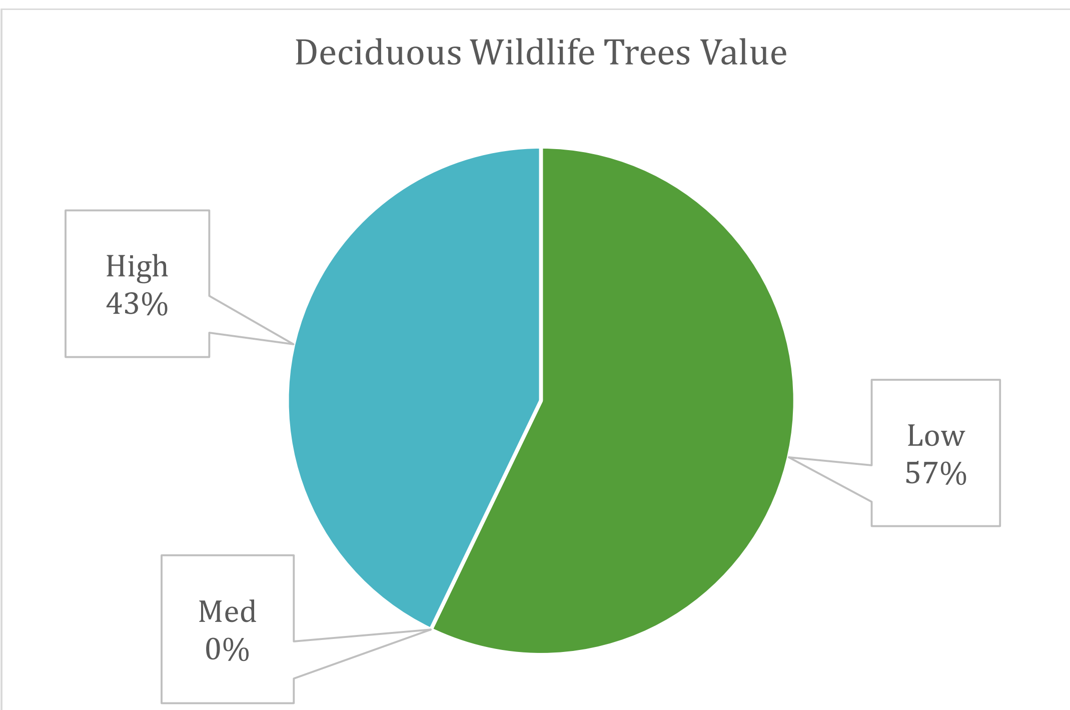

Figure 4.35. Deciduous wildlife trees found around the Beaver wetland based on value; 43% high, 0% medium, and 57% low value.

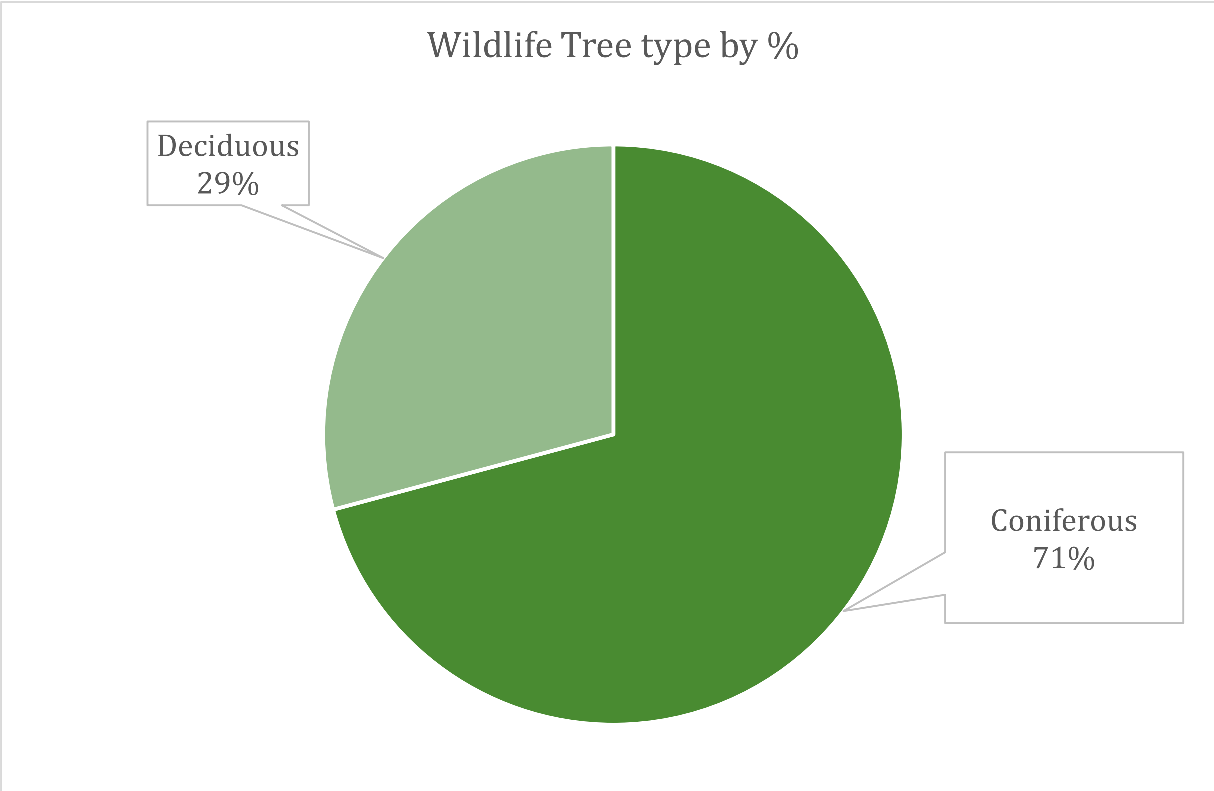

Figure 4.36. Percent of wildlife trees found around the Beaver Wetland by type, 29% deciduous and 71% coniferous

4.4 Crayfish Gee Trapping

4.4.1 Beaver Wetland

Gee traps were set up along the outer perimeter and protected zones throughout the entire Beaver wetland to determine if crayfish were present. Having this information could better inform our sponsors if this wetland is potentially significant as crayfish are a source of food for predators. Three crayfish trapping efforts were conducted on March 29th, April 12th, and June 21st. Signal Crayfish (*Pacifastacus leniusculus)* were recorded during the final trapping efforts on June 21st with one crayfish observed outside of the trap at the WL-Outlet site before trap retrieval (Table 4.9 & Figure 4.37). Multiple crayfish were observed throughout the Millstream creak at the connection to Beaver Wetland at the WL-Inlet Site, which can be referenced in Figure 4.38. Three different types of bait were used on each sampling date and targeted locations to determine if catch results would change as no catch was recorded on March 29th and April 12th.

Table 4.9. Final crayfish gee trapping results in Beaver Wetland on June 21, 2023.

Crayfish Gee Trapping Beaver Wetland Collection Date: 21 June, 2023 Weather: Sunny 15 C			Habitat: Wetland shore, new plant growth. Woody debris, low/no flow. Abundant organics in substrate		Observations: Approximately 2-3 Signal Crayfish observed in WL-Inlet site in river rock substrate (6cm in length)		WILD RIPARIAN CONSERVATION	
Site	GPS (UTM)	Time In	Time Out	Water Temp(C)	Depth (m)	Species	Count	Length
GT-16	10 U, 0461981, 5372034	8:57	11:07	14.4	0.5	Signal Crayfish (*Pacifastacus leniusculus)*	1	~12cm
GT-17	10 U, 0462016, 5372080	9:02	23:08	14	0.5	No Catch	-	-
GT-18	10 U, 0462023, 5372086	9:08	11:15	14.1	0.5	No Catch	-	-
GT-19	10 U, 0462049, 5372111	9:24	11:25	12.6	0.5	No Catch	-	-
GT-20	10 U, 0462044, 5372099	9:30	11:28	12.3	0.5	No Catch	-	-
GT-21	10 U, 0462050, 5372084	9:24	11:25	12	0.5	No Catch	-	-

Figure 4.37. Crayfish observation at WL-Outlet site during gee trap removal on June 21, 2023.

Figure 4.38. Crayfish observation at WL-Inlet site in Millstream Creek during walkthrough of area on June 21, 2023.

4.5 Wildlife Incidentals

Wildlife incidental observations were recorded throughout the extent of the Mary Lake Nature Sanctuary field program in the months of March to June. The incidental observations were recorded through field observations and a wildlife camera that was set up in locations throughout Beaver Wetland. Sites were chosen based upon wildlife game trails or educated assumptions about where wildlife may travel throughout the wetland. Three sites were chosen around the wetland and the camera was able to capture Black-Tailed Deer (*Odocoileus hemionus)* and one Great Blue Heron (*Ardea herodias)*. Field crews were able to observe juvenile Coho Salmon (*Oncorhynchus kisutch)*, Cutthroat Trout (*Oncorhynchus clarkii*), River Otters (*Lontra Canadensis)* and an American Mink (*Mustela vison evagor*) during water quality collection and riparian assessments (Table 4.10).

Table 4.10. Wildlife incidental observations from wildlife camera and field crew through March to June 2023 at Mary Lake and Beaver Wetland.

Wildlife Incidental Form				
Mary Lake and Beaver Wetland				
Collection Method: Wildlife Cam & Field Observation				
Location/Site	**GPS (UTM)**	**Date**	**Species**	**Photo Reference**
WL Outlet	10U, 461977E 5372038N	31 March, 2023	Black-Tailed Deer (*Odocoileus hemionus*)	
WL Outlet	10U, 461977E 5372038N	02 April, 2023	Black-Tailed Deer (*Odocoileus hemionus*)	
WL Outlet	10U, 461977E 5372038N	05 April, 2023	Black-Tailed Deer (*Odocoileus hemionus*)	

WL Outlet	10U, 461977E 5372038N	07 April, 2023	Black-Tailed Deer (*Odocoileus hemionus*)	
WL Outlet	10U, 461977E 5372038N	09 April, 2023	Black-Tailed Deer (*Odocoileus hemionus*)	
WL Outlet	10U, 461977E 5372038N	11 April, 2023	Black-Tailed Deer (*Odocoileus hemionus*)	
WL Garden	10U, 462055E 5372019N	07 May, 2023	Great Blue Heron (*Ardea herodias*)	
WL Inlet (Millstream Creek)	10U, 462029E 5372102N	17 May, 2023	Coho Salmon (*Oncorhynchus kisutch*)	
WL Garden	10U, 462055E 5372019N	04 June, 2023	Black-Tailed Deer (*Odocoileus hemionus*)	

WL Inlet (Millstream Creek)	10U, 462029E 5372102N	21 June, 2023	Cutthroat Trout (*Oncorhynchus clarkii*)	
WL Outlet	10U, 461977E 5372067N	21 June, 2023	Beaver (*Castor canadensis*)	
WL Garden	10U, 462019E 5372057N	21 June, 2023	River Otter (*Lontra canadensis*)	
WL Outlet	10U, 461977E 5372067N	21 June, 2023	American Mink (*Mustela vison evagor*)	No photo available
Mary Lake - Lake 1	10U, 461709E 5372009N	28 June, 2023	River Otter (*Lontra canadensis*)	
Beaver Wetland	10U, 462055E 5372019N	May 10, 2023	Mallards (*Anas platyrhynchos*)	
WL Road	10U, 462092E 5372055N	May 10, 2023	Frog species egg mass	

WL Outlet	10U, 461977E 5372067N	May 10, 2023	Garter snake (*Thamnophis sirtalis*)	

WILD RIPARIAN CONSERVATION

5.0 Discussion

5.1 Water Quality

General trends are showing the warmer temperatures from the summer months affect Mary Lake and Beaver Wetland - the main indicator affected is dissolved oxygen concentrations which lower as temperature rise; this can result in a negative impact on the overall ecosystem health of the area.

5.1.1 Temperature

The temperature of Mary Lake and Beaver Wetland generally increased from February towards the end of June when water quality sampling finished for this project. This trend was expected as results from the 2019 and 2022 reports also had results displaying this (VIEC, 2019; EIEC, 2022). Temperature fluctuations were minimal among the various points sampled within the lake and wetland (Figure 4.6). The lake and wetland had a minimal overhead canopy, resulting in direct light for large portions of the days. Millstream Creak at WL-Inlet sampling site had juvenile Coho and Cutthroat present have a maximum temperature recommendation of 16°C in streams (BC MOE, 2001), which was surpassed on the last two sampling days on May 17 (17.2 °C) and June 28 (16.3 °C).

When compared to the 2022 results for Mary Lake and surrounding watershed, the temperature measures showed very similar average results with all sites having temperatures within a 1°C difference. The maximum temperature results showed a 1-3°C increase at sampling locations around Mary Lake and the surrounding watershed. The 2019 water quality results showed a much higher average and max temperature readings in comparison with this year's results, which could be due to higher ambient air temperatures in the months of April and June (Figure 5.1). The surrounding watershed including North Earsman, South Earsman and Dead Deer Creeks all had a large reduction in flows at the end of June which can contribute to higher temperature increases and potentially harm aquatic life.

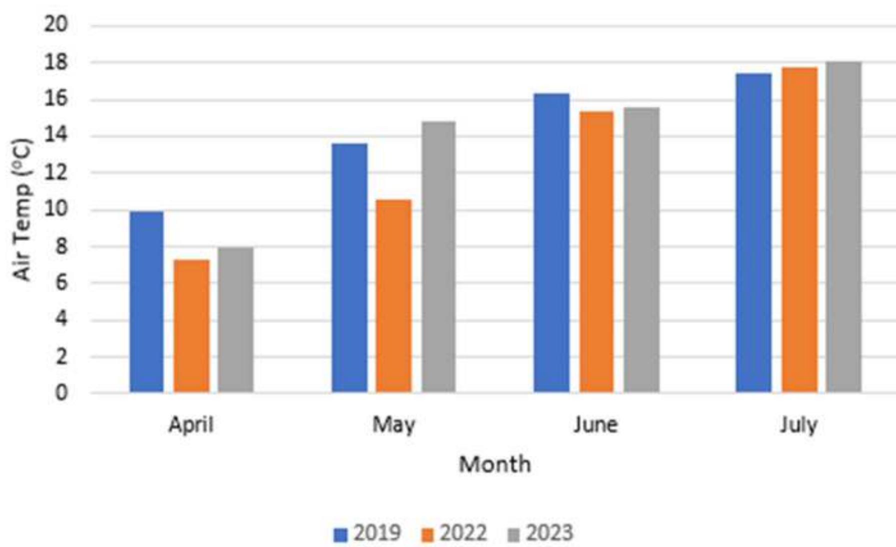

Figure 5.1. Ambient mean air temperatures from 2019, 2022 & 2023 through the months of April-July in Victoria BC.

5.1.2 pH

pH is a measurement that quantifies the concentration of hydrogen ions in water, rated on a logarithmic scale from 1.0 to 14.0. The acidity of water increases as the pH value decreases, while a higher pH indicates a more basic or alkaline nature. pH has a significant impact on various chemical and biological processes in water, and different organisms thrive within specific pH ranges. The majority of aquatic organisms thrive within a pH range of 6.5 to 9.0, thus this range supports the greatest diversity. When the pH falls outside this range, it negatively affects the stream's biodiversity by imposing stress on the physiological systems of most organisms and reducing their reproductive capabilities. Moreover, low pH levels can facilitate the mobilization and accessibility of toxic elements and compounds like heavy metals, which can be absorbed by aquatic plants and animals. This situation can create hazardous conditions for aquatic life, particularly for sensitive species such salmon and trout (B.C. MOE, 2021a).

The pH levels in comparison to those recorded in the 2019 and 2022 report showed to have similar results with no outliers or increased or decreased levels and all falling within pH 7.3 to 8.4. The Beaver Wetland pH levels ranged from 6.5 to 7.8, except for the Wetland Inlet site which had a minimum pH level of 5.7 recorded on February 21st. Potential for low pH levels in Millstream Creek (WL-Inlet) can be attributed to low and shallow flows over bedrock in creaks. This can be due to elevated levels of inorganic solutes from exposed rock leaching and have potential to raise the pH (BC MOE, 2021b).

5.1.3 DO

Dissolved oxygen (DO) is a critical parameter when assessing water quality. It refers to the amount of oxygen gas dissolved in water. The concentration of dissolved oxygen is influenced by various factors, including temperature, pressure, salinity, and the presence of photosynthetic organisms. Water quality guidelines typically establish recommended levels of dissolved oxygen and aim to ensure that sufficient oxygen is available for the survival and well-being of aquatic organisms. Generally, higher dissolved oxygen levels indicate better water quality. Mary Lake and Beaver Wetland show the opposite with dissolved oxygen concentrations decreasing as the summer months and warmer temperature approached in June. Adequate oxygen concentrations are necessary for the respiration of fish, invertebrates, and other aquatic organisms. Insufficient levels of dissolved oxygen can lead to hypoxia causing stress, suffocation or even death among some aquatic species (CCME, 1999e).

Water quality guidelines typically specify a range of dissolved oxygen concentrations suitable for different types of water bodies. For freshwater systems, like Mary Lake and Beaver Wetland, long term dissolved oxygen results above 8 mg/L and short-term results above 5mg/L are recommended for the protection of aquatic life as shown in the BC water Quality Guidelines reports. The CCME (1999e) outlines that water quality standard for aquatic life in warm water should have a dissolved oxygen level above 6 mg/L which Mary Lake shows at most sites during the June 28 field sampling.

As the summer months and warmer temperatures continue into the year, it is probable the dissolved oxygen levels will decrease in both water bodies as Beaver Wetlands' main input of freshwater had dried, with no flows observed from Millstream Creek on July 5th. This can be expected as flowing water introduces more DO to water bodies. Mary Lake may potentially follow a similar trend as Dead Deer Creek and North Earsman are the main inputs of fresh water into the Lake, and they were observed to already be in a low flow state on June 28 during the last *in situ* water sampling event.

5.1.4 TDS & Conductivity

Total Dissolved Solids (TDS) is a measurement that quantifies the combined content of inorganic and organic substances dissolved in water. It includes minerals, salts, metals, ions, and other dissolved compounds. TDS was expressed as parts per million (ppm) during *in situ* water quality measurements throughout this sampling program. Evaluating TDS levels is important in assessing water quality, as excessively high or low TDS concentrations can have implications for freshwater ecosystems.

In general, freshwater bodies such as rivers, lakes, and streams have natural TDS ranges that vary geographically. The factors affecting the TDS range at Mary Lake and Beaver Wetland can be attributed to the surrounding geology, climate, and human activities in the area. Natural TDS levels in freshwater ecosystems generally range from less than 100 mg/L to a few thousand ppm, with Canadian guidelines indicating ≤500 ppm as a recommendation (Canada, 2009). In freshwater systems like Mary Lake and Beaver wetland, there is no specific mandated threshold for Total Dissolved Solids (TDS) that must be maintained to support aquatic life (BC MOE, 2001). TDS includes all solutes present in the water, including both inorganic and abiotic organic substances. Conductivity differs in that it measures a solution's ability to conduct electricity, thus conductivity only indicates the presence of inorganic solutes since organic solutes do not contribute to electrical conductivity (US EPA, 2012).

Conductivity, when compared to sampling in 2019 and 2022, had similar results ranging from approximately 115 us/cm to 210 us/cm at Mary Lake (Figure 4.8), with one outlier of 405 us/cm recorded at the Dock Site last year (VIEC, 2019)(EIEC, 2022). Beaver wetland had slightly lower results ranging between 100 us/cm and 150 us/cm (Figure 4.8), which could be due the hydrology of the lake system compared to a wetland as the wetland is much smaller and stagnant and differs from the lake in how nutrients and inorganics react with each other.

5.1.5 Alkalinity

Alkalinity represents the water’s capacity to counteract acidity by acting as a buffer. It measures the ability of alkaline compounds present in the water, such as bicarbonates (similar to baking soda), carbonates, and hydroxides, to remove H+ ions and decrease water acidity, consequently raising the pH. These compounds react with H+ ions, forming new compounds. Without this capability to neutralize acids, any addition of acid to water would immediately alter its pH. Measuring alkalinity is crucial in assessing a waterbody’s capacity to counterbalance acidic pollution resulting from factors like rainfall or snowmelt. It serves as one of the most reliable indicators of a waterbody’s sensitivity to acidic inputs. Alkalinity is derived from various sources, including rocks and soils, salts, specific plant activities, and certain industrial wastewater discharges (Swain, 1987).

The primary source of alkaline minerals in Mary Lake and Beaver Wetland would be leaching from rocks in the surrounding area, as well as runoff into the water bodies from concrete from roadways or construction materials.

The lab tests show that all locations had a low sensitivity to pH changes, as indicated by alkalinity values greater than 20 mg/L (Figure 4.1.). In the last sampling analysis in June an increase in alkalinity was observed in the deeper areas of the lake and creeks compared to surface samples. This can be attributed to the closer proximity of deeper water to rocks along the lakebed, which results in increased leaching of alkaline materials into the water as well the rock substrate along the creek beds. In comparison to the 2022 report, there were similar results ranging from 30-50 mg/L (Figure 4.1.) with higher levels recorded along the depth samples and creeks (EIEC, 2022).

5.1.6 Phosphate

Phosphate is a key nutrient found in water, and its concentration plays a significant role in water quality, particularly in freshwater systems as it is sometimes the limiting nutrient in the environment. Certain origins of phosphorus in Mary Lake and Beaver Wetland may stem from nearby construction, residential communities, agricultural activities, and sewage discharge. Excessive levels of phosphates can lead to eutrophication, which was not visually observed throughout the sampling dates. Although some algae was observed around Beaver Wetland and Mary Lake in July (after water sampling had stopped), water levels decreased and water temperature increased leading to more aquatic plant growth. Phosphate concentrations were below the detection limit of 0.01mg/L for the colorimetric testing technique using the spectrometer for all sample sites during the April 5th, May 17th, and June 28th sampling.

5.1.7 Nitrate

Nitrate is a nitrogen-based compound found in water, and its concentration is an essential parameter for assessing water quality, particularly in freshwater systems. Nitrates can originate from various sources, including agricultural runoff, wastewater, industrial discharges, and natural processes like atmospheric deposition and nitrogen fixation by certain plants and bacteria. The main indication of nitrate inputs at Mary Lake could be from fish digestion which is a natural by-product. Excessive nitrate levels can lead to eutrophication, similar to the concerns with phosphates, where an abundance of nutrients stimulates excessive plant growth, particularly algae (CCME, 2012).

Water quality guidelines for nitrate concentrations aim to prevent or minimize eutrophication and maintain a balanced and healthy aquatic environment. The Canadian Water Quality Guidelines for nitrate indicate that the 30-d average concentration to protect freshwater aquatic over long term exposure is 13.0 mg L^{-1} (CCME, 2012). The levels sampled throughout the three days of lab analysis show the levels from Mary Lake and Beaver wetland were below 1mg/L (Seen in Figure 4.2) which would not pose any potential hazards for aquatic life or indicate any anthropogenic sources are affecting the lake or wetland. It is also necessary for plant growth as aquatic vegetation relies on nitrate as a vital nutrient, so dropping below these levels could disrupt the diversity and well-being of plants around the riparian zone.

5.1.8 Bacteria

The presence of coliforms, microorganisms typically present within soil, surface water influenced by organism waste (total coliforms) and the gastrointestinal tract of larger warm-blooded organisms (fecal coliforms), has been shown to be of great value in assessing water quality for both drinking and recreational use as they are classified as an indicator species. Indicator species such as total and fecal coliforms can indicate risk of pathogenic bacteria concentrations present within a water source and are used as indicator species because coliforms live within the same environment as pathogens and sampling allows to test for all possibilities. Results from total coliform and fecal coliform testing can indicate the health of the sampled site and what extent the effects to other organisms are if the site's water is ingested. Both membrane filtration and most probable number techniques of bacterial testing are historically used to determine the presence of pathogenic bacteria in water (Water Quality Criteria for Microbiological Indicators, 2021). Total coliforms, commonly found within soils can be present in stagnant, warm, and shallow water due to runoff. Given the Mary Lake water sampling site's geographical and biological characteristics it contains abundant favored ecosystems for total coliforms to thrive. With the abundance of wildlife in the area and easy access to waterbodies throughout the Mary Lake property, fecal coliforms commonly found in warm-blooded gastrointestinal tracts have a high probability of survival with these ecosystems. Both total and fecal coliforms have the typical environment present of successful colonization in Beaver Wetland, and shallow Mary Lake water sampling sites (creeks), predicting high colony results in these area. Leading up to the *ex-situ* sampling days, the weather remained consistent with no rainfall, thus limiting alterations of coliform results via runoff from the land. High animal activity in all sampling areas, specifically the wetland and creek sites resulted in detectable levels of fecal and total coliforms from both water sampling days on May 17th and June 28th, 2023. From both sampling days, the lowest concentrations of coliforms were present within lake sites except for South Earsman and North Earsman Creek which had overall higher concentrations of both fecal and total coliforms (Figures 4.3 to 4.5). Wetland samples from the road, bike, and garden had lower concentrations compared to the inlet and outlet sites. Most sites had higher coliforms during the second set of sampling on June 28th, likely due to higher temperatures and decreased water levels. Seasonal temperature increase results not only in lower water levels in the lake and wetland but also is likely to cause higher TDS concentrations and osmotic pressure. Both of these influence coliform colonies through increasing their rate of survival compared to lower temperatures and TDS concentration (Maddah & Chogle, 2016). During the June 28th, 2023, sampling period all bacterial results (except for South Earsman and Wetland Outlet sites) from both MF and MPN methods were within recreational standards whereas only the Lake 1 site was within drinking water quality standards (Water Quality Criteria for Microbiological Indicators, 2021).

5.2 Sediment Sampling

Analyses of metals in sediment samples from three sites along the perimeter of the Beaver wetland were conducted twice. These two sets of results can be compared to the CCME guidelines as well as to each other for consistencies.

Analysis of sediment using an XRF machine has shown samples to have metals in concentrations above the guidelines determined by the Canadian Council of Ministers of the Environment (CCME). As seen in table 4.1, only one of the fifteen samples did not have concentrations exceeding the guidelines. The metals of ecological concern are chromium, cadmium, copper, zinc, mercury, lead, arsenic, and nickel. All of these metals were found to exceed the guidelines except for mercury in at least one of the fifteen samples. It was found that four of the five inlet samples exceeded the CCME guidelines for cadmium. All other metals tested were within a normal range within the inlet samples.

The bike site samples had several metals in high concentrations. The concentrations of zinc, arsenic and copper exceeded guidelines in two of the five samples. Table 4.2 shows that the average copper concentration at the bike site is above the guidelines and that the concentration of zinc is just below the guidelines. The average concentration of arsenic could not be determined because one of the five samples was below the detection limit. All the bike site samples exceeded the CCME guidelines for chromium, lead, and vanadium. Vanadium was not initially a metal of concern; however, the concentrations within these samples was unusual and prompted further inquiry. A possible source of contamination for all of the metals at the bike site is thought to be the rusting of metal fencing and several bicycles submerged in the water.

The road site was the area of interest indicated by GVGS to determine if runoff from the road is contaminating the wetland. The sampling technique was altered at this site to increase the testing area, by spreading the sample locations along the length of the road. All the road site samples exceeded the guidelines for copper, chromium, nickel and vanadium. Zinc, lead, cadmium, and arsenic were within normal ranges within the road site samples. It is possible that this contamination is attributed to road runoff contamination since research has shown that zinc, lead, copper, cadmium, chromium, nickel as well as iron and manganese are the metals commonly found in road runoff (Marsalek et al., 1997). The source of the vanadium is unknown at this point. Vanadium is a naturally-occurring metal in the earth's crust at varying concentrations though vanadium has a tendency to partition to the atmosphere (CDC, 2011). The metal is also a constituent of coal and crude oil and is often released into the air as a result of burning these fuels (CDC, 2011). Anthropogenic release of vanadium to soil is uncommon but can occur from certain fertilizers and disposal of industrial waste though this is unlikely because there are no known industries nearby that would be producing waste containing vanadium (CDC, 2011).

A second set of samples was collected on June 21st and was analyzed on July 5th to verify the results from the first set of samples. The second set of results provided data that were vastly different than many of the concentrations determined in May. Significantly higher concentrations of arsenic, chromium, copper, lead, and zinc were found in the bike site. Nickel, cadmium, and vanadium were found in similar concentrations between samples. There were large spikes of zinc and arsenic concentrations within these samples. The reason several metal concentrations are higher is thought to be in part due to the dropping water levels in the wetland. During both sample dates, sediment was collected close to the water line; however, there were several months between the sample dates and the water level had changed significantly. It is likely that during the second round of testing, sediment was collected closer to the source of the contamination. The sediment samples from the bike site exceeded the CCME guidelines for all the metals of concern including arsenic, copper, chromium, cadmium, nickel, lead, zinc, and vanadium.

In comparing the road site sediment samples between dates, the concentrations of each of the metals remained relatively similar. In both sets of testing, it was found that copper, chromium, nickel, and vanadium concentrations exceeded the CCME guidelines. Though several metal concentrations exceeded the CCME guidelines, there were no spikes present.

Lead was the only metal found to be different between the inlet sampling results, as there were massive spikes in the inlet samples from July 5th. None of the metal concentrations exceeded the CCME guidelines during the first sampling at the inlet site; however, the lead concentrations found during the second sampling exceed the guidelines. It is possible that contamination had come from upstream since the first sampling date. There are several industries upstream such as electricians, gunsmiths as well as development in the area which could serve as potential sources of metals.

5.3 Riparian Assessment

5.3.1 Wetland Overview

The riparian assessment is focused on the main part of the Beaver wetland. The west arm, depicted in light blue (Figure 5.2) was excluded from the assessment because of safety concerns: the vegetation is denser, the slopes are steep, there is rusted out barbed wire and debris, and it is very close to Millstream Road. The perimeter of the wetland was broken into 23 polygons, each ~15m in length, as this is the minimum polygon size for a riparian assessment (Fletcher, et al. 2021). Polygons one to eight were assessed around one meter in width as these polygons follow the preexisting path along the north edge of the wetland, cross Millstream Creek, and then trail around a boulder. The polygons after that were assessed with a width up to three meters as the water level of the wetland changed drastically on this side throughout spring. Assessing a wider width here allows for a more accurate assessment of plants.

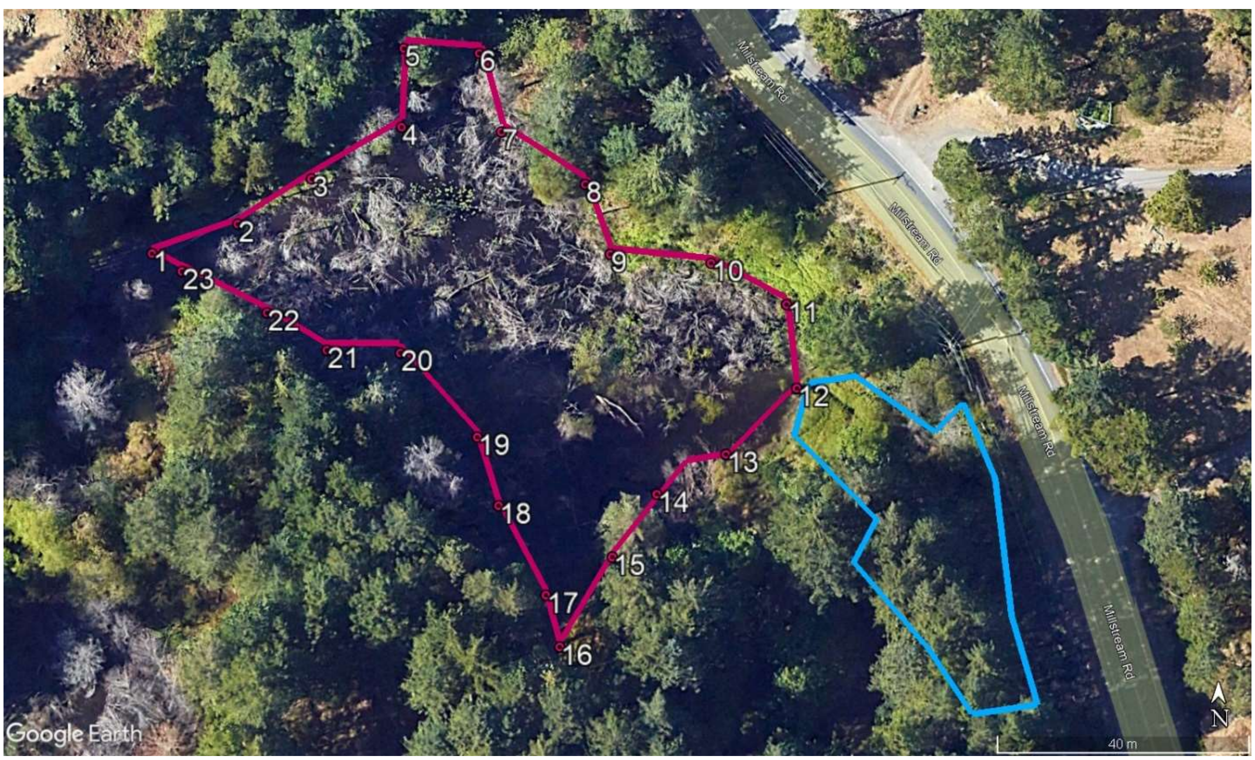

Figure 5.2. Map of the vegetation polygons at the Beaver Wetland at Mary Lake Nature Sanctuary, the pink outline is the main wetland focused on and blue outline is the west arm not focused on for safety reasons; Map made in Google Earth Pro by Kimberly Groome; May 29, 2023, NAD 83 WSGS U10.

5.3.2 Riparian Vegetation

The spring vegetation survey's purpose was to build a list of possible plants present at the Beaver Wetland. During the spring, plant identification is difficult without proper knowledge of what to look for, such as alternate, whorled, or opposite symmetry of buds or the colour of new growth versus old growth (Pojar & MacKinnon, 2016). For this reason, the identification of plant species in the spring assessment was subject to error, which the summer assessment tried to mitigate. The plants identified in both the spring and summer assessments are confirmed as being present, whereas plants that were only identified in one season can only be assumed to be present as they could have started growing after the spring assessment or are due to identification error.

The drastic drop in moss, lichen, and aquatic species between the spring and summer assessments was due to the drop in water level as spring 2023 was uncharacteristically dry for Vancouver Island (Canada Weather Stats, 2023). One thing to note about the five trees in polygon 15, they are all less than 5 feet tall, three are dying and two have already died. These trees are trying to grow on top of a large boulder, which cannot support the trees' water demand, especially in a dry season. Previously the carpet of moss on the boulder was supplying the saplings with a water source.

In polygons 1-8 there were six western red cedars planted by the GVGS as part of a site remediation plan created by Rob Shoemaker (2022), a conservation technician with the Capitol Regional Distract (CRD). The restoration site is the access road parallel to Millstream Creek along polygons 1-8 (Shoemaker, 2023). The site prescription outlines native shrub and tree species that will create a natural barrier preventing people from accessing MLNS property. Phase one aligns with the WRC objectives of assessing the plants present and conducting analysis on water quality and sediment samples in the area (Shoemaker, 2023). Overall, polygons 1-8 saw a drop in moss and lichen species as well as aquatic plants (Figures 4.23, 4.25).

Polygons 9-12 became dominated by grass species; the topography of the land here was a gradual northwest-facing slope. This water level here changed drastically, field visits during the spring required technicians to jump over or wade through a deep narrow part of the wetland, whereas in the summer the area had no standing water, but the sediment remained muddy. Polygons 13-15 saw a drop in moss, lichen, and aquatic species like the rest of the polygons, due to a drop in water level.

Polygons 16-23 saw a drastic drop in all species except for trees, there was a rocky mountain maple (*Acer glabrum*) found during the summer survey that was not accounted for in the spring (Figure 4.27, Table A.39). This drop in species could have been due to polygons 16-23 having more shade than the other polygons. Spring 2023 was drier than usual which could have accounted for the loss of species. There was also surveyor error along these polygons; instead of following the set polygon perimeter, the technicians followed the water line and were therefore measuring outside the polygon resulting in plants being excluded. An additional field day was conducted on August 2nd; however, only the trees were resampled due to time constraints.

A strong dominance of grass species over aquatic species due to a drop in standing water is characteristic of a marsh wetland, which supports the most diverse array of species out of any wetland type and is therefore critical habitat (BC MoFR and BC MoE, 2010). Marshes are early seral stage wetlands (BC MoFR and BC MoE, 2010). Since this area used to be the site of a house and garden in the 1940's, it has most likely been receiving more water over the last 80 years. Atmospheric rivers over the last few years have brought higher amounts of water to Millstream Creek which would contribute to the overall amount of water, but there is a suspected ground water source as well (Flood Wise, 2022).

5.3.3 Wildlife trees

The objective for the wetland is to preserve its ecosystem functions, this makes all the wildlife trees valuable assets; however, there are characteristics that make some trees more valuable than others. Based on the BC MoE standards (2012), the most valuable wildlife trees to the Beaver wetland are trees 7 and 20, both large Douglas-fir; tree seven is 20m tall and 83cm wide and tree 20 is 22m tall and 90cm wide (Table 4.8). In the spring trees 2, 3, 5, 6, 12, 17, and 19 had evidence of new excavations indicating wildlife use; however, no animal species were visually observed using the wildlife trees when WRC visited the site.

By nature, red alder trees decay faster than Douglas-fir trees (Edmonds, et al. 1986); for this reason, only three alder trees, trees 2, 3, and 4 were considered to be of high value (Table 4.8). The western redcedar (tree 21) was ranked low in value, as it was completely dead, had all its branches still intact and had no evidence of cavities or excavation. Overall, there are more coniferous wildlife trees than deciduous. Of note as well is there was a 25th wildlife tree identified in the preliminary survey, but the tree had fallen before the spring assessment took place, thereby nullifying its value as a wildlife tree, but not its ecological value, as it will release nutrients back to the wetland as it decays.

5.4 Gee trapping

The Signal Crayfish (*Pacifastacus leniusculus*) is native to British Columbia, and is the only crayfish species currently found on Vancouver Island. Gee traps were used to target these crayfish in Beaver Wetland and identify the presence or absence of the species, which gives an indication of wetland health. Crayfish offer a wide variety of benefits including nutrient cycling, algae control, and food for a variety of predators. The presence of crayfish provides a vital food source for birds and mammals in the area, as well as contributes to the overall biodiversity and ecological balance of the wetland ecosystem (Bondar et al, 2005).

Generally Signal Crayfish prefer temperatures lower than 25° C and an ambient level of pH above 6 is needed for survival (Bondar et al., 2005). Signal crayfish are efficient scavengers and omnivores, consuming various organic materials, detritus, and decaying plant matter like algae. By actively foraging and feeding on decaying vegetation and organic debris, crayfish contribute to nutrient cycling within the wetland ecosystem. Their feeding activities accelerate the decomposition of organic matter, releasing essential nutrients such as nitrogen and phosphorus back into the environment. This process enhances nutrient availability and fosters nutrient recycling, supporting primary production and overall ecosystem productivity. (Bondar et al., 2005).

Three separate sampling day efforts were conducted throughout March – June to confirm the presence of crayfish in Beaver Wetland. Gee traps were left to soak for approximately two hours to limit potential mortalities of fish or amphibians if present, while still targeting crayfish. During the last field effort on June 21, our field crew was able to observe multiple Signal Crayfish present in Millstream Creek around water quality site WL-Inlet which is directly connected to Beaver Wetland and one larger Signal Crayfish present on top of the gee trap at the WL-Outlet Site.

5.5 Incidentals

Wildlife incidental observations are valuable sources of data that provide crucial insights into the distribution, behavior, and ecological interactions of various species. Wild Riparian Conservation recorded observations of wildlife throughout the entire time on site to offer general knowledge of the species present. One wildlife camera was used in multiple locations around Beaver Wetland to detect any species present but mainly picked up Back-tailed Deer throughout April – June. Other species recorded by field crews around Beaver Wetland and Mary Lake included: River Otters, Canadian Geese, American Mink, waterfowl species, Coho salmon and

Cutthroat trout, indicating the high conservation value of the Mary Lake Nature Sanctuary. Having salmonid species present in Millstream Creek while it was connected to Beaver Wetland shows this wetland to be a potentially significant area and protection zone for spawning salmonid species (Province of British Columbia, 1995).

6.0 Conclusion

6.1 Water Quality

Wild Riparian Conservation wanted to build on the existing water quality monitoring plan used by East Island Environmental Consulting (EIEC) in 2022 and the recommendations from Van Isle Eco Consulting (VIEC) in 2019. The same sampling sites and water quality parameters were monitored for the multi-year sampling of Mary Lake. Beaver Wetland was also selected as a second water body on GVGS property to have a water quality monitoring conducted during the 2023 year.

Overall, the trends from the current water quality observations were similar to those from VIECs 2019 report and EIECs 2022 report along most parameters, aside from temperature which showed an increase of 2-5°C, which was also observed in the 2022 EIEC report. Conductivity on average was slightly higher than last year's sampling data but lower than the 2019 reports findings. Dissolved oxygen averages continued to decrease as the temperature increased this year, but were much lower compared to the 2022 EIEC report, showing 3-5 mg/L difference at each location. These results were most likely due to lower average ambient air temperatures throughout the sampling period which can be seen in Figure 4.7. Results in comparison with the 2019 report showed similar averages of dissolved oxygen with steady decreased levels as warmer temperatures approached. Coliform testing showed similar trends from the past 2022 report (EIEC, 2022) data of all the lake sites, but found an overall decrease of colonies present in the lake 2 site (70 fecal coliforms/100ml in 2022 (EIEC, 2022) and 43 fecal coliforms/100ml in 2023) and overall average increase of 30 fecal coliforms/100ml within the South Earsman Creek site likely caused by lower water levels. Beaver Wetland sites observed high total and fecal coliform levels mainly caused by the shallow warm low flow water and high animal presence in the ecosystem.

Temperature and dissolved oxygen were the parameters with the most movement towards a negative result for Mary Lake and Beaver Wetland. They are critical water quality parameters for this area's health due to their profound influence on various ecological processes and the overall well-being of aquatic ecosystems. Temperature directly affects the metabolic rate, reproduction, and behavior of aquatic organisms, shaping their distribution and abundance (BC. MOE, 2001). Proper dissolved oxygen levels are vital for the survival of aquatic life, supporting respiration, decomposition, and nutrient cycling processes (CCME, 1999). In the context of climate change and long-term monitoring, these parameters can disrupt the timing and intensity of seasonal temperature patterns affecting nutrient cycling leading to hypoxic conditions. Species that are affected may have to adapt to increased changing temperatures and oxygen ranges in this area. They may also be forced to face increased stress with some species being more resilient to these changes than others, potentially leading to shifts in aquatic biodiversity.

6.2 Sediment Sampling

One of the original research questions examined if the road was a source of contamination for the wetland. Overall, there is heavy metal contamination in the sediment adjacent to the road, but it is still unknown how much of the metals are making into wetland. It is also clear that the metal debris present at the bike site is contaminating the surrounding sediment with toxic heavy metals. Therefore, the road is a source of contamination for the sediment surrounding the wetland; however, the metal debris in the water is a greater source of contamination and is of greater concern at this time. It is also likely that sources upstream are contributing to the metal contamination of the wetland; however, more research needs to be completed to test this. In conclusion, arsenic, lead, cadmium, chromium, copper, zinc, vanadium, and nickel are all found in various samples throughout the wetland sites at concerning levels that exceed the CCME guidelines for soil quality guidelines for the protection of environmental and human health.

6.3 Wetland Assessment

Overall, the Beaver Wetland's vegetation is healthy, although there are some invasives present due to the historic garden and house that was occupied in the 1940's. There is a healthy distribution of plants around the wetland, and over all the wetland is dominated by moss and lichen, and grass species; these are characteristics of a marsh wetland (BC Ministry of Forests and Range and BC MOE, 2010). Aquatics are common if there is standing water, but the distribution is dependent on water level changes (BC Ministry of Forests and Range and BC MOE, 2010), such as observed at the Beaver Wetland. Marshes provide critical habitat for a diverse array of species making them important ecosystems to maintain. The survey discrepancies in polygons 16-23 indicate a major loss of species; however, this is most likely not the case and should be reassessed ensuring technicians follow the set GPS coordinates (Appendix A.40). The wildlife trees are all valuable and are being used, as there is evidence of excavation and newly broken limbs, all indicative of a healthy ecosystem.

6.4 Recommendations

1. Heavy Metal Contamination

- Given the levels of heavy metal contamination in the sediments at the bike site, it is recommended that GVGS removes the rusting bike, fencing, and other debris present in the wetland to prevent further contamination.

2. Continue Water Quality Monitoring

- The water quality monitoring program at Mary Lake and Beaver Wetland should continue. Removing Bathing Pond or South Earsman Creek site should be considered as the location for sampling at South Earsman Creek is within 10m of Bathing Pond and shows almost identical water quality results.
- Create an open-source document for water quality analysis so following RRU students or community members can easily access previous data. Open-source portals may include SharePoint, Google Drive, etc., where access can be given to sponsors and faculty advisors to pass on to future Mary Lake research groups.

3. Water Level Measurements

- Both lake and wetland water levels should be continually monitored throughout the duration of sampling to obtain a quantitative measure of water level decreases throughout seasonal change.

4. Vegetation Assessment

- A vegetation assessment of the whole wetland could be done in the future; however, this is only necessary if the wetland is to be studied fully. Since polygons 1-8 are a restoration site it is recommended to follow the site prescription created for GVGS and continually monitor the wetland in this area to ensure the restoration work is successful. If heavy metals are found to be continually high in sediment samples around the wetland, it would be in the best interest of the wetland to sample plants for heavy metal contamination as well. Doing so would show if the metals are being taken up by the plants or if they are remaining in the sediment. Monitoring the wildlife trees as well as documenting other wildlife trees around the nature sanctuary is recommended as they are good indicators of the health and activity of the area as many species use these trees. Tree 14 has a large excavation hole in it that could possibly be occupied. It is recommended to place a wildlife camera to monitor this (Table 4.8).

6.4.1 Future Research

Further research should be conducted on the heavy metal contamination at the Beaver wetland to understand the extent of the contamination in the sediment. More sample sites should be established to understand the distribution of the metals around the known sources of contamination as well as to look for upstream sources of contamination. It is recommended that sites be created extending outwards from the bike site as well as around the perimeter of the wetland. Additionally, it would be interesting to sample around Mary Lake and other features of the property. There are several other areas that historically had houses or sheds that may be sources of contamination similar to the bike site. There may be other sites throughout the property where items were discarded of and have been contaminating the environment.

References

BC Ministry of Environment. (2021a). *British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture - Guideline Summary.* Water Quality Guideline Series, WQG-20. Prov. B.C., Victoria B.C.

B.C. Ministry of Environment. (2021b). *pH Water Quality Guidelines* (Reformatted from: British Columbia Ministry of Environment, 1991. Ambient water quality criteria for pH). Water Quality Guideline Series, WQG-09. Prov. B.C., Victoria B.C

BC Ministry of Environment. (2001). Ministry of Environment Water Quality Water Quality Guidelines for Temperature Overview Report. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/temperature-or.pdf

BC Ministry of Agriculture and Food. (2023). Riparian Areas. Victoria, BC. https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/water/riparian-areas

BC Ministry of Environment. (2012). Wildlife/Danger Tree Assessor's Course Workbook.(pp. 1-136). Victoria, BC. https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-habitats/wildlife-tree-committee/assessor-s-courses

BC Ministry of Forests and Range and BC Ministry of Environment (2010). Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems. 2nd ed. Forest Science Program. (pp. 1-271). Victoria, B.C. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh25-2.htm

Bondar, C.A., Y. Zhang, J.S. Richardson, and D. Jesson. (2005). The conservation status of the freshwater crayfish, *Pacifastacus leniusculus*, in British Columbia. British Columbia Ministry of Water, Land and Air Protection. Fisheries Management Report No. 117

Canada. (2009). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Total Dissolved Solids (TDS) - Canada.ca. Canada.ca. https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-total-dissolved-solids-tds.html

Canada Weather Stats. (2023). *Total precipitation - monthly data for Vancouver*. Amateur Weather Statistics for Vancouver, British Columbia. https://vancouver.weatherstats.ca/charts/precipitation-monthly.html

CCME. (1997a). *Canadian Soil Quality Guidelines for the Protection of Environmental and*

Human Health: Arsenic (inorganic). Canadian Counsel of Ministers of the Environment. https://ccme.ca/en/res/arsenic-inorganic-canadian-soil-quality-guidelines-for-the-protection-of-environmental-and-human-health-en.pdf

CCME. (1999a). *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Cadmium.* Canadian Counsel of Ministers of the Environment. https://ccme.ca/en/res/cadmium-canadian-soil-quality-guidelines-for-the-protection-of-environmental-and-human-health-en.pdf

CCME. (1999b). *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Total Chromium.* Canadian Counsel of Ministers of the Environment. https://ccme.ca/en/res/chromium-canadian-soil-quality-guidelines-for-the-protection-of-environmental-and-human-health-en.pdf

CCME. (1999c). *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Lead.* Canadian Counsel of Ministers of the Environment. https://ccme.ca/en/res/lead-canadian-soil-quality-guidelines-for-the-protection-of-environmental-and-human-health-en.pdf

CCME. (1999d). *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Mercury.* Canadian Counsel of Ministers of the Environment. https://ccme.ca/en/res/mercury-inorganic-canadian-soil-quality-guidelines-for-the-protection-of-environmental-and-human-health-en.pdf

CCME. (1999e). *Canadian Water Quality Guidelines for the Protection of Aquatic Life DISSOLVED OXYGEN* (Freshwater). https://ccme.ca/en/res/dissolved-oxygen-freshwater-en-canadian-water-quality-guidelines-for-the-protection-of-aquatic-life.pdf

CCME. (2015). *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Nickel.* Canadian Counsel of Ministers of the Environment. https://ccme.ca/en/res/nickel-canadian-soil-quality-guidelines-for-the-protection-of-environmental-and-human-health-en.pdf

CCME. (1997b). *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Vanadium.* Canadian Counsel of Ministers of the Environment. https://ccme.ca/en/res/vanadium-canadian-soil-quality-guidelines-for-the-protection-of-environmental-and-human-health-en.pdf

CCME. (2018). *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Zinc.* Canadian Counsel of Ministers of the Environment. https://ccme.ca/en/res/zinc-canadian-soil-quality-guidelines-for-the-protection-of-environmental-and-human-health-en.pdf

CCME. (1999e). *Canadian Soil Quality Guidelines for the Protection of Environmental and*

Human Health: Copper. Canadian Counsel of Ministers of the Environment. https://ccme.ca/en/res/copper-canadian-soil-quality-guidelines-for-the-protection-of-environmental-and-human-health-en.pdf

CCME. (2012). Canadian water quality guidelines for the protection of aquatic life: Nitrate. In: Canadian environmental quality guidelines, Canadian Council of Ministers of the Environment, Winnipeg.

Centers for Disease Control and Prevention. (2011). *Toxicological profile for vanadium*. https://www.atsdr.cdc.gov/ToxProfiles/tp58-c6.pdf

East Island Environmental Consulting. (EIEC). (2022). 2022 Mary Lake Nature Sanctuary Research Project. Royal Roads University. Victoria, BC.

Edmonds, R. L., Vogt, D. J., Sandberg, D. H., Driver, C. H. (1986). *Decomposition of Douglas-fir and red alder wood in clear-cuttings*. Canadian Journal of Forest Research. https://cdnsciencepub.com/doi/10.1139/x86-145

US EPA. (2012). *5.9 Conductivity | Monitoring & Assessment | US EPA*. Epa.gov. https://archive.epa.gov/water/archive/web/html/vms59.html

Fletcher, N.F., Tripp, D.B., Hansen, P.L., Nordin, L.J., Porter, M., and Morgan, D. (2021). *Protocol for the Wetland Health Management Routine Effectiveness Evaluation*. Forest and Range Evaluation Program, B.C. Ministry of Forests, Lands, Natural Resources Operations and Rural Development. (pp. 1-61). Victoria, B.C.

FloodWise. (2022, March 8). *Atmospheric Rivers - BC Flood*. FloodWise. https://floodwise.ca/flood-101/types-of-floods-in-bc-2/atmospheric-rivers/

Fondriest Environmental, Inc. (2014). Conductivity, Salinity and Total Dissolved Solids. Fundamentals of Environmental Measurements. Retrieved March 7, 2023, from https://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/#cite

Fondriest Environmental, Inc. (2013). Dissolved Oxygen. Fundamentals of Environmental Measurements. Retrieved March 7, 2023, from https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/#info

Forest Preserve District Will County. (2023). *What's the difference?* River vs. Stream vs. Creek. Accelerator. Retrieved March 7, 2023, from https://www.reconnectwithnature.org/news-events/the-buzz/what-s-the-difference-river-vs-stream/

Government of British Columbia. (2021). *Water Quality Criteria for Microbiological Indicators*. Retrieved from Government of British Columbia:

https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_env_microbiological_indicators_waterqualityguidelines_overview.pdf

Government of New Brunswick. (2012). What is a lake? Environment and Local Government. Retrieved March 7, 2023, from https://www2.gnb.ca/content/gnb/en/departments/elg/environment/content/water/content/lakes/lake.html

Greater Victoria Greenbelt Society (GVGSa). *History of the Land*. Mary Lake Nature Sanctuary. Retrieved February 28, 2023, from https://www.marylakeconnections.ca/history-2/

Greater Victoria Greenbelt Society (GVGSb). *Nature's Protector*. Mary Lake Nature Sanctuary. Retrieved February 28, 2023, from https://www.marylakeconnections.ca/history-2/

MacKenzie, W. H., & Moran, J. R. (2004). *Wetlands of British Columbia: A Guide to Identification*. British Columbia, Forest Science Program.

Maddah, H., & Chogle, A. (2016, October 27). Biofouling in Reverse Osmosis: Phenomena, Monitoring, Controlling and Remediation. Retrieved from *Springer Link:* https://link.springer.com/article/10.1007/s13201-016-0493-1

Marsalek, J., Brownlee, B., Mayer, T., Lawal, S., & Larkin, G. A. (1997). Heavy metals and PAHs in highway bridge runoff. *Water Quality Research Journal, 32*(4), 815–828. https://doi.org/10.2166/wqrj.1997.044

Ministry of Forests, Lands, Natural Resource Operations and Rural Development: Fish and Aquatic Habitat Branch. (2019). *Riparian Areas Protection Regulation Technical Assessment Manual*. (pp. 1-63). Victoria, BC.

Pojar, J., & MacKinnon, A. (2016). *Plants of the Pacific Northwest Coast: Washington, Oregon, British Columbia & Alaska*. Lone Pine Publishing.

Province of British Columbia. (1995). B.C. salmon habitat conservation plan. Strategy Paper. Victoria, B.C.

RRU Environmental Consulting. (2020). Mary Lake Nature Sanctuary – Lake Stewardship Project. Royal Roads University. Victoria, BC.

Shoemaker, R. (2023). Riparian Habitat Restoration Plan for a Section of Millstream Creek in Mary Lake Nature Sanctuary, Highlands, BC. Capitol Regional District (CRD), Victoria, B.C.

Swain, L. (1987). *Water Quality Second Report On Chemical Sensitivity Of BC Lakes To Acidic Inputs*. Water Management Branch Environment And Resource Division Ministry Of

Environment, Lands And Parks. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/monitoring-water-quality/second_report_on_chemical_sensitivity_of_bc_lakes_to_acidic_inputs.pdf

Van Isle Eco Consulting. (VIEC). (2019). Mary Lake Nature Sanctuary – Lake Stewardship Project. Royal Roads University. Victoria, BC.

Data File Links

MLNS Appendices.docx

MLNS Water and Sediment Data.xlsx

XRF Data July 5.xlsb

XRF Data May 10.xlsx

MLNS - WQ in-situ data.xlsx

Alkalinity Data Final April 5 ex-situ Mary Lake.xlsx

Alkalinity Data Final May 17 ex-situ Mary Lake.xlsx

Alkalinity Data June 28 ex-situ Mary Lake.xlsx

Final Compiled MF Mary Lake.xlsx

Final Compiled MPN Results.xlsx

2023 Mary Lake Laboratory Procedure.docx

Wetland Polygon Data Workbook .xlsx

MLNS Wildlife Trees Data.xlsx