UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

The Vital Importance of Biodiversity at UBC Cascading Fountain

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ENVR 400

Themes: Biodiversity, Land, Water

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Executive Summary

The University of British Columbia has committed to enhancing biodiversity and sustainability on campus. In order to build a path to meet this goal, the cascading fountain along University Boulevard is recommended to be established as a biodiversity feature. A large component of the fountain environment was made up of algal mats that were identified to the genus level as *Mougeotia spp..* This genus forms the base of ecological productivity in the fountain environment. Additionally, high productivity allows the fountain to support a diverse amount of aquatic life, spanning multiple trophic levels. The cascading fountain's potential to be a biodiversity feature at UBC is further addressed, based on the fountain's biodiversity and interactions within the fountain community.

To better understand the environment in the cascading fountain, algae samples were taken to understand the algae community and its' interactions with the environment, as well as other organisms. Additionally, further sampling to obtain photos of fountain biodiversity was conducted by collecting surface and benthic algal mats to identify aquatic insects residing in the algae. A variety of algae species, insects, freshwater zooplankton, and microscopic organisms were identified. To quantify the biodiversity in the fountain, a biodiversity catalogue of organisms found was created.

These findings are relevant to initiatives incorporating biodiversity on campus such as the Campus Biodiversity Initiative Research & Demonstration (CBIRD), Integrated Stormwater Management Plan, and emerging Urban Forest Management Strategy and emerging Biodiversity Strategy. All of which have goals aligned with the goals of this project: to improve the biodiversity at UBC. Additionally, as established in UBC's 2018 strategic plan, this establishment of a biodiversity feature will succeed in meeting numerous goals such as leading globally in research excellence, discovery and creative endeavours, inspire and enable students through excellence in transformative teaching and student experience, and becoming a leader both globally and locally in sustainability, well-being, and safety across our campuses and communities.

UBC published a 20-year sustainability document in 2014, which states 3 main goals: teaching, learning and research, operations and infrastructure and the engagement of UBC community. There are various courses that could benefit from an established biodiversity feature the size of the cascading fountain including Ecohydrology, Insect Ecology Courses, and Aquatic Plant Ecology. iNaturalist and Bioblitz can increase the participation of communities in citizen science, and help UBC gain global exposure. Visitors and students on campus actively inquired during sampling about the goal of the project. All were pleased to know there was the potential to continue to foster biodiversity on campus. We suggest signage to be implemented, in order to showcase some of the diversity in the cascading fountain. This will assist in bridging education to the community, as well as for students and faculty on campus.

Several recommendations were made for after the establishment of the fountain as a biodiversity piece that should be maintained to help with the recirculation, maintenance, and improvement of the biodiversity of the fountain. To improve the functionality of the cascading fountain, a copper mesh can be installed over the cistern to act as a filter to catch free floating algae, preventing the clogging of pipes when water is being recirculated. Secondly, to maintain the biodiversity of the fountain, potted lily pads can be added to provide surface coverage to visually hide some of the algae growth. Adding lily pads can be beneficial as they provide additional habitat, shade, and food to various aquatic insects and organisms in addition to providing coverage of the algal mats; increasing the aesthetics. Maintenance practices (annual cutting of all aquatic reeds) should be altered. Cutting only a portion of the reeds allows dragonflies and damselflies to lay their eggs in the aquatic environment throughout the season. This increases the populations of larvae found in the aquatic environment, further fostering biodiversity.

Lastly, future research should be done to quantify the biodiversity present in the fountain to allow more accurate measure of changes in biodiversity from the current successional stage of the fountain. Additionally, continued sampling of nutrient concentrations, algae bloom composition, and species richness need to be continued through spring and summer seasons as these are vital seasons for both algae blooms and insect life cycles. This information is essential to further understand the nutrient cycling of the system which will benefit future research projects. Further information collected on the species composition of the fountain will assist in expanding information for signage, if installed in the future. Moreover, further investigation into the native and invasive plants species will be relevant to future decisions made toward planting plans.

Given the cascading fountain’s central location, the fountain has the potential to engage the community and offer an on-campus learning site for students and faculty of UBC. The establishment of the fountain to become a biodiversity feature will undoubtedly benefit the entire UBC community.

Author Bios

Jeff Sha: *Jeff is a 5th year Environmental Science student with a degree concentration in Land, Air and Water. As a volunteer at Harley Lab at UBC, Jeff works regularly with enclosed water systems and performs routine nutrient level testing as part of his volunteer duties. Jeff has a strong academic background in ecology and marine ecosystems.*

Melissa Lin: *Melissa is a 4th year Environmental Science student majoring in Land, Air and Water. She has experience in project management and coordination from a co-op placement at Stantec Consulting. Melissa has a strong academic background in ecology and the marine ecosystem. Melissa also has field experience in species identification and population surveys from both industry and academic fields.*

Samantha Lee-Wardell: *Samantha is a 5th year Environmental Science student majoring in Land, Air and Water concentration, particular skills in identifying aquatic species and native terrestrial plant species. She has experience through co-op working for Maxxam Analytics in their food laboratory, and as a data analyst for Environment and Climate Change Canada's Fuel Section.*

Alene Wong: *Alene is a 5th year Environmental Science student majoring in area of concentration of Land, Air & Water. She is comfortable working with microscopes and has developed strong microscopy skills from her years in academia. Alene is proficient in species identification skills through morphology and possesses numerous research experience from various co-op placements in her academic career.*

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Introduction

Research Objectives:

The original purpose of this project was to reduce the algae mats currently plaguing the cascading fountain along University Boulevard at the University of British Columbia (UBC) (Figure 1). The cascading fountain was developed as a stormwater management feature for use on campus. The initial design included biofiltration through plants such as reeds (*Typha spp*., Figure 2) resulting in naturally filtered water being released back into the environment in a controlled manner with lesser erosive effects on the surrounding substrate. The fountain comprises of nine levels in which the water flows through (Figure 3). The water is stored and collected at the bottom in a cistern, then pumped back to the top for recirculation. Any overflow of water is directed to storm drains leading to the Georgia Straight.

Figure 1: Fountain location, at the intersection of University Boulevard and East Mall at the University of British Columbia. Retrieved from: http://www.maps.ubc.ca/PROD/index.php


Figure 2: Westward view of the fountain from lowest level. Early photo, depicting reeds that have since been removed. Retrieved from: https://news.ubc.ca/2013/08/12/107073/

Social Ecological Economic Development Studies (SEEDS) has collaborated with UBC Sustainability and Engineering to develop a project for ENVR 400 students to take on the task of increasing the aesthetic appearance of the fountain for UBC building operations, without the means of biologically damaging chemicals or expensive labor for mechanical removal. In order to tackle the original issue, the present algae needed to be identified to tailor a solution to the ecology of the genus identified, and water quality data (pH, inorganic nitrogen concentrations, temperature) needed to be provided as baseline data for future SEEDS research.

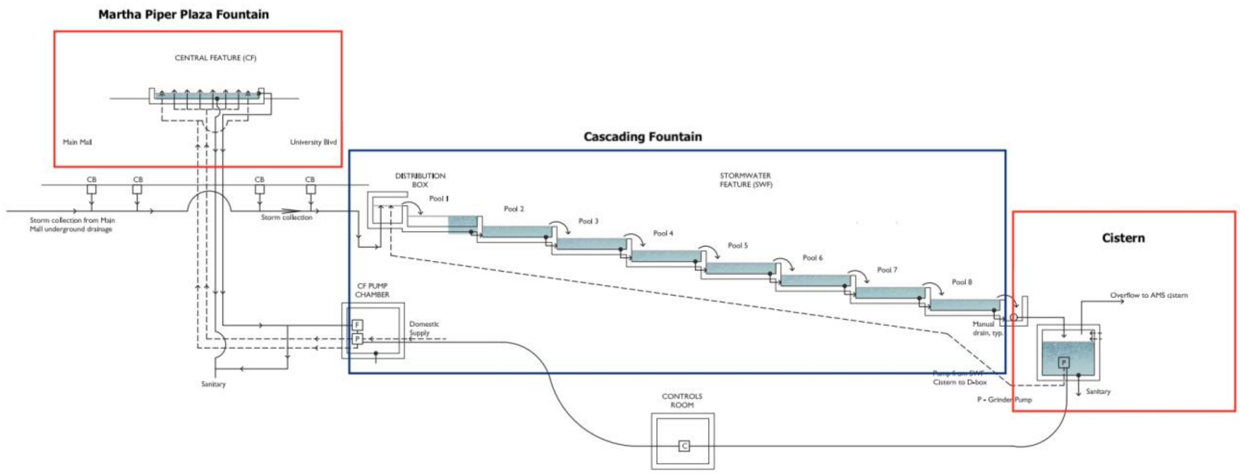

Figure 3: Schematic of the water system. Sources include stormwater runoff, with a large portion of the water sourced from the Martha Piper Plaza Fountain located on Main Mall at the University of British Columbia. Water flows through the cascading fountain and collects in a cistern at the base, which pumps water back to the top of the cascading fountain to repeat the cycle.

Background

Importance of Biodiversity

The importance of natural green and blue spaces in human health and well-being has been well established (Gearey et al., 2019, Gascon et al., 2017, Markevych et al., 2017, Hartig et al., 1991, Ulrich et al., 1983, Kaplan & Kaplan 2011, Kaplan 1995). There is clear improvement shown in reactiveness and self-reported mental wellness when exposed to natural settings in comparison to urban environments (Hartig et al., 1991). Though the mechanisms providing this benefit are still unclear and require further study (Gascon et al., 2017, Ulrich et al., 1983), there is strong evidence that exposure to natural settings replenishes the exhausted mental energy of individuals in communities with access to greenspace (Kaplan 1995, Kaplan & Kaplan 2011). There is recognized benefit in constructing common spaces that provide the opportunity for communities from multiple social and economic classes to come together (Gearey et al., 2019, Edgorov et al., 2016), creating shared spaces where people can interact. This evidence is incentive to preserve and create more natural features around UBC to enhance these effects on campus. Proximity to nature, and the knowledge of the presence of diverse ecosystems has the potential to intrinsically benefit all faculty, students, and visitors to the UBC campus.

Ponds are known to provide regulation ecosystem services such as water retention, water purification, sediment development and recreational ecosystem services (Fu et al., 2018). Globally, ponds have been noted to sequester as much carbon as marine environments (Céréghino et al., 2014), and it is beneficial for UBC to foster features that can model these systems. UBC is well known for supporting biodiversity and sustainability on its' campus (Campus and Community Planning, 2018), and the preservation of the aquatic ecosystems in the cascading fountain is in line with the goals of the university.

UBC Sustainability Goals

UBC has several organizations committed to enhancing sustainability and biodiversity on campus. Campus Biodiversity Initiative: Research and Demonstration (CBIRD) is a committee that includes stakeholders from 17 UBC departments, supporting biodiversity through places, people, programs and projects that enhance, conserve and educate about biodiversity on campus. Other groups include the Integrated Stormwater Management Plan, emerging Urban Forest Management Strategy and Biodiversity Strategy, which are in place to integrate biodiversity into all managing bodies and developments on campus.

UBC sustainability goals focus on the collective result of social and economic consequence and actions. UBC's 20-year sustainability document (University of British Columbia, 2014) contains three main goals: 1) teaching, learning and research, 2) operations and infrastructure and 3) UBC community. Preserving the biodiversity in the fountain contributes to each of these endeavors set out by the university. The preservation of the fountain as a biodiversity feature will allow multiple classes and organizations (ie: Beaty Biodiversity Museum) to utilize the fountain as a site for field sampling; for teaching, learning, and research. This site could be utilized by a variety of sustainability focused faculties; Science, Architecture and Landscaping, Land and Food systems, Population and Public health. All these faculties have the potential to benefit from courses targeting anything from pathogen content to biofiltration. Building Operations are responsible for the annual maintenance of the fountain. There is opportunity to educate them in better ways to maintain these features to reduce impact on the aquatic community (pulling reeds instead of cutting them down, targeting invasive species and replanting native fauna). These ideas can be implemented in stewardship programs, allowing students and faculty to learn about ways to sustainably maintain natural features. Water features require maintenance, but there are ways in which to carry out this maintenance that can best benefit the aquatic communities making these features their home. This involvement would connect UBC as a community as well, providing visitors the opportunity to learn about the freshwater habitat and participate in stewardship programs.

Methods

To better understand the organisms in the cascading fountain and its environment, algae and water samples were taken from the fountain. Sampling occurred bi-weekly from October 2018 to March 2019 (Figure 4). Algae samples were taken to understand the algae community and their interactions with the environment and other organisms. Water samples for nutrient tests provided a baseline set of nutrient data as well as insight to the chemistry of the fountain. Nutrient level results from this sampling process provides the first set of baseline data to include temperature, pH, nutrient content (NO_2^-, NO_3^-, NH_3^-) and community composition over a period of 7 months.

Aquatic insect sampling occurred on three different days in early spring. Although species richness is likely to peak in the summer, due to the temporal restrictions of this project, insect sampling was only feasible in early spring. The results of the aquatic insect sampling was combined with algae samples to create an aquatic biodiversity catalogue.

Date (mm/dd/yyyy)	SAMPLE ID
10/29/2018	1FLOW
11/8/2018	T1STAG
11/8/2018	T1FLOW
11/8/2018	M2STAG
11/8/2018	M2FLOW
11/8/2018	B3STAG
11/8/2018	B3FLOW
11/15/2018	T2STAG
11/15/2018	T2FLOW
11/15/2018	M1STAG
11/15/2018	M1FLOW
11/15/2018	B1STAG
11/15/2018	B1FLOW
12/7/2018	T1STAG
12/7/2018	T1FLOW
12/7/2018	M3STAG
12/7/2018	M3FLOW
12/7/2018	B2STAG
12/7/2018	B2FLOW
2/5/2019	T3STAG
2/5/2019	T3FLOW
2/5/2019	M1STAG
2/5/2019	M1FLOW
2/5/2019	B3STAG
2/5/2019	B3FLOW
3/8/2019	T2STAG
3/8/2019	T2FLOW
3/8/2019	M3STAG
3/8/2019	M3FLOW
3/8/2019	B1STAG
3/8/2019	B1FLOW

Figure 4: Sample schedule for water quality testing. Nitrates, Nitrites, and ammonia was tested for.

Sampling

The cascading fountain was divided into three transects (top, middle, bottom), each containing three levels of the fountain. Within each transect, levels were labeled from 1 to 3 in order of descending elevation (Figure 5). Preliminary observations shows similar community composition in the freshwater community in all transect. As a result, random selection through a random number generator (RNG) was deemed sufficient in eliminating associated bias moving forward. For each transect, the corresponding numbered level resulting from the RNG will be sampled for each period. One sample was taken from an area of high flow rate (FLOW) where water is moving from a higher to lower level of the fountain, and another from an area of low flow rate (STAGNANT). Only one level per transect was sampled during each sampling day.

Figure 5. Sampling Schematic of the cascading fountain separated into three transects (top, middle, bottom), each with 3 individual sections.

At each sampling location (Figure 5), the 450 ml sampling jar was triple rinsed (US EPA, 2006) with fountain water to remove any pre-existing substances that are foreign to the fountain environment. The sampling jar was used to collect the water-algae sample. To ensure enough of the algal mat was obtained, the sampling jar broke the surface of the algal mat during the scooping motion. Sample jars were then capped, labelled, and refrigerated at UBC until analysis.

Algae Identification

Algae samples were extracted for identification on the day of sampling. Samples were identified under a inverted microscope at UBC. Samples were removed from the sample jar using a 5 mL transfer pipette onto a slide and viewed under a microscope. Images of the algae were taken through the microscope using the Leica LAS Core software. Algae samples were photographed 200x to establish general community composition and begin initial identification and 400x for further identification of physical indicators and cell structures. Images were labeled with the convention [MMDD-TRANSECTELEVATIONAREA] and kept for future reference. As species are identified, related images and physical characteristics were recorded and compiled. Algae that were difficult to identify were sent to Leilane Ronqui (Biologist specializing in algae biota) for assistance. Identification of the algae species present in the fountain was imperative to tailoring effective solutions to control their growth. As some algae are bioindicators, identification of these species could provide some insight to factors contributing to the bloom (Bellinger and Sigee, 2015).

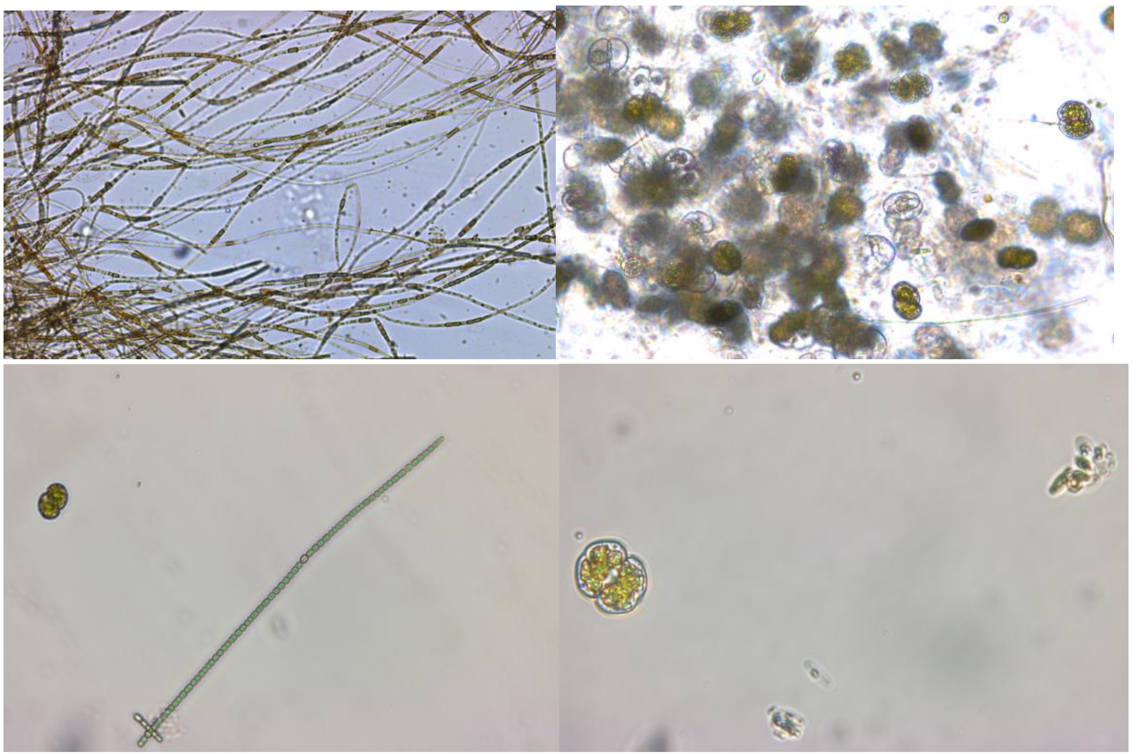

Figure 6: Top Left - Mougeotia spp. at 200x magnification. Top Right - Cosmarium spp. at 400x magnification. Bottom Left- Anabaena at 200x magnification. Bottom Right - Cosmarium spp. at 400x magnification.

Aquatic Insect Identification

At each sampling location, surface and benthic algal mats were collected using aquarium fish nets. Algal mats were placed into a plastic storage container filled with fountain water. The algal mats were then manually broken into smaller pieces while searching for aquatic insects residing within the mats. Insects were removed from the container into an empty sampling jar filled with fountain water and photograph using a smartphone while under a microscope at UBC. Images of aquatic insects were sent to Karen Needham (Entomology curator, Beaty Biodiversity Museum) for identification.

Nutrient and pH Testing

Water samples used for nutrient testing were removed from the sampling jar on the same day of sampling. Concentrations of NO_2-, NO_3-, NH_3- and aquatic pH levels were tested for each sample. Nutrient and pH levels were determined using the API Freshwater Master Kit (Figure 7). Preliminary nutrient test results and observations indicated that the cascading fountain exhibited a mesotrophic freshwater environment with intermediate amounts of nutrients and productivity. Thus, no extensive nutrient analysis was carried out. Each nutrient test required API test tubes to be filled with water directly from the sample jar. Test tubes were dipped into the sampling jar and filled up to the indicated amount. Special caution was made to not include visible debris in the test tube water. Water samples then went through a round of nutrient tests using reagents and instructions provided by API. Nutrient concentration results were then recorded. Test tubes were cleaned and tripled rinsed before reuse to avoid contamination (US EPA, 2006).

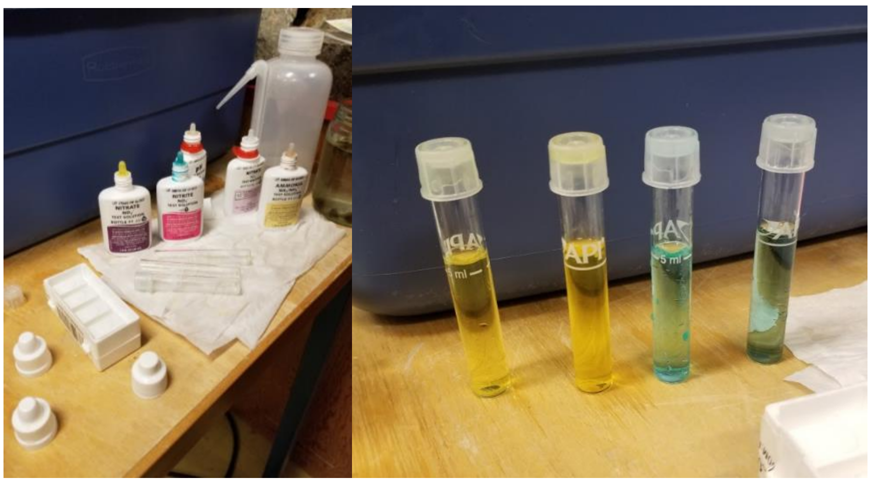

Figure 7: API Freshwater Master Kit used to test nutrient levels

The API Freshwater Master Kit used has a detection limit of and 0.25ug/L for nitrate, nitrite and ammonia. As such all nutrient concentration values between 0 - 0.25 ug/L will be reported as 0 ug/L by the test kit. Test kit results that came back as zeros were replaced with the value of 0.125 ug/L (½ * detection limit) in the calculations of means.

Results

Temperature and Light Intensity

Preliminary hypotheses explored temperature and light intensity as potential causes of the growth of the benthic mat in the fountain. However, due to the shallow depth of the fountain's water column, light can penetrate the entire water column. This reduces potential for drastic temperature differences in the water column and allows the entire water column to be euphotic. Seasonal variation in temperature and light intensity make it difficult to control these factors in the fountain. Thus, temperatures and light intensity were ruled out of final analysis.

Nutrient Limiting Environment

Nutrient test results taken from October 2018 to March 2019 show non-eutrophic conditions in the cascading fountain at UBC. As indicated in Figure 8, average concentration of nitrate, nitrite and ammonia consistently remain below the 0.8ug/L eutrophic threshold determined by Environment and Climate Change Canada (Environment Canada, 2011). Thus, ruling out the potential for excess nutrients from anthropogenic loading as the cause for the observed algal growth. Conversely, nutrient levels would implicate the fountain as a nutrient limiting environment. Average nitrate, nitrite, and ammonia concentrations were regularly below detection levels (0.25 ug/L) of the nutrient test kit used. As nutrient concentrations consistently reported below detection levels, it was concluded that the fountain maintains a fairly oligotrophic environment throughout non-summer months. Oligotrophic conditions in the fountain would indicate either slow algae growth rates or a very active algal uptake cycle. These hypotheses were well reflected in the biodiversity found in the fountain during algae and aquatic insect sampling.

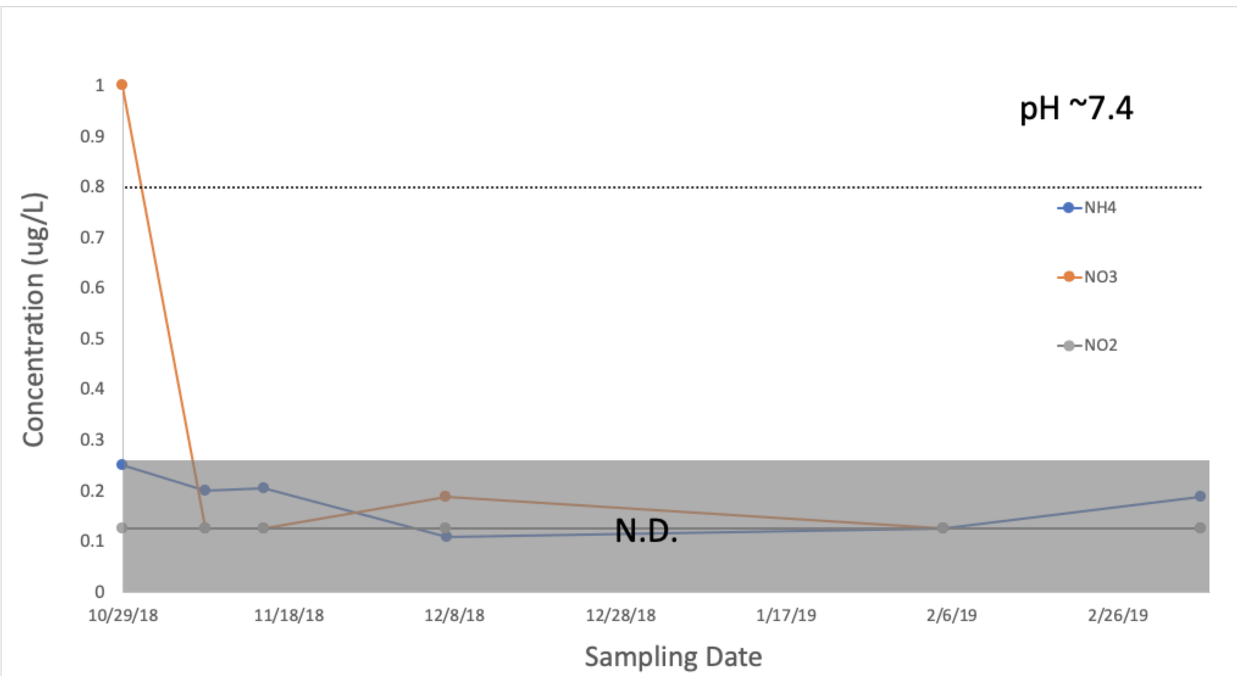

Figure 8: Averaged measurements of inorganic nitrogen concentration (ug/L) taken at cascading fountain along University Boulevard at the University of British Columbia. NO2 measurements were below detectable levels, so are reported as 0. In reality, these measurements likely fall within oligotrophic conditions (0.2 ug/L). NH4 and NO3 remain well below the levels of eutrophic conditions, indicating there is no excess of nutrients in the cascading fountain. 0.8 ug/L represents concentration levels found within eutrophic conditions as determined by the Environment and Climate Change Canada.

Biodiversity Catalogue

Algae and aquatic insect samples obtained were identified and compiled into a list (Table 1) below for summarized list, full catalogue with pictures available in Appendix II. The biodiversity catalogue represents a variety of organisms spanning several trophic levels.

Abundance of individual species were visually noted. A homogenous community was found throughout the fountain as there were no visual variation in species presence between tiers of the fountain. *Mougeotia spp.* made up most of the algal mat biomass along with *Cosmarium spp.*, *Anabaena, Chromulina*, and freshwater diatoms. *Mougeotia spp.* are filamentous green algae, *Cosmarium spp*., *Chromulina*, and freshwater diatoms are single celled green algae, and *Anabaena* are nitrogen fixing cyanobacteria. Aquatic insects were sparsely distributed throughout the fountain and often found by disturbing the benthic algal mats. Identified species and their abundance were in line with the results of the nutrient concentration tests. The oligotrophic conditions in the water likely made it difficult for many species of algae to succeed in fountain. In turn, the abundance of *Mougeotia spp.* was justified due to the genus' ability to persist in low nutrient conditions (Middleton and Frost, 2015). The genus is also resilient to many algicides, trace metals, and is able to succeed through a wide range of temperatures and pH levels (Albay and Akçaalan, 2003; Graham et al, 1996). Despite *Mougeotia spp.* being the dominant algae in the community, growth rate seemed to slow with much of the algal mat dying and creating a thick brown benthic mat (Figure 9). *Chironomidae spp.* (commonly known as midges) larvae were found in abundance within the benthic mats. Other detritivores and decomposers such as nematodes, rotifers, mayfly nymphs, and copepods were also found. The presence of these organisms strongly supports the hypothesis that the fountain has a very active decomposition cycle. Further up the food chain, various insects such as backswimmers (*Notonecta kirbyi*), damselfly (*Odonata zygoptera)* and dragonfly nymphs (*Odonata Anisoptera)* were also found. Overall, the organisms found through our sampling process indicate a healthy ecosystem involving several trophic levels and a strong decomposition cycle.

Figure 9: Thick green/brown benthic algae mats from dead and decomposing algae and detritus located on the bottom of the fountain structure. Picture taken in October 2018.

Table 1: Summarized Biodiversity Table of all aquatic species that were identified during sampling at the UBC Cascading Fountain. The ecology, distribution, and habitat are described for each species to note their importance to biodiversity. (No pictures included).

	Ecology	Distribution and Habitat
Algae		
Cosmarium spp.	Food source for a large population of grazers i.e. rotifers, midge larvae etc.	Found in ponds, lakes, ditches and other reservoirs
Mougeotia	Bioindicator of acidified waters and clean, oxygen-rich, mesotrophic aquatic habitats subject to seasonal warming in fossil studies	Found in clear, shallow freshwater habitats worldwide Can inhibit waters of a wide range of pH (3-10) No environmental constraints
Insects		
Baetidae Baetis sp. (Mayfly - Nymph Stage)	Feed on algae, organic waste, and contaminants Important sources of food for fish, birds, amphibians, spiders and other dragonflies Serve as bioindicators of ecosystem health and quality as their populations are quite sensitive to changes in water chemistry	Found worldwide except the Antarctic/Arctic
Chironomidae. (Midge - Larval Stage)	Decomposer and primary consumers of freshwater ecosystems Various insects (i.e. dragonflies), birds and other aquatic invertebrates feed on Midges	Found in wide variety of benthic freshwater environment
Dragonfly Nymph Order: Odonata Suborder: Anisoptera	Important predators of mosquito and midge larvae As adults they feed on mosquitoes, midges and other small insects	Live near calm or slow-moving waters
Damselfly Nymph Order: Odonata Suborder: Zygoptera	Feeds on aquatic animals smaller than itself e.g. mosquito and midge larvae Nymphs are a food source for fish and other insectivores	Commonly found in North American ponds, freshwater pools and slow flowing streams abundant with aquatic plants
Notonectidae Notonecta kirbyi (Backswimmer)	Secondary consumers in the aquatic food chain	Commonly found in North American ponds, freshwater pools and slow flowing streams abundant with aquatic plants
Freshwater Zooplankton		
Freshwater Copepod	Usually omnivores and commonly consume algae, detritus, bacteria, pollen and rotifers Prey to various Chironomidae insect larvae, predatory copepods and fish	Found in a variety of habitats ranging from freshwater lakes, rivers, ponds and streams Able to survive harsh conditions by entering diapause
Microscopic Organisms		
Nematode	Feeds on algae, bacteria, fungi, protozoans, organic matter etc. Food source for benthic and pelagic invertebrates/vertebrates	Found worldwide and can be present in all types of limnetic habitats including those of unfavorable conditions (i.e. high T, acidic etc..)
Rotifer	Aid in natural water purification Food source to many aquatic insects	Free-swimming on open surfaces of ponds/streams Can also be found in moist soil

Discussion

Mougeotia spp. (Figure 6) are a genus of filamentous green algae that forms free-floating masses or dense submerged mats in clear, shallow and freshwater habitats around the world (Barton et al., 2013). There are currently 174 taxonomically accepted species. Identification of species can only be done by looking at zygospores. Difficulty of species identification is high as opinion on taxonomic validity varies from expert to expert (Guiry and Guiry, 2019). Individual cells are shaped as elongated cylinders with rotatable ribbon-like chloroplast in the center (Margulis and Chapman, 2009). The algae are highly competitive in nature and common in some acidified lakes of Canada (Guiry and Guiry, 2019). *Mougeotia spp.* tend to bloom in highly stratified oligotrophic conditions due to their unique chloroplasts and filamentous nature; allowing them to remain afloat and utilize the entirety of the photic zone. Growth rates for *Mougeotia spp.* are consistent through a variety of nutrient concentrations found in aquatic environments (Middleton and Frost, 2014). Members of the genus can inhabit a wide range of pH (3-10). *Mougeotia spp.* often outcompete other algae due to their ability to succeed in highly acidic or basic water conditions; and lack of natural predators. As the genus are able to tolerate low pH environments, *Mougeotia spp.* are often used as bioindicators for acidified waters. Some species of *Mougeotia* exhibit high tolerance to trace metals (Graham and Graham, 1996). See Appendix I for comprehensive Mougeotia literature review.

Identification and research of *Mougeotia spp.* was found to place this algae among one of the most resilient and adaptable genuses. This discovery made most sustainable control methods unrealistic, leading the team to take a route toward biodiversity and sustainability. The revised project took on the task of establishing the cascading fountain as a biodiversity feature on UBC's campus.

Benefits of Biodiversity

Freshwater ecosystems are some of the most species rich environments on the planet, but also remain one of the most threatened to this day (Hermoso et al., 2016). Nearly 100,000 described species inhabit freshwater (6% of total described species), but are under the strongest pressure from habitat change, pollution, and invasives (Dudgeon et al., 2006). In particular there is a lack of information available in the literature regarding a complete understanding of invertebrate and microbial diversity. Knowing this, it makes it difficult to disregard the importance of establishing features that have the potential to bring more awareness to the threat to freshwater biodiversity. There is an opportunity to educate classes and the community on the importance of freshwater environments and their role in connecting terrestrial and marine ecosystems. Freshwater ecosystems act like a reservoir feeling the effects of; fertilizer runoff, grey water from municipal sources, and effects stemming from terrestrial ecosystem alteration (deforestation destabilizing river banks) (Dugeon et al., 2006). The cascading fountain does this through the collection of stormwater, in addition to collecting municipal waste and pollution (packaged meat, beer cans, lawn signs have all been noted in the fountain during sampling). Not only can this feature serve as a site providing information on biodiversity and the ecosystem function of freshwater systems but can help connect people to the proximity of the natural environment to their urbanized community.

Sites like the cascading fountain have the potential to create habitat for native and non-native species alike, with higher levels of disturbance tending to favor invasive species (Hüse et al., 2016, Godefroid 2001). Continued disturbance of the fountain destabilizes the ecosystem, preventing an equilibrium from establishing that would allow the regulation of invasives or pest species. Mosquitos tend to breed in still water, and while the fountain does not have turbulent flow in 100% of the areas this introduces patches of habitat suitable for mosquito larvae. While draining the fountain annually may prevent the hatching of mosquitoes laid prior to the clean, this does not prevent breeding over an entire season. Dragonfly larvae (freshwater ambush predators), are a species identified in the fountain known to consume mosquito larvae. With an established population of dragonfly larvae and other predatory species, there is continual maintenance of any mosquito larvae that may attempt to establish itself. However, dragonfly larvae require low levels of disturbance in order to reach maturity. High rates of disturbance have been shown to decrease dragonfly and damselfly species richness and diversity (Luke et al., 2017). The continual disturbance of the fountain reduces the effect of this free maintenance provided by these species and the multitude of other insect larvae making up the freshwater food web. These larvae have influence over the amount of mosquito larvae surviving to the adult stage. The mosquito population will be much larger without predators to impose a limiting effect. This will contribute to mosquito population reduction, reducing diseases transmission and the nuisance they cause to communities in the area.

Alignment with UBC Goals

UBC has outlined the following goals in “Shaping UBCs Next Century: Strategic Plan 2018-2028”:

1. Lead globally in research excellence, discovery, scholarship and creative endeavors
2. Lead globally and locally in sustainability, wellbeing and safety across our campuses and communities
3. Lead as a model public institution, fostering discourse, knowledge exchange and engagement

To satisfy these goals, we have structured the following recommendations to align with UBC.

Labs and Lectures at UBC

Over the past few years there has been a great reform in the idea of how learning should be done to maximize the student’s potential. One big step towards a changing education system is the implementation of active learning. Active learning is the process of which students engage in some sort of activity that allows them to reflect upon ideas and consider how they are using those ideas (Michael, 2006). Additionally, active learning has the ability to keep the students mentally and physically active in their learning through various activities (Michael, 2006).

As a leading educational institute in British Columbia, UBC has already started implementing and encouraging the notion of active learning in lectures. The cascading fountain provides an opportunity to be an on-site location for active learning activities provided the biodiversity of the fountain is maintained or improved upon. Various courses already sample at the cascading fountain, ENVR 420 (Ecohydrology of Watersheds and Water Systems) samples yearly from the cascading fountain for water quality in specific, various nutrient levels. If the current biodiversity of the fountain (See Biodiversity table, Table 1) could be maintained or improved over time the cascading fountain would be idyllic for various courses to hold teaching labs. Some courses that could benefit from this are APBI 327 (Intro to Entomology), APBI 427 (Insect Ecology), BIOL 327 (Intro to Entomology). While the topics of these courses correspond perfectly to the organisms found within the cascading fountain it is important to note that these courses also include a lab section where hands-on learning is conducted. The fountain has the potential to become an on-campus destination for sampling and teaching labs. In addition to improving student learning, by incorporating lectures/labs at the fountain, the work done by the students through sampling can also help the university catalogue the biodiversity in the fountain for future reference.

The push towards a flourishing ecosystem within the cascading fountain will further benefit student learning through the incorporation of active learning techniques into lectures and labs through techniques such as hands-on learning and real-life application. By maintaining/improving the biodiversity present in the cascading fountain lies an opportunity for UBC to create a hub for the community, student learning and Beaty Museum for additional live sample exposure and special educational opportunities.

Beaty Biodiversity Museum has the opportunity to utilize the fountain as a site for BioBlitz, community pond pokes, and public education programs. There is the potential to take community groups to sample at the fountain, allowing Beaty to educate beyond UBC students. Elementary and high school class trips can be done to the fountain to inspire young people about biodiversity and science at UBC. This presents a potential site on campus that will be known and utilized for its' diverse aquatic environment. Allowing Beaty to use the fountain for this purpose not only makes the fountain a landmark for the UBC students and staff, but for the rest of the community as well.

Operations and Infrastructure

If the fountain is to be established as a biodiversity feature some practices that align with UBC goals would be to change maintenance methods of the cascading fountain. An example of this is to pull out reeds which are located on the sides of the fountain (Figure 2) instead of current practices of mowing down all the reeds. The action of pulling out some reeds by hand leaves behind numerous reeds in place for which aquatic insects such as dragonflies and damselflies can lay their eggs. When there are no reeds present, this deters the dragonflies and damselflies from approaching the fountain which can hinder the maintenance and improvement of biodiversity at the cascading fountain. Additionally, a stewardship program can be considered to help with reed pulling as a method to educate community volunteers, faculty and students on the relationship between aquatic plants and insects as well as basic knowledge in pond maintenance. To ensure maintenance practices are align with UBC sustainability goals, there needs to be more engagement between building ops, courses and Beaty Biodiversity Museum. Opening communications between various departments will ensure operations in/near the fountain will not harm the thriving ecosystem but rather foster an area of growing biodiversity.

New infrastructure to include in the future of the cascading fountain is to install signage about the biodiversity (i.e. species found here) and the role of the algae (i.e. what is it, why is it important?). These signage installations will educate community members, students, faculty, and other visitors to UBC campus as well as spreading awareness of the cascading fountains key role in fostering biodiversity on campus.

Community Support

Sustainability in the UBC community has already been demonstrated during the sampling of the fountain. There was interest shown by community members (families, visitors, students) who approached the team during sampling. Many people expressed support for the project after an explanation to them about catalog of biodiversity and how it was being constructed for the fountain in order to establish the fountain as a biodiversity feature.

Figure 10: A family visiting UBC assisted in the sampling of aquatic species.

A family (Figure 10) stopped on their way to the biodiversity museum, their son stopped and inquired as to what the team was doing. He assisted in sampling the bottom of the fountain and was very interested in the dragonfly larvae and backswimmers.

Figure 11: Visitors from China assisted in the sampling of aquatic species.

Visitors from China (Figure 11), passed by and expressed their interest in what aquatic species we had collected. They helped gather some algae samples that potentially had various aquatic species

Figure 12: An ENVR 400 student assisted in the sampling of aquatic species.

An ENVR 400 student (Figure 12), assisted in the project by sampling at various locations of the fountain during her study break.

Future Community and Student Involvement

Around the world, thousands of research projects are engaging in citizen science as a means of collecting data. Citizen science is especially helpful in collecting data and information in resolution and scales unattainable to researchers (Bonney et al., 2014). Currently, the fountain is home to various insect and plant species (See biodiversity table) however if the fountain environment can be maintained/improved, the increasing biodiversity of the fountain will allow for many more observations becoming a hotspot for citizen science to occur. Members of the community can download a free app, “iNaturalist” or sign up online at https://inaturalist.ca/

and participate in citizen science by taking pictures and uploading this information to the app. The nature app created by National Geographic Society and California Academy of Sciences allows the general public to document observations and locations of various plants/organisms which are then identified by professionals through the app itself. The information and data collected from the app can be used by researchers as data as well as entered into scientific data repositories such as NatureServe Canada, Global Biodiversity Information System and Canadensys. iNaturalist is an easy and inexpensive way to engage and educate the community during their visit at UBC.

In addition to everyday citizen science, with increased biodiversity at the cascading fountain there is potential to host a bioblitz at the fountain in the future. A bioblitz brings together biologists, naturalists and the general public to inventory as many species as possible within a 24-hr period using the iNaturalist app. The species records are compiled into one data set to showcase the biodiversity present at the location at that point in time. Community style bioblitz can also include guided educational activities as well as nature programming therefore making this activity inclusive to everyone.

UBC's 2018 Strategic Plan

The establishment of the cascading fountain as a biodiversity feature also aligns with UBC's 2018 Strategic Plan. Some of the key goals of the strategic plan include:

1. Lead globally in research excellence, discovery, scholarship and creative endeavours
2. Inspire and enable students through excellence in transformative teaching, mentoring, advising and the student experience
3. Build a diverse culture that integrates themes of innovation, collaboration and inclusion, and infuses them with UBC's activities
4. Lead globally and locally in sustainability, wellbeing and safety across our campuses and communities
5. Lead as a model public institution fostering discourse, knowledge exchange and engagement

These 5 goals can be achieved through the incorporation of active learning from lectures/lab at the fountain and the discourse between faculty experts and building operations to facilitate maintenance operations that can foster biodiversity. In addition, by establishing such a biodiversity feature at such a central location of the campus, UBC can encourage and engage the academic community as well as the public. This engagement will allow UBC to establish themselves as leaders in research, discovery and a model public institution as stated in their strategic plan goals.

Recommendations for the Cascading Fountain

Lily Pads

To improve the aesthetics of the cascading fountain we recommend the implementation of potted lily-pads. In specific, the species *Nuphar variegata* commonly known as the Yellow Pond-Lily (Figure 13) would be the ideal choice as this is a native BC plant species (E-flora BC, 2017). The Yellow Pond-Lily is commonly found in basic to slightly acidic waters in lakes, slow moving streams and ponds across Canada and the United States (New England Wildflower Society). They possess heart-shaped leaves that span 10-40 cm in length and 6-30 cm wide and blooms a bright yellow flower from May to October (E-flora BC, 2017 and Haberland, 2016). The Yellow Pond-Lily grows best with sun to part shade in soft sediment of 0.3m - 1m in depth which is similar to the depth of the cascading fountain (Haberland, 2016). The flower and leaf stems of the Yellow Pond-Lily die back to rhizomes in the fall and over-winters as rhizomes/seeds (USDA, 2015).

Figure 13: Nuphar variegata, Yellow Pond Lily. Photo credits: Cindy Goeddel. Retrieved from: http://goeddelphotography.com/portfolio/landscapes/flowers/yellow-pond-lily/

The potted lily pads (Figure 14) would be able to provide coverage of some of the surface of the water hiding the algae growth underneath thereby improving the aesthetics whilst also providing habitat, shade and food to various aquatic insects and organisms (Haberland, 2016). The pots are highly recommended due to their easy implementation as no new substrate will have to be put directly into the fountain. Additionally, the pots are low maintenance and provides the ability to control the lily-pad growth to ensure they do not completely cover the surface of the water. Complete coverage of the surface of the water can result in the decrease of biodiversity within the cascading fountain as the lily pad leaves will block the sunlight thus negatively affecting the living organisms within the water column. Furthermore, the pots will allow control over placement and easy removal when necessary.

In addition to the aesthetic appeal, the rootstock and rhizomes of the Yellow Pond-Lily have been known to be used in many traditional First Nation medicine such as treating colds, internal pains and other issues for the Haida Gwaii population (Fretwell & Starzomski, 2013). This may open up the opportunity for harvest before winter for other educational purposes.

The recommendation of the potted lily-pads provides a promising opportunity to improve the aesthetics of the pond while also maintaining the biodiversity present. The pots will limit the species growth to ensure no over-growth occurs and the biodiversity of the cascading fountain is kept intact and may be improved over time.

Figure 14: Potted lily pad plants seen in a Hong Kong water feature. Picture taken by group member Alene Wong

Copper Alloy Mesh over Cistern

To improve the functionality of the cascading fountain, a copper alloy mesh could be installed over the cistern. The mesh would act as a filtration system to catch any of the free floating algae masses and detritus to ensure the algae will not clog the pipes when the water is being recirculated. Copper is an essential nutrient for aquatic organisms however it can be toxic to at levels as low as 1ug/L (Levy et al., 2007). The component of copper on the mesh is present to kill off any live algae that enters the cistern to prevent clogging (Chen et al., 2012). There will need to be careful inspection of the copper alloy mesh to ensure levels of copper that enter the water stream will not be too high and inadvertently harm the rest of the ecosystem. Any of the remaining benthic algal mats and detritus should not be forcibly removed as they provide habitat for various insects and organisms to burrow in. By leaving the benthic mats alone there is potential to foster more biodiversity in habitats thereby creating a more biodiverse community composition. The implementation of the copper alloy mesh is simply a precautionary maintenance measure to ensure smooth operation of the recirculating feature.

Continued Research

Future research should focus on quantifying the biodiversity of the fountain. This will allow accurately measurable changes in biodiversity from the current successional stage of the fountain. It will provide hard data to measure the increase or decrease seen as a result from the changes made to maintenance practices and can be carried out by future SEEDS student groups. The Shannon Wiener Index can be utilized for calculating species richness and evenness in a given habitat (Oxford Dictionary, 2017).

Continuing sampling for determining nutrients concentrations, algae bloom composition, and species richness composition should be continued through the spring and summer season. During this time of year aquatic insects and algae are most active and will have the greatest influence over nutrient concentrations. The nutrient data will provide further understanding in the nutrient cycling of the system, which is vital data to have for any future projects occurring in the cascading fountain. Evaluation of algae and aquatic insect composition will assist in expanding information for signage, if installed in future. Future investigation into native and invasive plant species identification will also benefit knowledge of the vascular plant species composition. This information will be useful when building operations makes decisions regarding species to annually plant, as well as continuing to build a catalogue of species for signage.

Conclusion

Through the journey of this project, the importance of algae and the foundation of aquatic systems was reiterated. The literature made clear in the initial search for a sustainable reduction method, that the importance was not in the aesthetic appearance of the water feature but in the biodiversity of the mesotrophic system it was supporting. The amount of species collected and identified demonstrated the hidden richness that had not before been realized. This provides the opportunity to utilize and maintain this fountain for research and education, bringing the public closer to the natural community through stewardship and learning. Ensuring the fountain is a dynamic entity will allow a multitude of faculties to benefit from courses geared toward sustainability in future. Allowing the aquatic system to exist and installing information that lets the public engage in this biodiversity will contribute to better mental health and well-being on UBC campus.

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Appendix I:

Mougeotia Literature Review

Introduction:

Mougeotia spp. are a genus of filamentous green algae that forms free-floating masses or dense submerged mats in clear, shallow, freshwater habitats around the world (Barton et al., 2013). Individual cells are shaped as elongated cylinders with rotatable ribbon-like chloroplast in the center (Margulis and Chapman, 2009). The algae is highly competitive in nature and common in some acidified lakes of Canada (Guiry and Guiry, 2019). *Mougeotia spp.* tend to bloom in highly stratified oligotrophic conditions due to their unique chloroplasts and filamentous nature; allowing them to remain afloat and utilize the entirety of the photic zone. Growth rates for *Mougeotia spp.* are consistent through a variety of nutrient concentrations found in aquatic environments (Middleton and Frost, 2014). Members of the genus can inhabit a wide range of pH (3-10). *Mougeotia spp.* often outcompetes other algae due to a lack of natural predators and ability to succeed in highly acidic and basic waters. As the genus is able to tolerate low pH environments, *Mougeotia spp.* is often used as a bioindicator for acidified waters. In addition it serves as a bioindicator for clean, oxygen-rich, mesotrophic aquatic habitats subject to seasonal warming in fossil studies (Guiry and Guiry, 2019). Some species of *Mougeotia* exhibit high tolerance to heavy-metals.

There are currently 205 listed species of *Mougeotia spp.*, with 173 currently acknowledged by citings in literature (Guiry and Guiry, 2019). *Mougeotia spp.* is difficult to identify down to the species level as zygospores need to be present, though even with these structures' experts have difficulty in identification (Tapolczai et al, 2015).

Purpose of study:

Although *Mougeotia spp.* has been relatively well studied, its resilience to major biotic factors prompts interest in related physiological traits. Evidence of *Mougeotia spp.* maintaining consistent growth rates despite freezing temperatures, changes in pH, or nutrient (nitrogen, phosphorus, carbon) concentrations have been well cited in literature (Hawes, 1989; Klug and Fischer, 2000; Middleton and Frost, 2014; Tapolczai et al., 2015; Graham, Arancibia-Avila, Graham, 1996). In many cases, *Mougeotia spp.* outcompetes other organisms and dominates the entire habitat (Tapolczai et al., 2015; Zohary et al., 2018; Graham, Arancibia-Avila, Graham, 1996; Turner et al., 1991; Salmaso, 2002; Knisley and Geller, 1986; Mills and Schnidler, 1986; Futatsugi et al., 2014). *Mougeotia spp.* is notoriously characterized as a troublesome invasive species in most bodies of water where it is identified. Limited research has been conducted on effective biological control methods thus far. Aside from using specialized algicides, *Mougeotia spp.* poses a difficult question to solve for people utilizing freshwater habitats for resources and recreation.

Mougeotia spp. is an algae genus known to have a wide range of geographical ranges and environmental tolerances. *Mougeotia spp.* can be found in freshwater habitats worldwide (Guiry and Guiry, 2019). There does not seem to be limitation by environmental constraints such as pH, temperature, photic level, or nutrient concentration; making this algae the ultimate freshwater inhabitant.

Mougeotia spp. has been shown to be relatively unaffected by variations in pH. At times the members of genus are found even thriving compared to other algal species in acidified environments. Klug and Fisher (2000) tested 3 controls (at 8.1, 6.1 and 5.9), and two treatments at pH 4.7 constant and ph 4.7 pulsed. *Mougeotia spp*. was found to proliferate in all acidified treatments. However, maximum growth rate was found at pH 8.0. Further evidence is available showing increased growth rate at acidic pH (Turner et al, 1991, Graham et al, 1996), though *Mougeotia spp.* is not limited exclusively to acidic environments and is capable of growing over a range of pH 3-10 (Graham et al, 1996). At pH 3, the algae starts to show signs of degradation and stress, dying at pH below this level. Although growth rate is reduced for *Mougeotia spp*. in highly acidic environments, they still remain the dominant genus.

Increase in acidification of aquatic environments tend to increase the stress of organisms inhabiting the area. However, *Mougeotia spp*. continue to increase biomass in acidic conditions. This tolerance of low pH is hypothesized to be due to the algae's ability to utilize low concentrations of dissolved organic carbon (DIC) that occurs at these low pH levels. Efficient DIC uptake allows *Mougeotia spp.* to outcompete other species for DIC despite the stress of low pH (Klug and Fisher, 2000, Turner et al, 1991). Aside from an efficient uptake of DIC, this genus has shown exceptional resilience in low phosphate and nitrogen environments. No matter the concentration of nutrients, *Mougeotia spp*. showed little variability in the growth rate after 17 days of exposure (Middleton and Frost, 2015). Low concentrations of phosphorus have been shown to contribute to blooms of *Mougeotia spp*. (Tapolczai et al., 2015). The genus exhibits slower than expected growth rates, which may contribute to lower requirements of phosphate and nitrogen. Stoichiometric variability in the cell concentration for P and N indicated the algae was able to alter physiological requirements depending on the surrounding environmental concentrations. This, in addition to herbivory avoidance (Klug and Fisher, 2000, Knisely and Geller, 1986) allows *Mougeotia spp*. to occupy an ecological niche that lets it persist among fast growing algal species (Tapolczai et al, 2015).

Mougeotia spp. contains chloroplasts with the ability to shift position in order to capture the optimal photic intensity (Guiry and Guiry, 2019). This trait unique to the genus allows it to inhabit depths ranging from near surface level to 40m, in which an study conducted in Lake Kinneret (Israel) found no relationship could be determined between the observed *Mougeotia spp.* biomass and measured photic intensity (Zohary et al, 2018). Tolerance for high photic intensity has been shown (Naselli-Flores, 2000), with the algae's persistence also noted for circumstances in which light was the limiting factor in the environment (Reyolds et al, 2002). Such variability and efficiency in light harvesting allows this genus to maintain growth over winter, giving the algae a head start in early spring (Tapolczai et al., 2015).

Common algicides known to be effective in reducing biomass of algae (eg. copper sulfate) have been found to be ineffective in controlling blooms of *Mougeotia spp*. (Albay and Akçaalan, 2003). In Albay and Akçaalan's study, the Ömerli reservoir in Istanbul was treated with copper sulfate to control the blue-green cyanobacteria bloom that had occurred there, and copper resistant algae (including *Mougeotia spp*.) were found to increase in biomass. *Mougeotia spp.* was found in high abundance amounts in all sampling sites below 10m, regardless of euphotic and mixing depth. This indicates a high tolerance for light and nutrient limitation, and resistance to copper sulfates. Copper sulfate exposure over 18 months showed significant increase in *Mougeotia spp.* biomass, with macrophytes showing marked reduction in biomass (Roussel et al., 2007). This increase may be a result of reduced competition between non-tolerant and tolerant species, freeing up resources to allow *Mougeotia spp*. to bloom.

Iron oxide, cadmium sulphide, and silver sulphide (in particular, the nanoparticles) were found to have an overall negative effect on *Mougeotia spp*. growth (Jagadeesh, Khan, Khan, Chandran, 2015). Iron oxide was found to be non-toxic in low concentrations, but increased concentrations contributed to apoptosis. Cadmium sulphide nanoparticles, and silver sulphide nanoparticles showed toxicity, particularly nanoparticle composites. Toxicity is caused by reduced production of antioxidant species, causing a buildup of reactive oxygen species in cellular matrix. Cell membrane damage contributed to cell lysis, and cell death. For this study *Mougeotia spp.* was used as a model species to showcase the toxicity of metal nanoparticles in aquatic ecosystems, therefore this eliminates these compounds as a viable option for targeting and reducing biomass of *Mougeotia spp.*; despite the negative effect on biomass.

Mougeotia spp. from Little Rock Lake, Wisconsin were exposed to Aluminum and Zinc levels 100 and 400 times greater respectively than their natural background concentrations. The filamentous algae was found to have little variation in growth rate and chlorophyll a concentration regardless of the metal concentration in the water (Graham, Arancibia-Avila, Graham, 1996). The only impact was shown at concentrations of 1200ug/L, where filaments began to break off more readily and small metal deposits were located inside the cell though no change in the membrane slime-sheath was detected. This demonstrates an exceedingly high tolerance over other algae for metals in the aquatic environments where *Mougeotia spp.* are found. This algae was found to show tolerance to Chloride up to concentrations of 290mg/L, after which no specimens were located (Zohery et al., 2018).

Mougeotia spp. has few natural consumers in the zooplankton community. Peak periods for zooplankton have little impact on the biomass of *Mougeotia spp.,* as the filaments are considered to contain little nutritional value and are therefore inedible to these organisms (Salmaso, 2003). A study conducted by Knisely and Geller (1986) used species *Daphnia hyalina, D. galeata, Eudiaptomus gracilis, and Cyclops sp.,* (Daphnia and Copepod species) to test the preferential grazing on varying types of phytoplankton. Nearly all forms of phytoplankton were found to be grazed efficiently or with some preference shown to certain sizes. *Mougeotia spp.* was the only phytoplankton genus tested that was found to undergo no significant grazing. The choice in phytoplankton was higher for moderately sized genuses assuming small phytoplankton were too small to be effectively filtered, while larger plankton were assumed to be too large to fit through the carapace opening. While *Daphnia hyalina* was able to graze on filamentous blue-green algae, it was not able to consume *Mougeotia spp*.. The longer filamentous structure of *Mougeotia spp*. may contribute to the inedibility, though it is possible that a potential consumer of *Mougeotia spp*. was not tested. There are controversial results in the literature on the palatability of filamentous algae for zooplankton species, but further experimentation does seem to show some zooplankton have the ability to consume filamentous species (Holme, Ganf, Sharpio, 1983, Peters and Downing, 1984). Klug and Fisher (2000) found no effect of grazing zooplankton on their cultures of *Mougeotia spp*., but hypothesize fish, crayfish, tadpoles and macroinvertebrates may contribute to grazing effects on the genus. Further testing of large filtration and grazing species should be examined to attempt to identify potential *Mougeotia spp*. consumers.

Though few natural predators of *Mougeotia spp.* are identified in the literature, there are examples of infections by rare fungi present in the genus from a small pond by Lubiec, Poland (Kadłubowska, 2014;1998). *Micromyces zygogonii* and *Rhizophydium ampullaceum*, two rare parasitic fungi known to infect *Mougeotia spp.* and *Spirogyra*. There is little information available on these spherical fungi, however they are known parasites and decomposers in aquatic environments and are most commonly found on *Mougeotia* and *Spirogyra* (Couch, 1937, *Dictionary of Microbiology & Molecular Biology*, 2006).

Tadpoles of the species *Rana aurora* were found to significantly reduce biomass of filamentous algae, with particular impact found for *Mougeotia spp.* (Dickman, 1968). While tadpoles remained in the herbivorous stage of their life cycle, algae levels were maintained between 1/50th and 1/100th portion of control algae crops with high densities of *Mougeotia spp*. found in the digestive tract of the tadpoles. However once the tadpoles began metamorphosis to the adult stage, their diets change and the effectiveness of algal control was reduced.

Conclusion:

Mougeotia spp. is a versatile and adaptable algae that has a wide range of environmental tolerances. The range in pH can vary from 4 (very acidic) to 10 (highly basic). Low levels of nitrogen and phosphate do not affect the growth rate. It has been found to thrive in both light limited and light intense environments. It has a high tolerance for Zn, Al, and Chlorides, though has shown to be adversely affected by metal nanoparticles. These are also highly toxic to other aquatic organisms and would not be a suitable control method for *Mougeotia spp.*. Few zooplankton are found to graze on this algae genus, but there is a high possibility that a grazer has not yet been identified. Future studies exploring zooplankton grazers should focus on larger bodied species with high rates of filtration. Biomass of *Mougeotia spp.* Appears to be immune to most physiological limitations, so sustainable control methods will require diverse and stable communities with macrograzers to combat algal blooms.

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Appendix II:

Biodiversity Catalogue of the Cascading Fountain

All samples were collected at the cascading fountain near the UBC Bookstore.

Algae

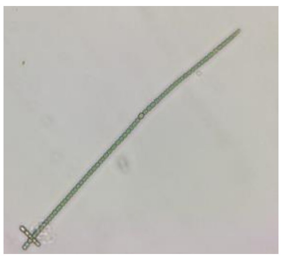
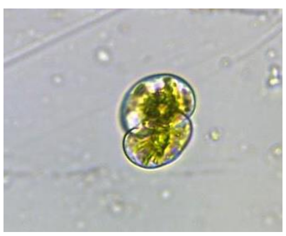
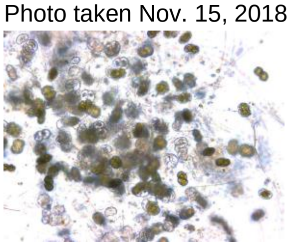
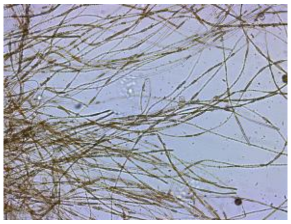
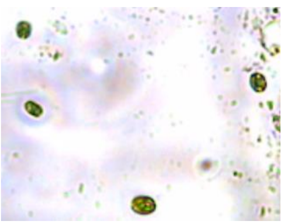
 Photo taken Oct. 22, 2018	Anabaena	Ecology • Form the base of the aquatic food chain • Photosynthesis aerates the aquatic environment • Nitrogen-fixing abilities (atm. N -> organic forms such as NO3- and Ammonia)	Habitat & Distribution • Found worldwide • Considered a major component of freshwater plankton species and sometimes in saline lakes
 Photo taken Nov. 15, 2018  Photo taken Oct. 5, 2018	Cosmarium spp.	Ecology • Food source for a large population of grazers i.e. rotifers, midge larvae etc.. • Form the base of the aquatic food chain • Photosynthesis aerates the aquatic environment	Habitat & Distribution • Free floating freshwater plankton • Found in ponds, lakes, ditches and other reservoirs • Tend to be intermingled with other algae species
	Freshwater Diatom	Ecology • Primary producers and important component of the base of the aquatic food chain • Photosynthesis aerates the aquatic environment • No specific predators but grazed upon by	Habitat & Distribution • Found in benthic habitats and sometimes nestled within plankton • Found worldwide and present throughout the year - higher

Photo taken Nov. 8, 2018		various aquatic invertebrates and organisms	abundances in spring and fall
 Photo Nov. 8, 2018	Mougeotia	<u>Ecology</u> ● Bioindicator of acidified waters and clean, oxygen-rich, mesotrophic aquatic habitats subject to seasonal warming in fossil studies ● Potential food source for tadpoles	<u>Distribution & Habitat</u> ● Found in clear, shallow freshwater habitats worldwide ● Can inhibit waters of a wide range of pH (3-10) ● No environmental constraints
 Photo taken Nov. 15, 2018	Chromulina	<u>Ecology</u> ● Photosynthesis aerates the aquatic environment ● Autotrophic species but can sometimes be mixotrophic	<u>Distribution & Habitat</u> ● Found in freshwater habitats worldwide ● Typically associated with waters that are of low-moderate nutrients and low alkalinity, a specific conductance and a pH of neutral - slightly acidic

Insects

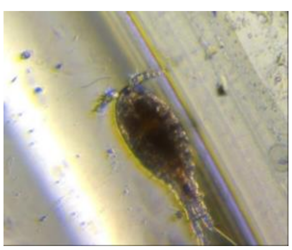
	Baetidae Baetis sp (Mayfly - Nymph Stage)	<u>Ecology</u> ● Feed on algae and organic waste. ● Play an important role in cleaning water bodies as they consume contaminants then as adults they carry them to land for degradation ● Important sources of food for fish, birds, amphibians, spiders	<u>Distribution & Habitat</u> ● Found worldwide except the Antarctic/Arcti c ● Nymphs occur in a wide variety of freshwater environments (still ponds to fast streams) ● Adult mayflies

Photo taken Mar. 3, 2019 Location: Mid Tier Fountain, benthic region		and other dragonflies ● Serve as bioindicators of ecosystem health and quality as their populations are quite sensitive to changes in water chemistry	are common near water however mating swarms are generally found 2-3 km away from the water
 Photo taken Mar. 3, 2019 Location: Upper Tier Fountain, algal mat. Note: Found in surplus throughout the fountain environment	Chironomidae (Midge - Larval Stage)	<u>Ecology</u> ● Primary consumers of freshwater ecosystems ● Larvae aid in decomposition of detritus and cycling of the nutrients back into the food chain ● Various insects (i.e. dragonflies), birds and other aquatic invertebrates feed on Midges	<u>Distribution & Habitat</u> ● Species can be found in moist/wet habitats including Antarctica ● Found in wide variety of benthic freshwater environment ● Many species are "burrowers" and can be found burrowed into the bottom substrate
 Photo taken Mar. 3, 2019 Location: Mid Tier level fountain, benthic region	Dragonfly Nymph Order: Odonata Suborder: Anisoptera	<u>Ecology</u> ● Important predators of mosquito and midge larvae As adults they feed on mosquitoes, midges and other small insects ● Most of a dragonfly's life is spent in the Nymph phase ● Nymphs are a food source for fish and other insectivores	<u>Distribution & Habitat</u> ● Found in streams, ponds, rivers, lakes and wetlands ● Live near calm or slow-moving waters ● Likely found under or near rocks and aquatic vegetation

 Photo taken Mar. 8, 2019 Location: Mid Tier level fountain, benthic region			
 Photo taken Mar. 8, 2019 Location: Mid Tier level fountain, benthic region	Damselfly Nymph Order: Odonata Suborder: Zygoptera	<u>Ecology</u> ● Feeds on aquatic animals smaller than itself ● Important predators of mosquito and midge larvae As adults they feed on mosquitoes, midges and other small insects ● Most of a damselfly's life is spent in the Nymph phase ● Nymphs are a food source for fish and other insectivores	<u>Distribution & Habitat</u> ● Found in marshes, ponds, streams, & other aquatic habitats ● Hide on substrate or a submerged plants
	Notonectidae Notonecta kirbyi (Backswimmer)	<u>Ecology</u> ● Secondary consumers in the aquatic food chain ● Feeds on other small aquatic larvae and sometimes on small aquatic invertebrates	<u>Habitat & Distribution</u> ● Found throughout North America ● Commonly found in ponds, freshwater pools and slow flowing streams abundant with aquatic plants

Photo taken Mar. 3, 2019 Location: Upper Tier level Fountain, benthic region			
 Photo taken Mar. 3, 2018 Location: Mid Tier level fountain, static benthic region (reeds)	Mosquito Larvae	<u>Ecology</u> ● Common food source for dragonflies, damselflies and other aquatic invertebrates and crustaceans ● Feeds on particulate matter within the water source	<u>Distribution & Habitat</u> ● Commonly found in slow-moving/stagnant waters i.e. ponds, marshes, swamps etc.. ● Prefer humid environments but are able to survive and thrive in a variety of environments

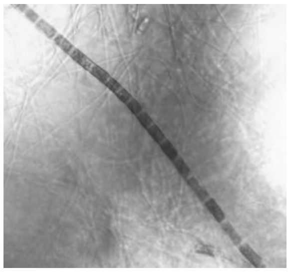
Freshwater Zooplankton

 Photo taken Oct. 15, 2018 Location: Upper Tier level fountain, algal mats Notes: Found throughout algal mats	Freshwater Copepod	<u>Ecology</u> ● Intermediate position in aquatic food chains ● Usually omnivores and commonly consume algae, detritus, bacteria, pollen and rotifers ● Prey to various Chironomidae insect larvae, predatory copepods and fish	<u>Distribution & Habitat</u> ● Found in a variety of habitats ranging from freshwater lakes, rivers, ponds and streams ● Able to survive harsh conditions by entering diapause ● Vertical migration is common in response to food abundance and predator avoidance

Microscopic Organisms

 Photo taken Oct. 15, 2018 Location: Lower Tier Fountai. Notes: Found throughout algal mats	Nematode	<u>Ecology</u> • Feeds on algae, bacteria, fungi, protozoans, organic matter etc.. • Food source for benthic and pelagic invertebrates/vertebrates • Important intermediate between microbial production and macroscopic consumers	<u>Habitat & Distribution</u> • Found worldwide and can be present in all types of limnetic habitats including those of unfavourable conditions (i.e. high T, acidic etc..)
 Image taken from Microscopy UK. Retrieved from: http://www.microscopy-uk.org.uk/mag/wimsmall/extra/rotif.html	Rotifer	<u>Ecology</u> • Aid in natural water purification • Feed on suspended organic particles and free-swimming algae • Foodsource to many aquatic insects	<u>Habitat & Distribution</u> • Free-swimming on open surfaces of ponds/streams • Can also be found in moist soil

Unidentified

 Photo taken Oct. 22, 2018	Tribonema/Microspora	<u>Reason</u> • Too similar in shape/size to determine at this level • Both species have H-shaped cell walls	<u>Steps Needed:</u> • Starch test - Microspora contains Starch while Tribonema does not

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