An analysis of surface water pH & community perceptions of greenspaces at Dalhousie University's Studley Campus

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Keywords

Greenspace, pH, Turbidity, Surface Water, Drainage System, Stormwater Management Practice, Community Perception, Biodiversity, University Campus

Abstract

Acidification and increased turbidity of surface water is a prominent issue in urban environments, as exposure to toxic materials, improper drainage, and other factors can lower the pH of the surface water leading to several adverse environmental effects (Hall & Anderson, 1988). Halifax uses a limited selection of drainage system types, most of which are industrial and perpetuate negative effects on the environment (Sheppard, 2012). Previous research reveals that increased exposure to healthy greenspaces relates to many mental and physical human health benefits (Wang et al., 2022). To see if there was any potential correlation between these facts, we decided to analyze whether or not specific drainage systems perpetuated negative effects of acidification on the environment, and whether or not these findings would correspond with Dalhousie Studley Campus' current perceptions of their greenspaces. We tested the pH and turbidity of surface water for 12 days, taking into account several different measurement factors such as weather, depth, and drainage systems present across five different greenspaces on Dalhousie University's Studley campus. Alongside this, for 15 days we ran a voluntary survey for the Studley Campus University community to determine their current perspectives on their greenspaces. With these data, we ran a regression analysis to determine if there was any correlation between our measurement variables and surface water pH. We found that at one of our locations there was a significant correlation between drainage systems and pH, additionally at two we found climatic factors to be more significant, our last two locations had insignificant data to determine correlation with significance. Based on location, this indicated that there was a potential benefit to be found in using natural drainage systems compared to non-natural options (Gutters, Manholes, etc.). Our survey indicated that there were relatively negative perceptions of current Studley campus greenspaces, and that this could be improved by increasing maintenance, as well as biodiversity across these spaces. We concluded that implementation of natural drainage systems with improved maintenance would improve community perceptions of Dalhousie's greenspaces, and with further research it could be determined that this would also reduce the impacts of acidification on surface water across these greenspaces.

Introduction

Stormwater management

Halifax, formed in 1996 through the amalgamation of four pre-existing municipalities (Canadian Encyclopedia, 2012), as a result Halifax faced the sudden integration of plans and policies related to stormwater management. As outlined in the Halifax Regional Municipality Charter, the stormwater management by-law encompasses key concepts crucial for effective management. Consideration of watersheds encompassing land activities impacting runoff quality, preference for simple passive solutions that mimic natural functions, importance of pre-development conditions and site-specific strategies, emphasis on enhancing runoff quality and reducing volume, recognition of season variations and methods to reduce flooding, erosion, groundwater contamination and inflow into wastewater systems caused by development. Additionally, the bylaw promotes the use of naturally occurring native vegetation, advocates for reducing site disturbances in new developments, and aims to minimize sediments, nutrients, and contaminants from being discharged into watercourses.

A storm drainage system is defined as a group of interacting, interrelated and interdependent elements carrying discharges in response to rain and snow, including overland flow, subsurface flow and snowmelt. A functioning system can be split into two categories "community systems" meaning infrastructure that serves two or more lots (Halifax Regional Council,2015). For example, roadside ditches, culverts, roadways, curbs and gutters, street and backyard catch basins, pipes, conduits, retention ponds, watercourses, floodplains, and drainage.

The second category is "individual lot systems" ; these are categorized by being elements which serve a single lot and are contained within its limits (Halifax Regional Council, 2015). For example, swales contained in lot limits, gently graded areas, slopes, roof downspout, seepage pit and parking lot catch basins.

Halifax's current stormwater management includes: ditches and culverts, combined sewers, separate storm sewers and street curbs and gutters (Sprague, 2012). The main issue, however, is the increasing frequency of rain events along the east coast (Halifax Regional Municipality). This increased volume of stormwater is not able to enter these already implemented systems. The result is once runoff encounters parking lots, lawns, roads and culverts it becomes contaminated in varying degrees- this water, because it is unable to enter the appropriate systems, goes directly into waterways. Negative impacts from this include: flooding, property damage, sewage overflows, public health risks, high maintenance costs and unfavorable environmental effects (Sprague, 2012). Once contaminants enter water systems, they can easily be spread along the food chain across multiple ecosystems.

pH

pH is the expression of hydrogen ion concentration in water, represented by a 1-14 scale where 0 represents higher acidity levels, 14 represents higher basic levels and a pH of 7 is neutral. Water pH influences the chemical and biological processes in water and higher acidity levels can impact ecosystem health (Aram et Al., 2022). pH is an important test when examining stormwater acidity, drainage systems and the subsequent impacts on greenspace health because it can determine solubility, biological availability, chemical composition of nutrients and certain levels of heavy metal in the water (Aram et Al., 2022). The article "The toxicity and chemical composition of urban stormwater runoff" uses pH testing in order to determine the acidity levels in stormwater runoff and the impacts this has on greenspaces. This article examines how land use affects the toxicity and chemical composition of stormwater, focusing the research in Burnaby, British Columbia. Contaminants included in their water tests are toxic metals, hydrocarbons, nutrients and pesticides (Hall & Anderson, 1988). Through these pH tests this study was able to establish that the intensity of rainfall and morphology of drainage systems affects the contaminants in water, and runoff from commercial and industrial sites is more commonly toxic (Hall & Anderson, 1988). pH tests have been represented in countless studies, facilities and classes and these articles display the importance of including pH tests when conducting research involving water contaminants. Testing pH can help research determine water health and how external factors can affect water acidification.

Turbidity

Turbidity is caused by a multitude of suspended solids invisible to the naked eye in a liquid. It is an optical parameter most narrowly defined as the effect of the clarity of the water. The measurement of turbidity is an important test in determining water quality. Water with high turbidity is opaque and it is often called murky. The scale ranges from low turbidity to high turbidity is called clear to murky (Woodsides, 2022). Erosion and drainage in urbanized areas can affect water bodies and soil, causing elevated sediment levels. When it rains, sediment flows into waterways, causing the waters to become turbid. Erosion and runoff can increase the amount of contaminants in water bodies, causing harmful effects to aquatic life and human health, which is why turbidity is measured in water systems (Atlas Scientific, 2022). As an important indicator of water quality, this cause will have a negative impact on the water body, increasing Total Suspended Solids (TSS) level in water and leading to the water temperature to rise. TSS is an optical measurement of water clarity, measuring the total mass of particles in water. High TSS levels not only harm aquatic life but also pose a risk of clogging stormwater systems, impeding their efficacy in managing runoff. The determination needs to be carried out in a laboratory setting and involves filtration, evaporation, and gravimetric analysis of the total mass of solids. The filtered solids are dried and weighed (Woodsides, 2022). Highly accurate results will be obtained after operation in the laboratory, but the time required to collect the sample, send the sample to the laboratory for processing and receive the results can be long, so the measurement of turbidity in this study will be done by comparing with the scale to get results.

Flows with height difference

Stormwater management is determined by the dynamics of rainfall flow, reflected in the changes between high and low points. After rain falls, water generally flows from high points to low points, taking into account soil texture and permeability. Differences in flow patterns can determine the effectiveness of stormwater infrastructure and provide feedback on better stormwater management practices. The concentration of runoff from highlands to low-lying areas not only increases the risk of local flooding, but also promotes the transport of pollutants and sediments to water bodies, posing the potential to inflict serious environmental and public health problems. Slope shapes produce different dispersion effects. For example, convex slopes tend to disperse water as it flows downhill, concave slopes create depressions, and straight slopes concentrate water on lower slopes (Rome, 1988). Often urban landscapes are characterized by impervious surfaces and topographic changes that exacerbate the effects of rainfall flow differentials, resulting in increased runoff volumes and velocities. Therefore, effective stormwater management strategies must take into account differences in stormwater flow across different terrains, using measures such as retention ponds, green infrastructure and engineered drainage systems to mitigate flood risks and safeguard water quality.

Greenspace Variables

There are many changing and determining factors when analyzing the health and drainage of a greenspace. Factors such as depth, temperature, precipitation, etc. can all impact greenspace health differently depending on the conditions. Halifax is an extremely rainy city, and has almost double the average yearly precipitation compared to the Canadian national average (Average annual precipitation for Canadian cities). A higher level of precipitation means more strain on the greenspaces and their respective drainage systems, and can cause various negative effectives such as flooding, shifting pollutant/debris, disturbing habitats and so much more.

Temperature can also greatly impact a greenspace's health and drainage abilities. Extreme temperatures can result in green spaces freezing over and cause higher levels of surface water runoff when temperatures rise, straining that greenspaces drainage system (Hillibish, 2007). Depth is also an important factor when examining greenspace drainage, as the depth of the water can display how much stormwater is in that particular area of the greenspace, and how much drainage is happening. It is essential to consider these factors when analyzing greenspace health because each factor can severely impact a green spaces drainage ability and overall well being.

Community greenspace perception

Greenspace health is an important factor in determining community perceptions, space use and overall well being. A study conducted on Guangyanggu Urban Forestry Park in China determined when and why people use their local greenspaces and highlights the importance of greenspace health and practical utility within different regions. The park's user activities fall into three categories: restoration, physical activity and social interaction (Wang et. Al., 2022). This study concluded that while users entered the park mostly for physical activity, leisurely activities such as socializing and resting were an important aspect of that park's utility as well. Users typically stuck toward the center of the park, which had the highest concentration of biodiversity and natural aesthetic areas. This greenspace helped produce positive emotions and promote recreation and social interaction, and this study establishes the importance of aesthetic, healthy and accessible greenspaces in a community and the benefits they reap when taken care of properly (Wang et. Al., 2022).

A study conducted at a southern university in the United States establishes how these positive effects from greenspaces are integral for a higher quality of life for university students (Holt et. Al., 2019). When surveying students who attended a campus with a high density of healthy and biodiverse green spaces, the students were reported using the green spaces on campus most commonly to stay active and alleviate stress. Their survey concluded that consistent access to greenspaces for university students results in an overall better mood, and approximately 3/4 students believe nature is a necessity for human beings (Holt et. Al., 2019). These studies highlight not only the importance of ingression to greenspaces for communities, but also the core values that community members hold within greenspaces and their ability to freely utilize such areas. Increasing ease of access to healthy and biodiverse greenspaces can result in a higher overall quality of life.

These points of thought lead us to the following research questions:

R1: What is the influence of stormwater management practices on surface water pH and turbidity at Dalhousie University Studley Campus greenspaces?

R2: What are the perceptions of Dalhousie community members on greenspaces across Studley Campus?

Methodology

Field Methods

R1: What is the influence of stormwater management practices on surface water pH and turbidity at Dalhousie University Studley Campus greenspaces?

We collected surface water at five separate greenspaces that have varying levels of use by the Studley Campus population. These five locations were selected to have variation in utilization, drainage systems, intended purpose, present flora, and volume of surface water. **The five sampling locations are as follows:**

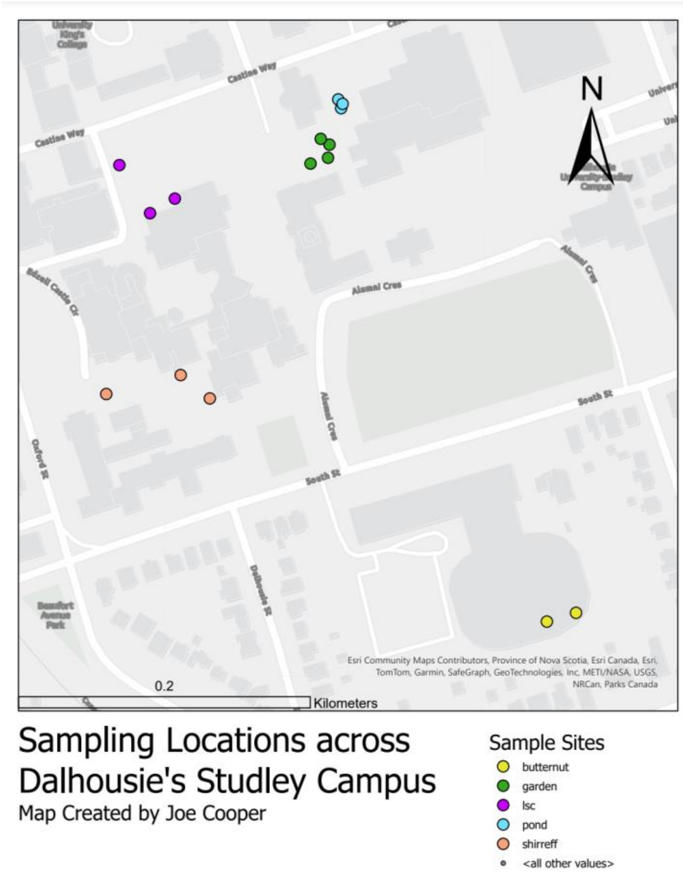
Site 1: The Dalhousie Ocean Pond, located near Studley Campus' second largest parking lot. This pond has water present year-round, is frequently passed by students due to its central location to campus, and has several different ecological communities (McCaffery, 2012). This was our most consistent sampling site due to the various water sources and ecological value.

Site 2: **Indigenous Pollinator Garden**, located directly behind the Chemistry building. This garden has great flora diversity, as well as a distinct, built-in system designed for drainage of rainwater as there is a gutter in the two back corners directly next to an artistic piece that collects water. Our sampling bounds of this location will include a large expanse of monoculture grass which is directly next to the garden. We expected that this stretch would hold onto surface water more consistently than the garden itself due to the drainage gutter, and artistic piece (Reeder, 2021) that acts as a trench that are both designed into the garden.

Site 3: The LSC ESS wing exit boasts a large, recreationally designed greenspace. This space is flat along the built-in walking trails, but there has been a new "desire path" created which has in turn built in a drainage trench. This location is also frequently passed by large vehicles, making it an interesting location for pH observation as diesel exhausts have been shown to lead to increased pH in water (Frey & Corn, 1967).

Site 4: Shirreff Hall's woodland (Verma & Reeder, 2021), is one of Studley Campus' largest greenspaces, covering the whole walkable area that is present between the LSC and Shirreff Hall itself. This selection was made due to its size, variation of drainage systems (manhole covers, drainage grids), and frequent student use.

Site 5: Dalplex Butternut Stand Unlike the other greenspaces that we have chosen, this "greenspace" is not inherently designed for community use, we selected this location on account of the presence of a stand of endangered **Butternut trees** *Juglans cinerea* (Nature Conservancy Canada, 2024).



Site 1

Site 2

Site 3

Site 4

Site 5

We measured surface water **pH**, **depth** (cm), **elevation** (m) & **turbidity** as well as the current time's **temperature**, **real feel temperature**, **UV index**, **wind speed** (Km/H), **percent cloud cover**, **precipitation** (mm at time of sampling), and **daily precipitation** (mm throughout the day of sampling). We also classified the relative **positioning** within the greenspace (**Low =1 or High =2**), and the **drainage system** nearest to our sampled surface water **(0 = no system present, 1 = Slope, 2 = Pond, 3 = Trench, 4 = Manhole Cover, 5 = Drainage Grid, 6 = Gutter)**. To do this we took a repeated, non-probabilistic sampling approach, wherein we collected surface water three times for both a relatively high location of surface water, and three for a relatively low location. We collected all of our weather data immediately following the time of sampling from **accuweather.ca**, to ensure consistency in our data. To select our sampling locations, we first scoped the entire greenspace each day of sampling, and then **chose the surface water we were to sample based on the following criteria:**

I. **Located on at least a semi-permeable surface** – this prevented us from collecting water on pavement, found collected inside litter, etc.
II. **Depth of >= ~*1 centimeter** – this ensured we didn't attempt to scrape up groundwater instead of our intended surface water. *2 or 3 samples did not adhere to this rule.

III. **Accessible without damaging local ecology** – this was especially important while sampling at the Ocean Pond & Butternut stand, as there are several unique, sensitive ecological systems in play at these sites (McCaffery, 2012), (NCC, 2024).

We collected daily samples from **March 7th - 18th, 2024** at all our locations using the criteria listed above. Our sample collections were executed as follows:

1. **Measure the surface water depth of our intended test site using a ruler.**
2. **Collect ~half of a 350mL glass beaker with sample water and take a photo of this to assess the general turbidity of the sample. These photos were assigned categories of no turbidity, low turbidity, moderate turbidity, and high turbidity depending on their appearance in the photos after testing to visualize present patterns. Unfortunately, this data was not included in our final analysis due to time constraints.**
3. **Rinse the sample container with the test water to ensure that the reading was consistent (Environmental Protection Policy, 2000), and dip a pH strip into the sample and promptly gather readings. The readings of the pH measurements were only overseen by two members of our research team, to ensure consistencies across all samples.**
4. **Move ~one meter from the first site and repeat the process.**
5. **We did this *6 times per sample location daily.**
6. **After all samples were completed, we boiled sampling containers to sterilize them for the next day (Labpedia, 2021).**

*Some sample locations did not have enough surface water present to collect the intended 6 samples daily. All sample data will be found in the appendices.

Among the test sites that we used in our research the methods of stormwater management are slope, culvert, catch basin/ pond, drainage grid and conveyance furrow.

Test site runoff management

Test Sites	Management Practice	Significance
Dalhousie Ocean Pond	Catch basin/ pond	Collecting rainwater that runs over impermeable surfaces such as parking lots, roads and buildings, the rainwater can be absorbed into the soil and taken up by trees and plants and provide habitat. Pollutants can be settled out before being released back into the watershed.
Indigenous Pollinator Garden	Conveyance Furrow	A surface irrigation method, includes small channels or furrows that follow down a uniform slope allowing for rapid loss of surface water. The use of mulch in these furrows allows for increased rapid drainage by creating channels that allow water to flow through and reach the root of the plants.
LSC	Slope	The use of a slope to manage stormwater relies on gravity to direct the water to an area with less of an incline that contains additional drainage. The slope in this case is not sufficient as it does not effectively direct surface water toward another drainage system. The land that is not sloped often experiences heavy eroding.
Shirreff Hall	Slope/ drainage grid	This site effectively utilizes a slope that directs surface water toward a drainage grid. The site as a result experiences significantly less erosion.
Dalplex	Slope/ drainage grid/ culvert	This site also utilizes a combination of a slope and drainage grid effectively. There are additional large above ground culverts that catch stormwater and prevent excess surface water runoff.

Table 1. Provides the stormwater management practices and their significance for each test site.

Survey Methods

R2: What are the perceptions of Dalhousie community members on greenspaces across Studley Campus?

For the purpose of understanding perceptions of Dalhousie community members on greenspaces across Studley Campus, awareness and values pertaining to the five test sites are the main foci, the general qualities of other spaces are also held in comparison to the study sites. In order to collect the data, a survey was conducted to qualitatively measure the factors of Studley population's accessibility, usage, visitation and values in regard to healthy greenspaces (Appendix, Survey).

We based our target sample size on a set of estimations, as the exact number of students, faculty, and staff that are present in Dalhousie's Studley Campus is not stated on open-source browsers. This calculation began with the two baseline stats that there are ~21000 students enrolled at Dalhousie, 1118 Professors employed, and approximately 2100 other staff roles across our various campuses (Dalhousie University, 2021). As Studley is by far our largest campus population wise, we will assume that ~20000 of the ~25000 students and staff involved with Dalhousie are most active at Studley. With a 95% confidence interval, this would mean a targeted sample size of 377 responses within our survey. Unfortunately due to time constraints, lack of benefits for surveyees, and also no funding to share, or incentivise our survey, the expected returns were much lower than this. A smaller CI was needed for analysis in this case.

Survey dissemination (Appendix: Survey) was completed by sharing a 'quick response' (QR) code for straightforward access of participants. The code was shared with classrooms of varying degrees and majors, as well as made shareable on Instagram. The methods of dissemination are expected to reach a variety of individuals, but are to heavily be composed of Earth and Environmental Science or Sustainability undergraduate students. These students are expected to have more knowledge, leading to greater possible care of such subjects. An important detail to account for is that the social circles of the research team are largely composed of these subgroups. To counteract these effects, various faculty members were contacted, to share our survey with students and peers. Attached to the email was a slide with the QR code (Figure 1B), the media poster (Figure 1A) and web link to our survey. We also requested that they post this slide at the beginning of lecture, or on their course's Brightspace page. Potentially bringing a more accurate and comprehensive sample of Studley campus users to analyze.

A

B

*Figure 1: Square poster (**A**) for social media sharing but may be matched as a postscript into lecture slides, accompanied by remarks on the matter. PowerPoint Slide (B) to be used as a slide in a PowerPoint, preferably in the introduction before planned lecture content. Shared as a Portable Network Graphic (PNG) displays the QR code as a high-quality digital image, ideal for easy sharing with conversational context.*

Field Analysis

To analyze the data that we collected, we utilized Microsoft Excel and RStudio to run regression analyses on each site to determine which of our selected variables would have an impact on pH. These included **numerical data (pH, Depth, elevation, Temperature C, Real feel Temp., UV, wind speed and precipitation), Percent % values (Cloud cover),** and **Numerical Codes (Drainage System, Relative Position).** The coding model that we used is at follows:

```
Fit <- lm (pH ~ High_Low + Depth + Elevation_m + Drainage_System + Temp_C + RealFeelTemp_C + MaxUV_Index + Wind_KmH + CloudCover +Hourly_precip +Daily_precip)

summary(Fit)
```

The first command assigns the regression code to the object "Fit" with pH being tested as the dependent variable, then the summary function was used to display the results of this regression. This indicates dependent variables levels of significance by annotating them with an asterisk*. From here, we complete the next codes.

```
Fit1 <-lm (pH ~Found Significant Variables of first model)

summary(Fit1)
```

This creates a new regression model renamed “Fit1”, then shows the results of which significant variables of the first model have the most impact on pH. Following this, we tested the strength of our models to ensure our newer model was an improvement using this code:

```
AIC(Fit) ; AIC(Fit1)
```

AIC informs us of the relative strength of a regression model, the lower the better.
The findings of this analysis can be found in our **Results.**

Survey Analysis

To analyze our survey data, we utilized a qualitative approach to determine significance of specific statements that were used as responses the arithmetic mean was recorded. From this we generated a number of graphs to visualize this data. For the purpose of understanding perceptions of Dalhousie community members on greenspaces across Studley Campus, we looked at the awareness and values associated with our sites. The survey was conducted to measure population’s accessibility, usage, visitation and values in regards to our natural spaces. These graphs and charts can be found in the **Results** section of this study (Appendix: Survey), (Results).

Ethical Procedures

Measures to consider the ethics regarding respect, consent and anonymity of the participants include, the fundament of voluntary-response within our standardized survey and the non-probabilistic sampling method to yield a representative population for our study.

Before continuing, respondents had to read about the terms and ethics particular to the survey, and indicate consent by proceeding to the next page, to ensure we had established informed consent about the contents to come (appendix, survey). The testing associated with this study was approved by **Dalhousie’s Research Ethics Board** and the **Department of Earth & Environmental Science**, and prior to the research proposal all authors completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans **(TCPS 2: CORE 2022)** course.

Results

FIELD

***** = massive correlation, ** = very strong correlation, * = correlation**

Ocean Pond Regression Analysis

First Pond Model

Variable	Estimate	Standard Error	P - Values
High vs. Low	-0.093	0.1013	0.363
*** Depth**	**0.014**	**0.0071**	**0.046 ***
Elevation	-0.018	0.0180	0.311
*** Drainage System**	**-0.138**	**0.0598**	**0.024 ***
Temperature	0.044	0.0291	0.138
Outdoor Temp. Feel	-0.009	0.0070	0.186
Max UV Index	0.053	0.0689	0.447
Wind Speed	0.005	0.0040	0.189
Cloud Cover	0.003	0.0025	0.194
Hourly Precipitation	0.011	0.0131	0.397
Daily Precipitation	0.0001	0.0016	0.948

Multiple R Squared: .273 Adjusted R Squared: .1397

Model P-Value: 0.0389*

Upgraded Model

Variable	Estimate	Standard Error	P - Values
*** Depth**	**0.014**	**0.0061**	**0.023 ***
**** Drainage System**	**-0.126**	**0.0471**	**0.009 ****

Multiple R Squared: .109 Adjusted R Squared: .083

Model P - Value 0.0186 *

The Ocean Pond was our most sampled site, and the site that we believe has the most importance to the results of our work. We first ran a linear regression analysis using all our listed measurement variables with pH as the dependent, and all others as the independents, although not entirely conclusive, this model showed us a potential correlation was present showing us that both “Depth” and “Drainage system” could have an effect on the surface water pH of this location from here, we reduced our model to use only these two variables as measurements, and this showed us that drainage systems had a relation with pH. The drainage system “Pond” had significantly less acidic surface water than the system “Slope” did at Ocean pond at significance = 0.01. The model itself also displayed significance at a 95% confidence interval. This was our most consistent sampling site due to the various water sources and ecological value as is indicated in the appendices, so we could see this pattern emerge fairly clearly. The AIC values showed improvement in the second model as well.

Pollinator Garden Regression Analysis

First Garden Model

Variable	Estimate	Standard Error	P - Values
*** High vs. Low**	**-3.081**	**1.1473**	**0.031 ***
Depth	0.001	0.0363	0.979
Elevation	-0.099	0.1013	0.362
Drainage System	0.928	0.3956	0.051
*** Temperature**	**-0.841**	**0.3244**	**0.036 ***
Outdoor Temp. Feel	0.012	0.0746	0.876
Max UV Index	2.793	1.2389	0.059
Wind Speed	-0.065	0.0427	0.174
*** Cloud Cover**	**0.030**	**0.0108**	**0.027 ***

Multiple R Squared: 0.940   Adjusted R Squared: 0.864

Model P-Value: 0.0016**

Upgraded Model

Variable	Estimate	Standard Error	P - Values
High vs. Low	0.247	0.2163	0.273
*** Temperature**	**0.256**	**0.0920**	**0.016 ***
**** Cloud Cover**	**0.026**	**0.0080**	**0.006 ****

Multiple R Squared: 0.561   Adjusted R Squared: 0.456

We used the same initial model as we used for the Ocean Pond to analyze our Garden data. This showed a correlation between temperature, relative height, and cloud cover. Upon reanalysis of this data, we saw that cloud cover and temperature had a more significant correlation with surface water pH at significance = 0.01. This shows us that weather has a stronger impact on surface water pH at this location than it did at the Ocean Pond.

LSC Regression Analysis

First LSC Model

Variable	Estimates	Standard Error	P - Values
High vs. Low	0.879	0.6731	0.218
Depth	-0.019	0.0839	0.819
Elevation	0.171	0.1061	0.135
Drainage System	0.228	0.2820	0.435
***** Temperature**	**4.018**	**0.8774**	**0.00079 *****
**** Outdoor Temp. Feel**	**-1.036**	**0.2461**	**0.0015 ****
***** Max UV Index**	**-7.762**	**1.6069**	**0.00053 *****
***** Wind Speed**	**0.281**	**0.0602**	**0.00069 *****
***** Cloud Cover**	**-0.656**	**0.1437**	**0.00081 *****

Multiple R Squared: 0.872   Adjusted R Squared: 0.768

Model P-Value: 0.00088***

Upgraded Model

Variable	Estimates	Standard Error	P - Values
*** Temperature	4.103	0.8033	0.00012
*** Outdoor Temp. Feel	-1.045	0.2324	0.00042
*** Max UV Index	-7.982	1.4758	0.00007
*** Wind Speed	0.299	0.04945	0.00002
*** Cloud Cover	-0.668	0.13578	0.00018

Multiple R Squared: 0.841 Adjusted R Squared: 0.788

Model P-Value: 0.000016***

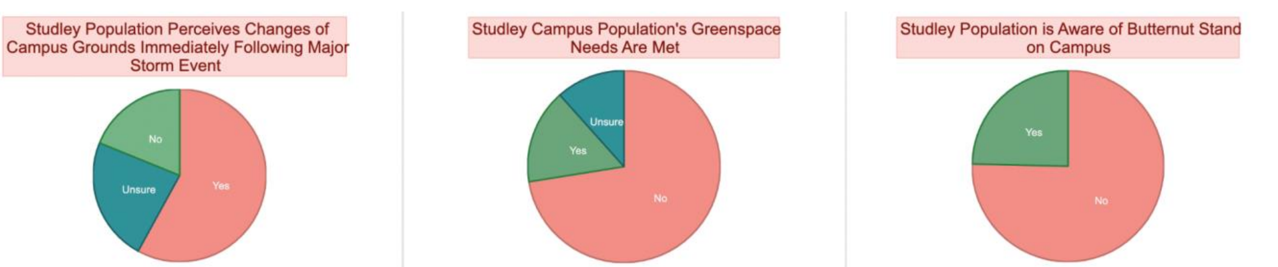
Similarly to our findings with the Garden, we saw that several different weather factors played a significant role on the pH of surface water at the Life Sciences Centre. These variables showed an extremely strong correlation in this location. Small numbers of samples could partially explain this.

<u>Last sites</u>

Unfortunately, the last two sites (Butternut, and Shirreff) did not allow for us to assess the values properly using a regression analysis, this was unfortunately most likely due to user error within the data, as well as low volumes of samples (Appendix). We suspect it is possible that weather would have continued to have a strong impact on surface water pH at the other locations, except for perhaps the Butternut stand (further elaborated in the discussion).

<u>Survey Results</u>

All graphs and depicted survey visuals are generated by **<u>Microsoft Excel</u>**, using a **<u>Google Forms</u>** survey (Appendix, survey) and its corresponding Google Sheets, the data was formatted and input.



A ***B*** ***C***

*Figure 2: (**A**)The Studley population that perceived changes on campus grounds immediately following a major weather event (**B**) It is of importance to understand that the mass population that responded to the survey feel that their needs and expectations of Dalhousie Studley campus' greenspaces have not been satisfied. (**C**) The respondent population that is aware of the species at risk, the butternut tree, is present on Studley campus grounds (appendix, Q20-22).*

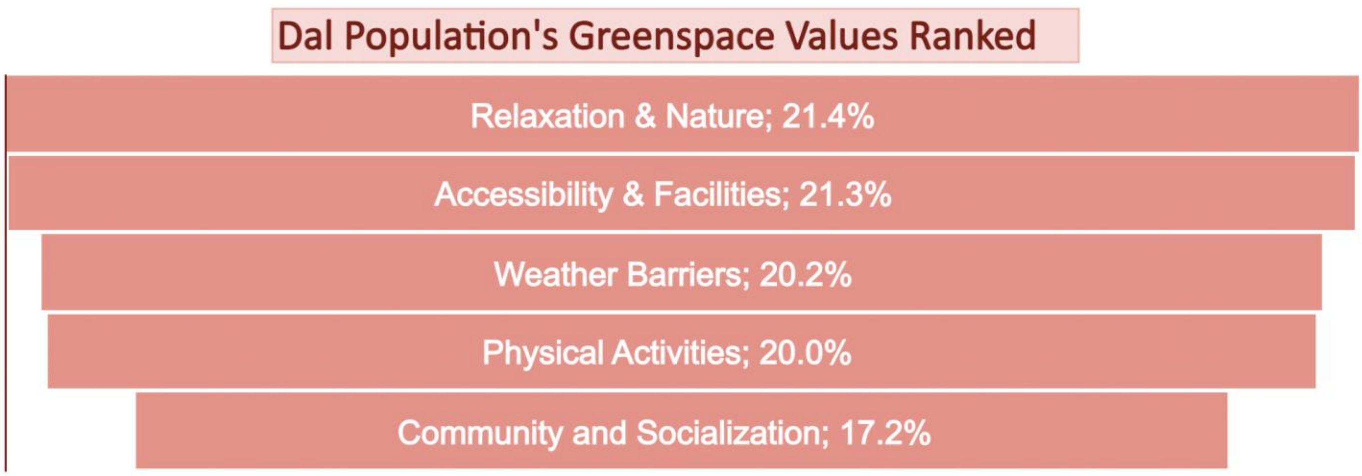


Figure 3: Funnel chart displays a ranking of 5 greenspace features in accordance with the responses of individuals personal values in urban greenspaces (appendix, Q16).

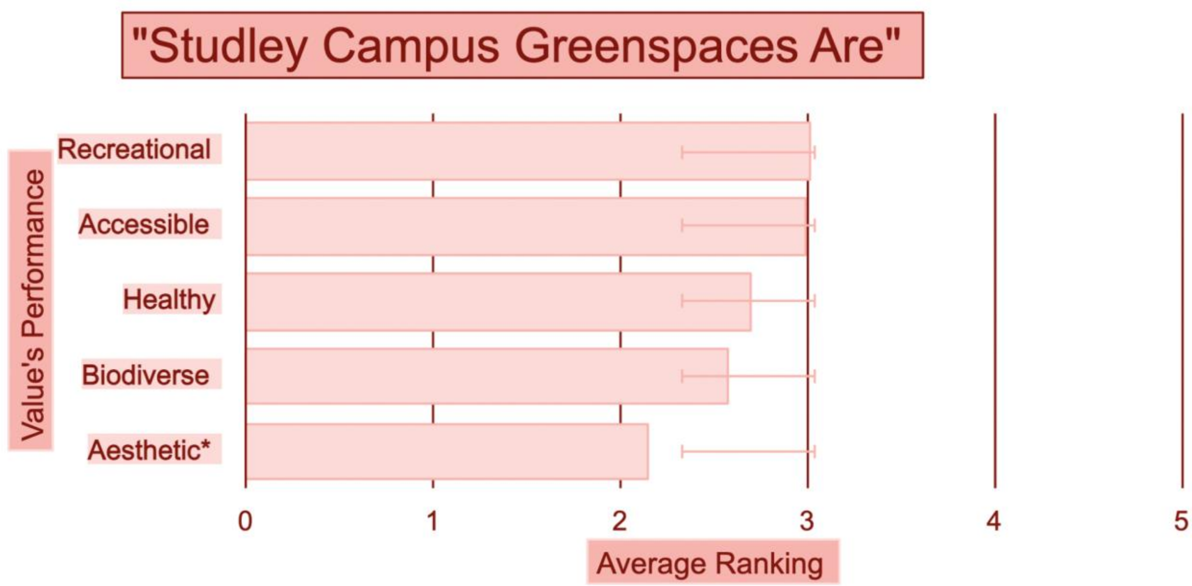


*Figure 4: Bar Graph displays the average rankings of 5 valued qualities of Studley campus greenspace on a scale with a maximum of 5; which indicates a strong agreement that such areas are, in fact, the corresponding value. *This survey question referenced a photo of Ocean Pond so that all respondents may be able to visualize a greenspace and to strengthen relatedness between the collected responses. Ocean pond is also our most tested site (appendix, Q6-10).*

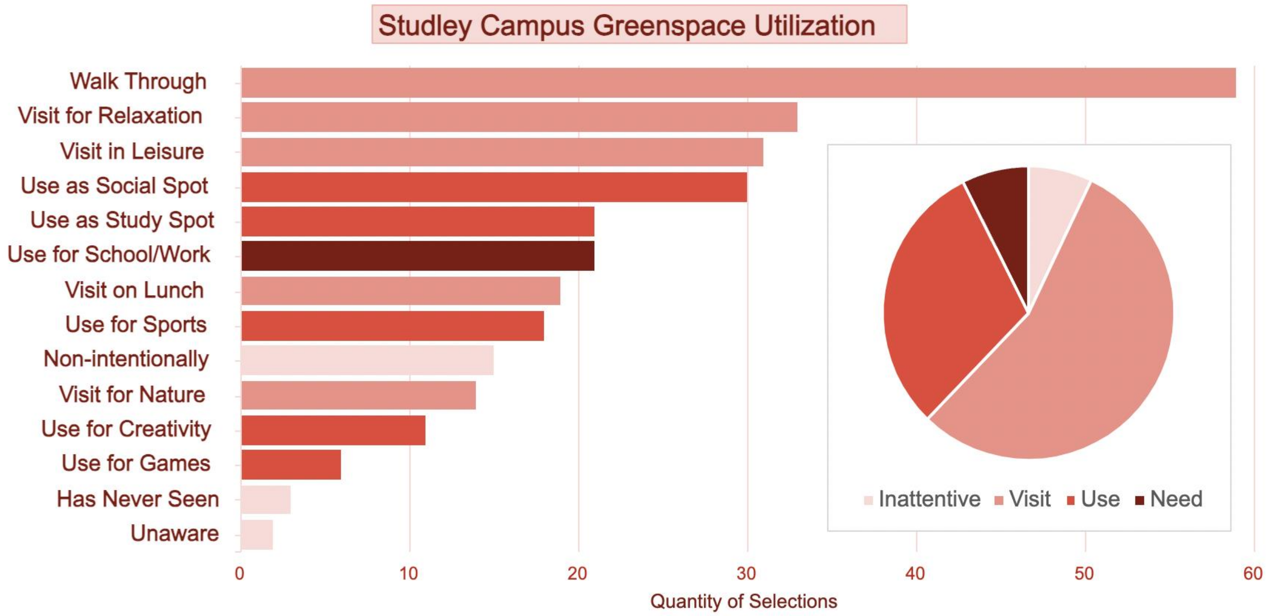
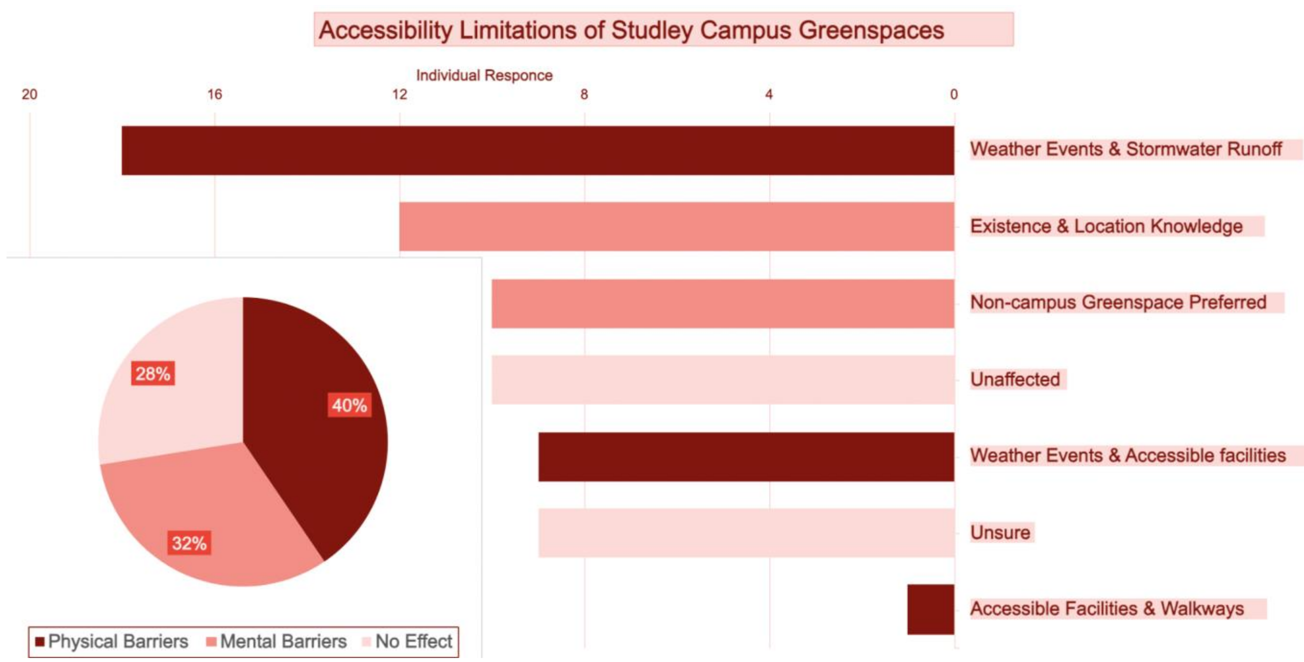
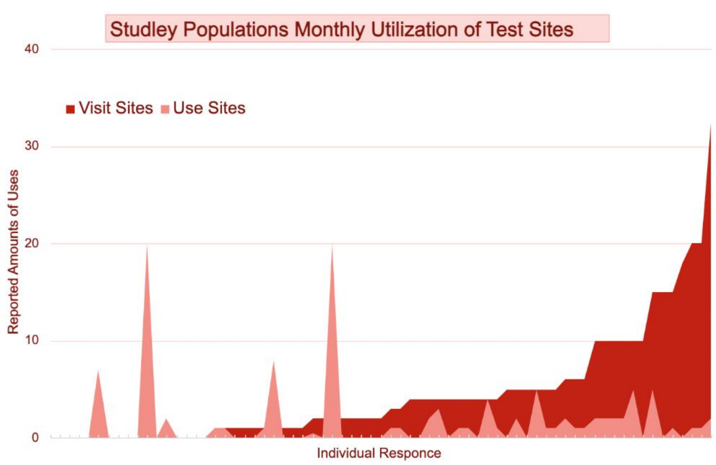


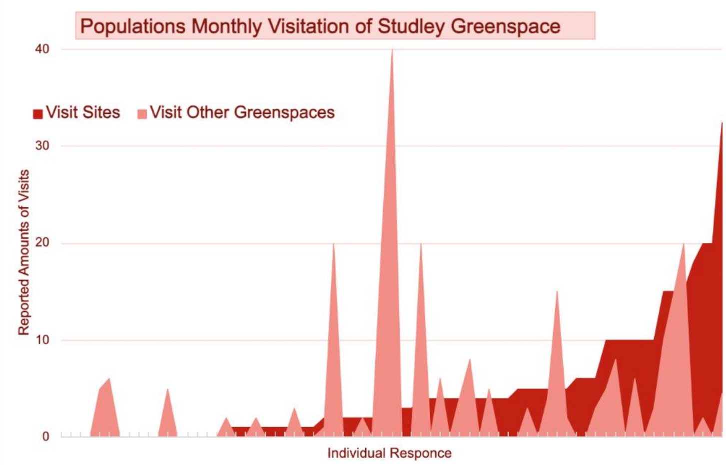
Figure 5: The pielegend summarizes the way in which respondents value such areas by visiting the greenspace, using, needing and displaying inattentiveness towards Studley's natural areas. Proportions are derived from the applicable statements connected to the y-



axis inherently checked off (appendix, Q4).

Figure 6: The pielegend divides respondents into the following three categories; no effect, physical limitations and mental barriers to explain the extent that population accessibility to natural campus space is affected by runoff. Physical accessibility of Studley greenspace in account of stormwater runoff, and practical facilities such as trails, bathrooms, garbage cans and seating. Mental barriers include knowledge of on-campus existence or location and preference of non-campus spaces (appendix, Q19).





A ***B***

*Figure 7: (**A**) The area chart consists of individual responses related to visited sites ordered from least frequent visitation to most frequent visitation on the horizontal axis (appendix, Q11&12). The individuals corresponding response of frequency of site usage is shown in line to show the difference in frequency of studley campus greenspaces. (**B**) this chart follows the same scheme of site visitation visualization, but comparatively the second variable indicates their respective monthly visitation of greenspaces not included in this study (appendix Q11&14).*

Discussion

Overview & Significant Findings

The results of our studies on their own show various levels of correlation between our measurement variables and surface water pH. Through simply the statistics, it may be difficult to understand the most appropriate way by which we can interpret the meanings of these results. By extrapolating specific information that we know about each individual site, many patterns emerge that would align with our beliefs that there are preventative measures that can be put in place that would both a) reduce surface water acidity, and b) improve community perceptions of Dalhousie Studley Campus greenspaces.

Firstly, at the Ocean pond we saw that there was a level of correlation present between drainage systems and surface water pH levels with a 0.01 level of significance. Since we did not see these same correlations at the other sites, we interpreted this to mean that the more natural drainage system (pond) present at the Ocean pond produced more standard pH values than the other sites. This could show that naturalized drainage systems such as bioswales, drainage ponds, etc. When compared to the findings of our survey, we could also assume that implementing and caring for these sites would improve campus biodiversity, reduce surface water acidity, and also improve the currently negative perceptions of campus greenspaces by the Studley community.

The other test sites showed much stronger correlation to a number of weather factors when compared to the Ocean pond, and there are several reasonable explanations for why this could be the case. One possibility is that in comparison to the Ocean pond, these sites have less natural weather barriers such as biodiverse greenery. This could indicate that improved health of weather barriers also improves the general health of surface water present across these sites, as the potentially adverse effects of acid rain, increased UV radiation, etc. are diminished by these barriers (UNCC, 2020). This gives further credence to our suggestion of implementing more naturalized drainage systems within our greenspaces. Another potential explanation for this is that the non-natural forms of stormwater drainage allow for these factors to have more effect than a natural system would. We expect that we would see reduced impacts of weather in the Dalplex Butternut Stand as well as the Ocean pond, as this area is inherently more protected from the elements due the various flora present, a larger study period would help to determine the accuracy of this theory. If this is the case, however, it would confirm our expectation and suggestion that implementing more native biodiversity amidst our greenspaces would have benefits from students mental health (Holt et al., 2019), as well as reduce the adverse effects of climate change on surface water acidity (US EPA, 2023).

The increased effects of weather on surface water pH at all sites other than the Ocean Pond led us to extrapolate that the weather barriers that are already present have reduced potentially negative effects on surface water pH at this site. From this information, we can extrapolate the finding that increased implementation of naturalized weather barriers similar to those at the Ocean pond would reduce surface water acidification, limiting the negative environmental, and social effects that acidification has on campus greenspaces. These findings are also in agreement with the results of our survey.

Survey

The majority of the survey respondents perceived a noticeable difference on Studley campus after a major weather event that resulted in increased surface water runoff, equating to 58% (Figure 2A). Along with Studley population perceptions of whether greenspace needs are met, 15.9% believe their needs have been met. Compared to the 72.4% who declare that they are not satisfied (Figure 2B). The relatedness of the two variables is unknown, but indicate shortcomings in implementation of naturalized areas on campus.

With focus on the following greenspace values of; accessible walkways and facilities, mental relaxation and contact with nature, physical health activities, socialization and community connections, followed by weather barriers; Compared through averaging the population's rankings, the results display a range of 4.2%. The low range reveals a relatively balanced importance of the Studley population's values. Individual responses uniquely varied in a way that equated in all the values being of equal importance to meet the needs of the population (Figure 3). When specifically ranking out of five, the extent of greenspace recreation, accessibility, health, biodiversity, and aesthetics factors, the values yield low to neutral feelings that such areas are, in fact, the corresponding factor (Figure 4). Such notions, combined with the previously stated 72.4% of the population feeling that their greenspace needs have not been met, it can be inferred that if Dalhousie produced improved and established more well rounded greenspaces, that may improve campus and ideally fulfill the potential of positive perceptions.

Studley campus greenspace is utilized most by walking traffic followed by visits for relaxation. Approximately 55% visit greenspace, followed by use, and need, abutted by inattentiveness towards natural areas (Figure 5). Ideally all of the population would feel that "Stormwater runoff does not affect [their] accessibility to campus greenspace, [they] visit anytime [they] want" however, only 10 of 69 ~14.5% respondents actually resonated with such ideologies. Education and improved space upkeep could increase access, and help us achieve the goals of producing no effect on individual accessibility (Figure 6). Said improvements may lead to an increase in overall greenspace utilization. We found that the population's self-reported monthly visitation to any and all greenspace within Dalhousie Studley campus averages to 14.4 times per month, our chosen test sites (Field Methods) allotting to 6.2 visits present within that total. Frequency of responses vary by 32.5 visits/month, the high range accompanied by the assorted points on the area chart (Figure 7), may indicate fluctuating quantities in individual visitation, as the different people surveyed have vastly different schedules, needs, and personal importance regarding greenspace utility.

It is apparent that generally, the population's perception of greenspaces are not entirely positive, and yield mixed feelings at best about their quality. As can be seen from the graphs, accessibility is largely limited by storms and weather events, indicating that something should be done to fix the runoff that interferes with access. As such a precipitation heavy city, reducing weather barriers would be one of the easiest ways for Dalhousie to create better rounded greenspaces and encourage use throughout the entire year for their community. There is also indication that students would appreciate more seating, community and socialization within our greenspaces, something Dalhousie could easily arrange. Our survey indicated that there were relatively negative perceptions of current Studley campus greenspaces, which suggest students' needs are not being met. Implementation of natural drainage systems with improved maintenance and biodiversity could better community perceptions. With further research it could be determined that this would also reduce the impacts of acidification on surface water in the areas.

Limitations

There were several limitations that became apparent within this research both before and after. Scope limitations were understood prior to the beginning of the research process. The specific focus on Dalhousie University Studley Campus may have a relatively low reproducibility factor when considering other campuses in different climates, limiting the applicability of the findings. Conducting a comprehensive assessment of stormwater management practices and community perceptions requires a larger time frame for exhaustive data collection. Limited time may have impacted the depth of data collection and analysis. Data related to stormwater management practices and historical surface water quality may be limited considering the relative size of Studley Campus compared to the HRM.

Within survey data collection there is a potential for sampling bias as the primary method of distribution was social media. The survey having been posted on the researcher's personal accounts means that the majority of the survey participants have a personal connection to the researchers. Within the results it also became apparent that ~50% or more of the participants were affiliated with the environmental science program in some capacity. Community member's responses to the survey may have been influenced by social desirability bias or their level of awareness about green space and stormwater practices specific to Dalhousie Studley Campus. The survey provides no benefits or incentivization to the 69 participants, producing a partial barrier to the response goal of 377 persons. This resulted in a less accurate representation of the selected community.

External factors such as weather conditions, construction activities and other environmental changes during the study influenced the outcomes related to surface water quality and community perceptions. The winter months lead to inconsistent weather patterns and a potential freezing or loss of surface water. This can lead to difficulties at field sites for collection samples. For example, lack of rain during sampling meant inconsistent testable areas at some times. Limited access to funding, equipment or expertise in specific areas of study (i.e. water quality analysis, stormwater management practices) may have restricted the researcher's ability to gather robust data.

Future Directions for Research

Despite the limitations present, there are lots of future directions that could potentially be explored regarding the connections that seem to be present between stormwater management practices, climate and the problematic nature of both surface water acidity & the community's rather negative feelings toward the current status of Studley's greenspaces. As we have indicated, a lack of expensive technology along with time have been one of our most significant barriers to accomplishing our research goals, however, we believe that with the findings that we were able to discover through our short term research, that this topic deserves a larger examination from those who have actual access to these financially straining types of equipment. We suggest that this research is continued by testing these factors over a longer period of time, with specific test equipment and sensors for other forms of contaminants and qualities, as well as an analysis of the effects of weather barriers on surface water pH.

It is within our best interest as members of the community to try and amplify attempts to better our ecological systems. This is why we think continuation of this research would be paramount, as it has the ability to improve community wellbeing, as well as ecological health of campus greenspaces. In conjunction with this research, we suggest the implementation of more biodiverse, naturally formed drainage systems such as the Ocean pond, bioswales, etc. This would have the ability to improve community perceptions of greenspace, but also improve the overall health of greenspaces and surface water across Studley Campus. We also believe that implementation of these systems would improve upon weather barriers, which could have the ability to reduce the effects of several climate factors on surface water pH.

Conclusion

We began our research to determine whether there was a possibility of an existing correlation between certain stormwater management systems and increasing acidity of surface water on Dalhousie's Studley Campus. We feel conclusively that this is research that deserves further exploration, as the potential correlation that we have seen through our statistical analyses, when combined with negative thoughts of campus greenspaces and negative connotations of decreasing pH in surface water of urban spaces (European Environment Agency, 2016), indicates that there is a possible way that we can reduce these severe issues by applying more natural forms of stormwater drainage across urban landscapes, and in particular, university campuses.

Acknowledgements

Special thanks to **Dr. Caroline Franklin & Madeline Healy** who assisted our research in numerous ways, corrected early mistakes, showed genuine interest in our work, and were quick to lend a hand throughout this whole process. We would also like to acknowledge all our survey respondents, and especially those who chose to share it to their peers and students.

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Appendix

Samples Collected per site

Ocean Pond	Pollinator Garden	LSC	Shirreff Woodland	Butternut Stand
72	18	26	17	7

Average measured variable Values Per Site

Variable	Ocean Pond	Pollinator Garden	LSC	Shirreff Woodland	Butternut Stand	Total
pH	7.03	6.66	6.91	6.89	7.0	6.94
Depth (cm)	7.03	2.46	2.11	1.41	1.38	4.74

Daily Weather

Day #	Temp	RealFeelTemp	MaxUV_Index	Wind_KmH	CloudCover	Hourly_precip	Daily_precip
1	4	-1	1 Low	30	100	4	40
2	1	-9	1 Low	37	98	0	0
3	9	5	3 Moderate	15	10	0	0
4	1	-6	1 Low	28	100	0-1	38
5	2	-4	0 Low	19	100	0.1	7.50
6	4	2	2 Low	25	82	0	0
7	2	-5	1 Low	28	95	0	0
8	2	-2	1 Low	28	95	0	1
9	3	2	1 Low	11	100	0.1	1.2
10	7	11	3 Moderate	20	32	0	0
11	2	-4	1 Low	22	100	5.1	5.1
12	3	6	2 Low	29	71	1	2

Survey: Greenspace Utility

While respecting the consent and anonymity of participants, the intention of this 23-question survey is for our research team, Jenna Dietrich, Joe Cooper, Madisyn Richards, Mads Milligan, and Rui Pu;

To investigate and understand any correspondences between our considered study on quality of local surface water runoff and the Dalhousie University populations accessibility, utility, and values regarding healthy greenspaces on Studley Campus. This is to help us with our goal of determining the correlations that may exist between surface water pH and turbidity, and the current stormwater management practices that Dalhousie is using across Studley Campus.

Please limit yourself to one response per person. All submissions are final so please answer carefully, you will be unable to edit after you submit.

Your participation in this survey matters. Accordingly, thank you for contributing your time and thoughts to our study, our team abundantly appreciates it.

Any questions or concerns may be directed by email to our Pollster,
Madisyn Richards
She/Her
Md545860@dal.ca

Continue to Next Section

Indicate Consent By Continuing To The Survey

You are invited to take part in a research study being conducted by Joe Cooper, Madisyn Richards, Madeleine Milligan, Jenna Dietrich and Rui Pu, undergrad students in the Department of Environmental Sciences at Dalhousie University. The purpose of this research is to investigate stormwater drainage systems and greenspaces on Dalhousie's Studley campus. Participants include anyone who is a Dalhousie University student or faculty member and visit Studley campus at least one day a week.

If you choose to participate in this research, you will be asked to answer 23 questions in an online anonymous format to the best of your ability. The questions will be regarding the topic of surface water runoff and how it affects your accessibility and enjoyment of on campus greenspace. The survey should take approximately 7-10 minutes.

Your participation in this research is entirely your choice. You are welcome to stop the survey at any time if you no longer want to participate. All you need to do is close your browser. We will not include any incomplete surveys in our analyses. If you do complete your survey and you change your mind later, I will not be able to remove the information you provided as I will not know which response is yours.

Your responses to the survey will be anonymous. This means that there are no questions in the survey that ask for identifying details such as your name or email address. All responses will be saved on a secure Dalhousie server. Only our research team will have access to the survey results.

We will describe and share general findings of this research in a final research paper and presentation. The research team will not be keeping the anonymous survey information, we will destroy all information one month after reporting the results.

The risks associated with this study are no greater than those you encounter in your everyday life.

There will be no direct benefit to you in participating in this research. The research, however, might contribute to new knowledge on the effect of excess acidity in surface water runoff on the overall health of greenspaces on Dalhousie Studley campus.

You should discuss any questions you have about this study with members of the research team, Joe Cooper, Madisyn Richards, Madeleine Milligan, Jenna Dietrich, or Rui Pu. You can also reach out to the professor supervising this research, Caroline Franklin. Please ask as many questions as you like before or after participating. The teams contact information in the same order as above js525124@dal.ca, md545860@dal.ca (289-990 9953), md992021@dal.ca , jn500721@dal.ca, rz427977@dal.ca. You can reach Caroline Franklin at caroline.franklin@dal.ca.

This research was approved by the Department of Earth and Environmental Sciences.

Continue To Next Section

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1. How are you connected to Dalhousie University? Check all that applies to you.
a) Faculty
b) Staff
c) Student
d) Alumni
e) Other:____________

2. If "Student" was chosen as the previous response, please indicate your degree program.

3. With which of the following statements do you most closely relate?
Greenspace: an area of grass, trees, or other vegetation set apart for recreational or aesthetic purposes in an otherwise urban environment. (Oxford Languages)
a) I am educated and engaged in on-campus sustainability and greenspace management.
b) I am educated on the importance of campus greenspaces.
c) I use on-campus greenspace but am not educated on sustainable greenspaces.
d) I visit on-campus greenspaces occasionally, but don't think about them much.
e) Dalhousie University's Studley campus has greenspaces?!?
f) What is a greenspace? (Revisit definition above options, then select if still applicable)

4. How valuable are Dalhousie Studley campus greenspaces to you?

Visit, in this context is, to go or come to see (a person, place, etc.). To Use is to put into service or action; employ for a given purpose. (Collins Dictionary)
Please select all statements that apply to you, to help us understand your general Studley greenspace perceptions.
a) I didn't know Studley campus had greenspaces till this survey.
b) I knew they existed but have never seen greenspace while on Studley campus.
c) I know Studley campus has greenspaces, but don't intentionally visit or use them.
d) I walk through campus greenspace on my way to class/work/ extracurriculars, etc.
e) I visit greenspace in leisure
f) I visit to see the plants, animals, insects, and other nature that Studley campus greenspace can offer.
g) I visit the greenspace for mental relaxation or a quiet outdoor break.
h) I visit the greenspace on lunch break or other eating intermissions.
i) I use the greenspace as a studying space.
j) I use the greenspace as a place of creativity for arts such as writing, reading, photography, drawing, dancing.
k) I use the greenspace as a place to play non- physically active games.
l) I use the greenspace to exercise or for sports games.
m) I use the greenspace to socialize and connect with others.
n) I use the greenspace in (some of) my class(es), jobs or extracurricular(s).
o) Other: _____

5. Rank the following 4 photos of selected Dalhousie's greenspaces pictured below, in order of: 1=most to 4=least, in relation to the spaces you use or visit most.
Options to fill blanks: 1, 2, 3, 4
___ Ocean Pond: beside Howe parking lots feeding street, Castine Way. Chemistry building pictured in the distance.
___ Pollinator Garden: located on the north side of the Henry Hicks Building.
___ LSC Biology Wing Level 2 Entrance: this greenspace offers frisbee golf and paths leading towards Kings campus.
___ Shirreff Hall Woodland: One of the largest greenspaces, nestled between Shirreff Hall and the Ocean Sciences building.

6. Indicate your degree of agreement with the following statement:
"I believe Dalhousie University Studley Campus has accessible greenspaces"
(i) Strongly Agree (ii) (iii) (iv) (v) Strongly Disagree

7. Indicate your degree of agreement with the following statement:
"I believe Dalhousie University Studley Campus has recreational greenspaces"
(i) Strongly Agree (ii) (iii) (iv) (v) Strongly Disagree

8. Indicate your degree of agreement with the following statement:
"I believe Dalhousie University Studley Campus healthy greenspaces"
(i) Strongly Agree (ii) (iii) (iv) (v) Strongly Disagree

9. Indicate your degree of agreement with the following statement:

Biodiverse is biological diversity in an environment as indicated by numbers of different species of plants and animals.
(Collins dictionary)
"I believe Dalhousie University Studley Campus has biodiverse greenspaces"
(i) Strongly Agree (ii) (iii) (iv) (v) Strongly Disagree

10. How would you personally rate the aesthetic quality of this Studley Campus greenspace on a Scale of 1-5?
(Ocean Pond behind Howe parking lot and in front of the pictured Chemistry building)
(i) makes me want to breakdown crying (ii) (ii) (iiv) (v) makes me want to cry tears of joy

Recall Definitions:
Visit, in this context is, to go or come to see (a person, place, etc.). To Use is to put into service or action; employ for a given purpose.
(Collins Dictionary)

11. On average, how many times per month do you think you visit the greenspaces photographed in the previous questions?
(Please respond with an approximate number answer, ex. 0, 2, 12….)

12. AND, on average how many times per month do you think you use the greenspaces photographed in the previous question?

13. Are you aware of greenspaces not photographed above AND that are within Studley Campus, Dalhousie University?
a) Yes
b) No
c) Unsure

14. If "YES", was selected for the previous question:
On average, how many times per month do you think you visit such areas?
(Please respond with an approximate number answer, greenspace not previously pictured, on Studley campus)

15. AND, on average how many times per month do you think you use such areas?

16. Rank the following, in orders: 1= most important, to 5= least important, in relation to what you personally value in urban greenspaces.
Options to fill Blanks: 1, 2, 3, 4, 5
__Accessible walkways and facilities (paved walkways, toilets, concession, dog park…)
__Mental relaxation and contact with nature (meditation, birdwatching…)
__Physical health activities (walking, jogging, fertility benefits…)
__Socialization and community connections
__Weather barriers (natural shade, wind, or rain protection…)

17. Considering all personally known greenspace(s), within the bounds of Dalhousie Universities-Studley Campus, how satisfied or dissatisfied are you with the general quality of such areas?
Please be sure to explain the reasoning behind your thoughts.

18. Considering all personally known greenspace(s), within the bounds of Dalhousie Universities-Studley Campus, how satisfied or dissatisfied are you with the general quantity of such areas?
Please be sure to explain the reasoning behind your thoughts.

19. To what extent does the stormwater runoff, effected by Dalhousie University's current surface water management infrastructure, affect your accessibility to campus greenspaces?
Stormwater runoff is the runoff drained into creeks, bays, and other water sources after a storm. Stormwater runoff includes all debris, chemicals, and other pollutants picked up by the rain or snow.
(National Geographic Society, 2023)

Please select the following statement to which you most closely relate:

a) Stormwater runoff does not affect my accessibility to campus greenspace, I visit anytime I want.
b) Stormwater runoff does not affect my accessibility to campus greenspace, but I prefer the mental relaxation and contact with nature in non-campus greenspaces.
c) My accessibility of campus greenspace is limited in times of weather events that result in stormwater runoff.
d) My accessibility of campus greenspace is limited by presence of accessible walkways and facilities.
e) My accessibility of campus greenspace is limited by my knowledge of their existence or where they are.
f) Both c and d

g) Unsure.

20. Do you notice a difference in greenspaces on campus following a major storm event?

a) Yes
b) No
c) Unsure

21. Overall, do you think your greenspace needs on Studley campus have been met?

a) Yes
b) No
c) Unsure

22. Did you know that an area on Studley campus holds a stand of Butternut trees (Juglans cinerea)?
Indicate by selecting YES or NO.
Butternut (Juglans cinerea) is an endangered species in Canada and listed under the federal Species at Risk Act. There has been a significant decline in butternut populations due to the fungal disease butternut canker.
(2024 Nature Conservancy of Canada)

a) Yes
b) No
c) Unsure

23. From your perspective, what amenities do you believe could be added to the Butternut tree stand greenspace, to increase personal value of the space?

Submit

Photo Attached to:

Q5

Q10

Q2