The public perception of urban stormwater ponds as environmental amenities

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Abstract

Integrating green or blue space into cities can provide environmental and public health benefits which maximize urban sustainability. One type of green/blue infrastructure that has been understudied is urban stormwater ponds, which are used to manage stormwater runoff. Their performance is typically only evaluated in terms of hydrological functions, with little focus on their capacity to provide ancillary benefits to communities. In this exploratory study, an online survey was distributed to six neighbourhoods in the City of Ottawa, ON to gain insight into the social value of urban stormwater ponds. The results revealed that despite some disadvantages, most respondents visited their neighbourhood stormwater ponds regularly and largely appreciated the cultural ecosystem services provided by these ponds, such as opportunities for experiencing nature, especially wildlife, and outdoor recreation. These findings can be used to improve the multifunctionality of stormwater ponds and optimize both environmental and social sustainability outcomes.

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1 Introduction

Half of the global population lives in urban areas, and this proportion is expected to increase in the coming decades (United Nations, 2018). While people living in cities may have more access to economic opportunities and services than their rural counterparts, urban dwellers are also exposed to unique environmental and health hazards associated with urban environments. Air, noise, light, and odour pollution; high temperatures that contribute to the Urban Heat Island (UHI) effect; pervasive flooding; and high volumes of solid waste are common issues that can threat the health and well-being of urban populations (Moore et al., 2003). Additionally, urban dwellers can experience higher levels of stress due to high congestion, overcrowding, and the “hustle and bustle” associated with city life (Moore et al., 2003). As cities expand, it is important to include design and planning elements that maximize the health and well-being of urban communities.

There is a growing recognition amongst urban planners and health professionals that integrating green space into urban areas enhances the resilience and sustainability of urban communities (Kondo et al., 2018; Markevych, 2017; Sussams, 2015). Green space is undeveloped land consisting of permeable surfaces and natural vegetation, which can exist in many forms such as parks, gardens, or tree-lined streets. Urban green space can provide many important societal benefits that improve the health and well-being of urban residents, including providing spaces for socialization, immersion in nature, physical activity and relaxation (Markevych et al., 2017). Green space can also help mitigate the threat of extreme temperatures, air, noise, and water pollution, and flooding (Markevych et al., 2017). Additionally, green space within a developed area can support urban biodiversity by providing habitat for wildlife (Brunbjerg et al., 2018). However, the benefits offered by urban green space largely depend on their location, design, and composition (Sander and Zhao, 2015). Thus, city planners and decision-makers need to consider the structure, function, and location of urban green space for these spaces to meet combined social-environmental objectives.

Much of the research on the social benefits of the naturalization of cities has focused on urban green space. Fewer studies have focused on the impacts of urban "blue space," which can be defined as "outdoor environments – either natural or manmade – that prominently feature water and are accessible to humans either proximally (being in, on, or near water) or distantly/virtually (being able to see, hear, or otherwise sense water)" (Grellier et al., 2017). Access to water is a major feature of most large cities, with a large proportion of them being situated by water and reliant on an extensive network of blue infrastructure. An example of blue infrastructure that has become widely implemented are stormwater ponds. Stormwater ponds are end-of-pipe stormwater management facilities characterized by having a permanent pool of water. In Canada, the use of stormwater ponds is considered a best practice for stormwater management (Moudrak and Feltmate, 2019) and may even be a requirement for new urban developments (MECP, 2003). These ponds are designed to collect runoff and remove contaminants, and can provide other secondary services, such as contributing to local biodiversity (Semerano et al., 2015). While there are clear motivations for stakeholders like developers and city planners to include stormwater ponds in new developments, the views of residents living near these ponds are poorly understood (Bastien et al., 2011). It is important to capture the perspectives of residents living near stormwater ponds to reveal if they can provide ancillary benefits to neighborhoods in addition to their intended infrastructural purpose. Moreover, negative perceptions of stormwater ponds can have implications for their use and design as developers attempt to maximize the appeal of new neighborhoods.

Using an exploratory approach, I set out to determine if stormwater ponds have the capacity to provide cultural ecosystem services to surrounding communities by answering the following research questions: (1) are urban stormwater ponds perceived positively or negatively by surrounding communities, and (2) what attributes of stormwater ponds contribute to residents' use and enjoyment of these facilities? To answer these questions, I distributed an online survey to residents living in six rapidly growing neighborhoods in the City of Ottawa, Canada, where the use of stormwater ponds is a standard practice for newly constructed developments. My study contributes novel research to this field, as the capacity of stormwater ponds to provide social benefits to communities has not been thoroughly assessed. Additionally, blue space studies have mostly occurred in European countries (Gascon et al., 2017), indicating the need for a Canadian perspective. The results of this study will reveal insights into the public's perception of the benefits of urban stormwater ponds, which can then be used by planners and decision-makers when designing these systems to improve their multifunctionality and optimize their environmental and social sustainability outcomes.

2 Literature review

2.1 Urban green space

The body of work acknowledging the societal benefits of green space in cities is extensive, recognizing a variety of ecosystem services provided by these spaces to surrounding communities (Table 1). Integrating green space into the urban landscape can work to counteract many of the environmental problems associated with built-up environments, including flooding, extreme temperatures, biodiversity loss, and pollution. The prevalence of impervious services, coupled with an increase in precipitation, has made flooding a growing concern for cities around the world. This issue is highly relevant for this study area, as the National Capital Region has experienced two 100-year floods in the past three years (Dangerfield, 2019). While traditional flood management is focused on increasing the capacity of existing grey stormwater infrastructure and relief measures such as sandbagging, the strategic use of green space is increasingly recognized as an effective strategy for flood control (Alves et al., 2019). One model showed that integrating various types of green infrastructure into an urban community can reduce the volume and peak flow of stormwater runoff by more than 85% over a 10-year period (Liu et al., 2014). In addition to managing the quantity of stormwater runoff entering waterways, green space can also improve the quality of runoff by filtering out nutrients such as nitrogen and phosphorous, protecting water bodies from eutrophication and harmful algal blooms (Yang et al., 2015).

Table 1. Examples of ecosystem services provided by urban green space (adapted from Niemela et al., 2010; Moore and Hunt, 2012).

Group	Ecosystem service	Description	Reference
Provisioning services	Water purification	Reduces pollutant/nutrient concentrations in runoff, protecting water bodies from eutrophication which can threaten drinking water supplies	Yang et al. (2015)
	Food	Green space such as community gardens can provide food to local communities	Russo et al. (2017)
Regulating services	Hydrologic functioning	Flood reduction by regulating the volume and peak flow of stormwater runoff	Liu et al. (2014)
	Air pollution mitigation	Reduces air pollution through filtration and absorption of particulates by vegetation and soils	Kumar et al. (2019)
	Carbon sequestration	Atmospheric CO_2 removed by urban vegetation	Nowak et al. (2013)
	Microclimate regulation	Provides cooling effects to mitigate UHI effects; stabilizes city air temperatures year-round	Saaroni et al. (2018)

	Habitat provision	Provides habitat to promote urban biodiversity/species richness; acts as stepping-stones for migratory species	Müller et al. (2018)
	Pollination	Enhances the species richness of important pollinators	Brunbjerg et al. (2018)
Cultural services	Recreation	Provides space for outdoor activities which promotes physical health	White et al. (2019)
	Psychological health benefits	Promotes relaxation; reduces stress levels and improves psychological health and well-being	Cheesebrough et al. (2019)
	Community building	Provides opportunities for socialization that can help build a sense of community	Kazmierczak (2013)

Urban greening can also help mitigate the urban heat island (UHI) effect, a condition of cities that experience warmer temperatures than surrounding rural areas as a result of built infrastructure and human activities (Xiao, et al., 2018). The UHI effect is caused by a combination of factors, including the high heat absorption of dark surface materials such as concrete and asphalt, the obstruction of wind by tall buildings, and the concentration of heat-producing activities such as driving cars (Wang et al., 2016). Cities can be on average 1.0 to 6.0°C warmer than surrounding rural areas as a result of the UHI effect (Dimoudi et al., 2013). Green space is often used as an intervention to minimize the UHI effect in cities and protect urban communities from heat-related mortality and morbidity (Saaroni et al., 2018). Dang et al. (2018) produced a model for Ho Chi Minh City, Vietnam, estimating that a 1 km^2 increase in green space for every 1000 people can prevent 7.4 heat-related deaths. Additionally, urban greening has the potential to stabilize ambient temperatures in cities year-round, which could reduce the amount of energy consumed for heating and cooling (Chun and Guldmann, 2018).

Green space can also be used to combat biodiversity loss in cities. Higher urban green space area is associated with higher species richness across multiple taxa, suggesting that urban green space supports urban biodiversity (Brunbjerg et al., 2018; Müller et al., 2018). Brunbjerg et al. (2018) found that small patches of green space (100 to 250 m) may enhance richness for important pollinators like bees and hoverflies. Another study demonstrated that urban green roofs can provide habitat for migrating and breeding birds and their prey (Partridge and Clark, 2018). In addition to being a determinant of the ecological health of urban areas, urban biodiversity has been positively associated with the psychological well-being of residents (Wood et al., 2018). These studies suggest that biodiversity is a key element that should be considered by planners when designing urban green space, as high species richness can provide both ecological and public health benefits to cities.

A few studies have examined the CO_2 sequestration potential of urban green space, although this undertaking is challenging as the carbon budget can be highly site specific and must consider the CO_2 emissions resulting from the site's construction and maintenance (Strohbach et al., 2012). A few studies have conducted large-scale estimates of the carbon sequestration contribution of urban green space. For example, Nowak et al. (2013) estimated that urban tree cover in the United States sequesters a net 18.9 million tons of carbon annually, equaling $1.5 billion USD per year (Nowak et al, 2013). Comparatively, a study by Chen (2015) estimated the total carbon sequestration from green infrastructure across 35 major Chinese cities to be 1.90 million tons in 2010, offsetting 0.33% of the CO_2 emissions produced by these cities. While these estimates suggest the sequestration potential of urban green space may only have minor impacts on a national and global scale, other evidence suggests that urban green space can play an important role in offsetting localized emissions (Niemela et al., 2010). For instance, Chen (2015) found that the green space in the city of Haikou, China, offset 22.45% of the city's total carbon emissions. Further studies quantifying the carbon sequestration potential of urban green space are needed, as current estimates may be undervaluing the carbon sequestration contribution of urban ecosystems (Davies et al., 2011).

Air pollution is a major problem in cities, with the World Health Organization (WHO) estimating that 80% of the global urban population live in cities exceeding air quality guideline levels (WHO, 2019). Major sources of air pollution are traffic, which accounts for 25% of global ambient particulate matter, followed by unspecified human activities (22%), domestic fuel burning (20%), natural sources (18%), and industrial activities (15%) (Karagulian et al., 2015). Green space is one potential intervention use to combat air pollution in cities. Green space can improve air quality due to the deposition and/or absorption of airborne pollutants by trees and other vegetation (Kumar et al., 2019). From a Canadian perspective, Nowak et al. (2018) estimated that urban trees in 86 Canadian cities removed 16,500 tonnes of air pollution in 2010, an estimated public health value of $227.2 million CAD.

Improving air quality is just one of the many public health benefits provided by urban green space (Kondo et al., 2018; Markevych, 2017). Studies have reported that populations with access to green space have a lower incidence of high blood pressure, diabetes, and cardiovascular disease (Richardson et al., 2013; Twohig-Bennett and Jones, 2018). Individuals living close to green space also have better self-reported mental health and lower stress levels compared to those with limited access to green space (Thompson et al., 2016; van den Berg et al., 2015). Additionally, access to green space can increase neighborhood satisfaction, which has shown to be positively related to well-being (Zhang et al., 2017). Green space can also provide residents with space for physical activity and recreation, which is important for maintaining a healthy lifestyle (Ambrey, 2016). A UK study reported that individuals who spend a minimum of 120 minutes per week in nature for recreation have better self-reported health and well-being compared to those who spend less time in nature (White et al., 2019). Urban green space also presents an opportunity for relaxation, reflection, and immersion in nature, which many consider a therapeutic escape from stressful city life (Cheesebrough et al., 2019). Tree cover in urban neighbourhoods can mitigate noise pollution from traffic, with positive outcomes for the mental health of residents (Dzhambov et al., 2018). Additionally, urban green space can provide opportunities for social interactions that may help build a sense of community (Kazmierczak, 2013).

Given the range of environmental and health benefits offered by urban green space, many experts consider the use of green space to be an important strategy for climate change adaptation in cities (Sussams et al., 2015). As global temperatures increase and extreme weather events become more frequent, severe, and unpredictable, green space can play an important role in mitigating the impacts of climate change and improving the resilience of cities. However, it is important for planners and decision-makers to acknowledge and address various barriers that may limit the success of urban green space as a tool for climate change adaptation. First, studies have shown that the type and quality of green space can influence the degree of benefit provided by the space (Müller et al., 2018; Reid et al., 2017; Zhang et al., 2017). For instance, Reid et al. (2017) showed that self-reported health was higher for residents living near green space with trees present, compared to the health of those living near green space with grass. Zhang et al. (2017) reported that residents living in a neighborhood with higher green space quality in terms of accessibility and usability had higher neighborhood satisfaction compared to residents in neighborhoods with lower green space quality. When examining biodiversity, Müller at al. (2018) showed that urban woodlands had higher species richness compared to parks and gardens. One strategy used to maximize the benefits of individual green spaces is to improve their multifunctionality, which is their capacity to successfully provide multiple ecosystem services (Hansen et al., 2019). However, confusion amongst stakeholders surrounding the concept of multifunctionality has made this approach challenging to implement successfully, potentially leading to trade-offs in the design of green spaces resulting in a non-optimal outcome (Sussams et al., 2015). Therefore, it is important to establish a clear link between green space features and their potential ecosystem services in order for planners to be able to select design elements which maximize the benefits offered by these limited areas (Belmeziti et al., 2018).

A second barrier that may limit the effectiveness of urban green space for improving the sustainability of cities is the inequitable distribution of green space within an urban area. Neighborhoods that are predominantly white and affluent tend to benefit from more green space compared to low-income neighborhoods and communities of colour (Wolch et al., 2015). The lack of green space in disadvantaged neighborhoods has public health implications, as these communities are often the most vulnerable to health challenges (Friel et al., 2011). While introducing green space to low-income neighborhoods may serve to benefit the health of these communities, it may also lead to 'green gentrification' whereby low-income communities are displaced by more affluent groups who are attracted to the increased greening and livability of the neighborhood (Wolch et al., 2015). Therefore, to maximize the sustainability of urban green space, it is important to consider socio-economic implications when deciding the location of urban green spaces to prevent exacerbating social inequalities.

2.2 Urban blue space

While the literature on the societal benefits offered by urban green space is extensive, these studies tend not to include water systems, such as lakes, rivers, and wetlands, in their investigation. To address this absence, a body of work focused on the unique benefits of water bodies and other forms of blue space in urban landscapes has emerged in recent years. The results of these analyses indicate that blue space offers many of the same societal benefits as green space, and may even have a greater positive effect on the well-being of urban communities as people tend to prefer landscapes that feature water (White et al., 2010; Volker and Kistemann, 2011). For instance, respondents to a survey conducted by White et al. (2010) considered built and natural environments containing water to be better suited for mental restoration compared to those without water. This survey also reported that built environments with water elicit a similar positive response as natural green space (White et al., 2010). A study in Beijing found that metropolitan residents valued urban blue areas (rivers, lakes, and wetlands) 4.3 times more than urban forests and 10.5 times more than grasslands (Dou et al., 2017). Blue space may offer several of the same direct mental and physical health benefits as green space by providing urban communities with opportunities for contemplation, restoration, socialization, and physical activity (Volker and Kistemann, 2015; Volker and Kistemann, 2013). Additionally, preliminary studies suggest that blue space may also offer similar indirect health benefits as green space, such as masking traffic noise (You et al., 2010) and mitigating high summer temperatures (Volker et al., 2013). However, it is important to note that while urban blue space may offer many of the same benefits as urban green space, urban blue space also presents unique health hazards that may influence the public's opinion of these spaces. Water bodies provide habitat for vectors of diseases, such as mosquitoes, and can be a source of exposure to waterborne diseases such as cholera and giardia (von Döhren and Hasse, 2015). The presence of water itself presents a drowning risk, and water level changes may lead to flooding which can cause property and infrastructure damage. Further investigation is needed to determine if and how these potential safety risks influence the public's opinion of urban blue space.

Despite promising early research illustrating the positive impacts of blue space on urban communities, there is a need for additional evidence which advances our understanding of the relationship between blue space and health (Gascon et al., 2017; Grellier et al., 2017). A systematic review of the urban blue literature indicates that a majority of studies have focused on coastal water bodies, with few studies dedicated to inland freshwater systems (Gascon et al., 2017). This tendency illustrates a need for studies that focus on various inland freshwater systems, including, lakes, rivers, wetlands, and engineered water systems. Additionally, most of the blue space studies have taken place in European and/or high-income countries with temperate climates, therefore more literature is needed from a broader range of countries showcasing diverse climates and socioeconomic conditions. This study will address some of those gaps by (1) providing a Canadian perspective, which is notably absent in the blue space literature and (2) focusing on constructed stormwater ponds, which have been largely excluded from blue space studies.

2.3 The use of stormwater ponds in Ontario

Prior to the 1990s, the focus of stormwater management in Canada was on controlling the volume and flow of runoff events to minimize stress on the sewer infrastructure and reduce flooding (Watt et al., 2003). Since then, stormwater management practices have evolved to become more comprehensive as impacts on water quality became a growing concern. Stormwater ponds were first used in the 1970s and ’80s to store runoff and minimize flow rates (Watt et al., 2003). In recent years the use of stormwater ponds has become a best management practice as their design has been adapted to address multiple objectives, including improving water quality, erosion control, and reducing peak flows. In Ontario, stormwater ponds are the most widely used stormwater management facility installed at sewer outlets (MECP, 2003). The design standards of stormwater ponds in Ontario are mandated by Ontario's Stormwater Management Planning and Design Manual. Stormwater ponds in Ontario require a minimum drainage area of 5 ha, with a preferred drainage area of at least 10 ha (MECP, 2003). Modern stormwater ponds have a forebay at their inlet where the flow of water is slowed allowing contaminants and nutrients to settle out into the sediment (Figure 1). The size of the pond depends on the percent imperviousness of the surrounding landscape but must have a volume, which allows for the removal of 80% of the suspended solids over 24-hour period (MECP, 2003). Ontario guidelines for the design of stormwater ponds and other end-of-pipe facilities emphasize the incorporation of vegetation into the pond design, noting several benefits such as nutrient uptake, bank stabilization, water temperature regulation, creating habitat linkages, and aesthetics (MECP, 2003). Stormwater ponds in Ontario and elsewhere in Canada also require special design features so they are effective in below freezing temperatures, a factor which need not be considered for ponds located in countries with milder climates. According to Ontario guidelines, stormwater management strategies should have a goal of integrating stormwater management practices effectively as amenities (MECP, 2003). Despite being a goal of Ontario's stormwater management strategy, little empirical evidence exists demonstrating that stormwater ponds are considered to be environmental amenities by surrounding communities.

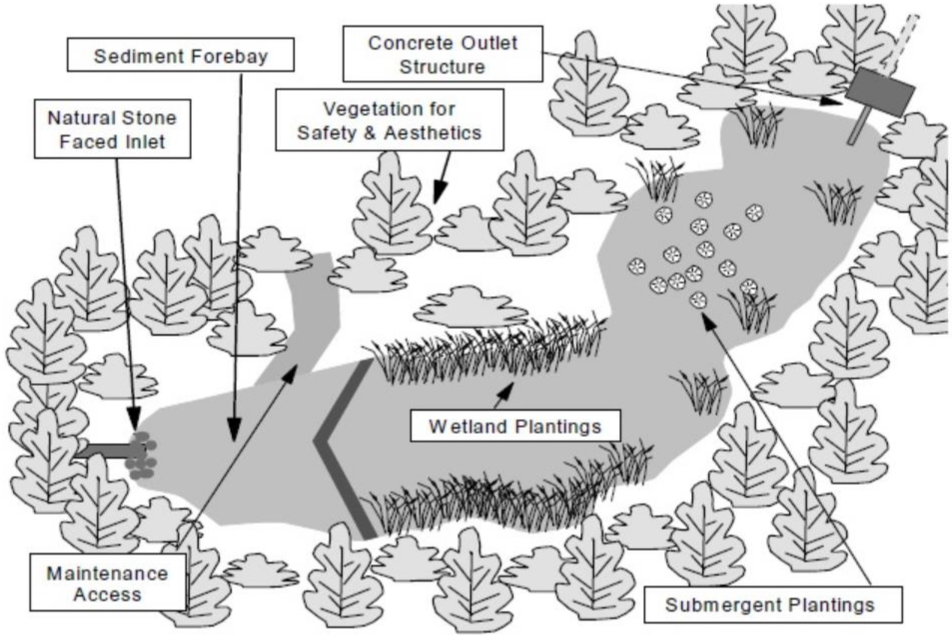

Figure 1. Diagram of a conventional stormwater pond (MECP, 2003).

2.4 Ancillary benefits of stormwater ponds

The performance of stormwater ponds is typically only evaluated in terms of hydrological functions, with little focus on their capacity to provide ancillary benefits to surrounding communities. However, there is an emerging body of work examining the secondary environmental and societal benefits provided by these constructed systems. For instance, studies have shown that stormwater ponds and wetlands can support local biodiversity across taxa (Moore and Hunt, 2012; Semerano et al., 2015). Strategically located ponds may act as stepping-stones for migratory birds (Semerano et al., 2015). Certain design features of stormwater ponds, such as the presence of a littoral shelf, can enhance macrophyte and macroinvertebrate species richness (Moore and Hunt, 2012). A study in Ottawa showed that urban stormwater ponds can support similar levels of biodiversity as natural wetlands (Hassall and Anderson, 2014).

Stormwater ponds with a well-established littoral zone may also serve as carbon sinks (Merriman et al., 2017).

In addition to secondary environmental benefits, some studies have examined secondary social benefits offered by stormwater management systems, although this field of study is under-researched. A systematic review of over 20,000 papers focused on green infrastructure used for stormwater management and flood control conducted by Venkataramanan et al. (2019) found only 18 studies that reported health or social well-being outcomes. This absence in the literature presents an opportunity for further research exploring the social benefits of stormwater infrastructure.

While research examining the social benefits of stormwater infrastructure is limited, a few preliminary studies have been conducted which illustrate the significance of this field of study. When comparing 20 constructed stormwater wetlands and 20 stormwater ponds in North Carolina, USA, in terms of their recreational and educational services, Moore and Hunt (2012) found that the wetlands were more likely to be used for recreation and education. The authors speculated that this result was because the wetlands in this study were more often located on public land and were more likely to have recreational infrastructure than the ponds, suggesting that accessibility and presence of walking infrastructure are important factors influencing the public's use of these facilities (Moore and Hunt, 2012). Similar results were also seen in a qualitative assessment by Ghermandi and Fichtman (2015) of the recreational and educational benefits offered by 166 constructed treatment wetlands and ponds located worldwide, which found that public use was highly influenced by the presence of recreational and educational infrastructure and legal accessibility. In this latter study, passive recreation and birdwatching were the most commonly reported activities at these sites, and the wetlands and ponds containing infrastructure which supported these activities (e.g. interpretive signs, wildlife lookout points) were associated with a high number of visitors (Ghermandi and Fichtman, 2015). Economic valuation methods have also been used to assess the public's preference for design features of stormwater management systems. Lee and Li (2009) used a hedonic price model to show that residential property value was higher for houses adjacent to a multi-use detention basin (drainage basin merged with a neighborhood park) compared to properties surrounding a uni-use detention basin. A choice experiment done by Carlsson et al. (2003) in Sweden showed that people prefer wetlands with high biodiversity and walking trails and were opposed to wetlands that have a fenced waterline. The presence of wildlife was also determined to be the most important benefit offered by naturalized stormwater ponds in two separate yet similar UK surveys of residents living within walking distance of such ponds (Bastien et al., 2011; Jarvie et al., 2017). The greatest disadvantages reported by residents of living near a drainage pond differed between the two studies, with one survey noting safety concerns (Bastien et al., 2011) and the other the presence insects, rodents, and litter (Jarvie et al., 2017). Pedersen et al. (2019) conducted a survey of residents in three separate towns, two of which were adjacent to peri-urban stormwater wetlands and one of which contained a network of urban stormwater wetlands and ponds. The results of the survey indicated that living close to these systems contributed to several aspects of quality of life, such as interacting with nature and experiencing beauty (Pedersen et al., 2019). The urban wetland system was better suited for socializing with friends and family than the peri-urban wetlands, suggesting that the location and level of integration within the surrounding area can determine the types of benefits offered by these systems (Pedersen et al., 2019). While all three wetland areas had equally high restorative qualities, the urban wetland elicited higher positive affective responses compared to the peri-urban wetlands, indicating that even small pockets of wetland in an urban landscape can benefit residents' well-being (Pedersen et al., 2019).

Other studies have examined the public's aesthetic preferences for wetlands and stormwater ponds. Dobbie (2013) found that treed wetlands and wetlands with open water were preferred over grasslands, and that wetland health and naturalness were strong predictors of preference. Another study in Florida, USA, which used a focus group and survey to document the knowledge and attitudes of homeowners living near stormwater ponds, found that while homeowners recognize the importance of natural shoreline vegetation for supporting wildlife, they were generally wary about vegetation blocking water views and appearing "swampy" (Monaghan et al., 2016). A survey of wetland aesthetic preferences conducted by Cottet et al. (2013) revealed that respondents preferred wetlands with transparent water and submerged vegetation. While these studies suggest that the public prefers low nutrient ponds, these systems are not necessarily the most ecologically productive or effective at treating stormwater. As with green space, it is important to consider the multifunctionality of these stormwater facilities and include design elements that not only maximize their environmental services but also offer ancillary benefits to their surrounding communities.

The aforementioned studies of the ancillary benefits of stormwater wetlands and ponds suggest that these systems can offer many cultural ecosystem services to communities that interact with these systems. High biodiversity seems to be the most valued attribute of these systems, as viewing wildlife is a commonly practiced form of recreation and can enhance people's enjoyment of nature. Accessibility and presence of recreational infrastructure seem to be large determinants of use of stormwater systems for recreation and education. In terms of aesthetic value, tree cover and open water seem to be the most favored features. However, given the relatively small body of evidence on the ancillary benefits of stormwater management systems, it is difficult to know if these attributes are wide-scale preferences, or if they might differ depending on the region or population. None of the studies examining the public perception of stormwater systems took place in Canada, so it is difficult to say whether the results of these studies are reflective of the Canadian population. Given that stormwater ponds are a widely used best management practice in Canada, it is important to capture the Canadian public's opinion of these systems.

2.5 Significance of research

This study is one of the first to examine the public perception of urban stormwater ponds in Canada. Stormwater ponds have been used in Ontario since the 1970s, yet their capacity to serve as urban green/blue space that provides both social and environmental benefits has yet to be evaluated. The results of this research will reveal how stormwater ponds are perceived by Ottawa residents, and determine which features of the ponds contribute the most to the public's perception of these facilities. The survey will also provide insight into the social value of these ponds and assess the public's preferences for pond attributes which enhance their use and enjoyment of these facilities. The results of this study can potentially be used by planners and decision-makers when designing new stormwater ponds to improve their multifunctionality and optimize both their environmental and social outcomes.

3 Methods

3.1 Study location

An online survey was distributed to residents in communities of Kanata and Riverside South in the City of Ottawa. Kanata is the largest suburb of Ottawa with a population of approximately 117,000 (Statistics Canada, 2017). Kanata is comprised of the Kanata North and

Kanata South Wards, which each contain four community associations. Riverside South is a suburban community in the Gloucester-South Nepean Ward located in the south end of Ottawa with a population of approximately 16,000 (City of Ottawa, 2019a). A total of six communities are represented in this study: Bridlewood; Briarbook, Brookside, Morgan's Grant (BBMG); Kanata Beaverbrook; Kanata Lakes; Trailwest; and Riverside South (Figure 2).

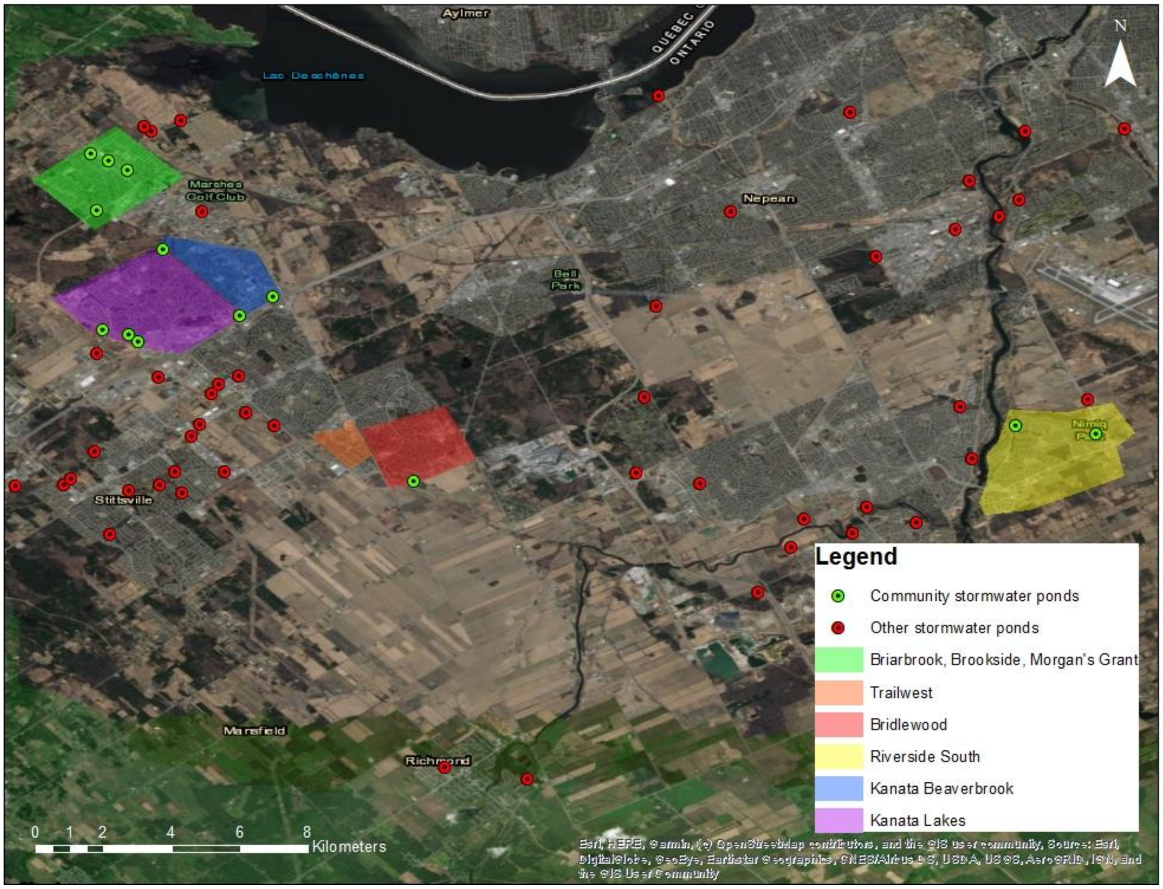

Figure 2. Map of the City of Ottawa, ON, identifying study communities (coloured polygons) stormwater ponds located in study communities (green points) and all other stormwater ponds (red points).

These communities were selected for a number of reasons. Kanata and Riverside South are some of the fastest growing areas in Ottawa; Riverside South is predicted to grow from 16,000 residents to more than 50,000 over the next two decades (Ottawa Citizen, 2014) and the population of Kanata increased by 12% from 2011 to 2016 (Statistics Canada, 2017). The City of

Ottawa in general is predicted to experience a population increase of 13% to 38% by 2036 (City of Ottawa, 2019b). As a result of this anticipated growth, areas like Riverside South and Kanata have seen an increase in the number of new residential developments, many of which contain stormwater ponds. Members of these communities are likely aware of and possibly interact with the stormwater ponds in their neighborhoods, and potentially have formed an opinion of their local stormwater pond. There are currently 133 stormwater ponds in the City of Ottawa (City of Ottawa, 2019c), and the number of ponds is likely to increase as suburban neighborhoods continue to expand and multiply. Kanata Lakes contains the most stormwater ponds (five), followed by BBMG (four), Riverside South (two), Bridlewood and Kanata Beaverbrook (one) and Trailwest (zero). While Trailwest has no stormwater ponds within its boundary, it is adjacent to the stormwater pond located in Bridlewood. Similarly, two ponds in Kanata Lakes boarder Kanata Beaverbrook, so it is likely that both communities have access to these ponds.

3.2 Survey design

The online survey used in this study was developed using SurveyMonkey, an online survey development software made available through a license purchased by the University of Ottawa. An online survey has been successfully used in similar studies examining the perceptions of various types of green space (Bertram and Rehdanz, 2015; Cottet et al., 2013; Monaghan, 2016). The survey consisted of 19 questions that could be competed in under 10 minutes (Appendix A). A brief introduction to stormwater ponds was included at the beginning of the survey to provide some background information and context to the respondents. Given that longer surveys tend to have lower completion rates (Liu and Wronski, 2018) the survey was kept as brief as possible with the intent of reducing dropout rates. The question types consisted of yes/no questions, 5-point Likert-type scales, open-ended questions, a photo array, and demographic questions. The survey consists of three sections: context questions (questions 1-5), perception and use questions (questions 6-14), and demographic questions (questions 15-19). Question 1 asked respondents to indicate if they lived within a 5-minute walk of a stormwater pond. Respondents who answered "yes" were sent to Questions 2 and 3; all other respondents were sent directly to Question 4. Question 2 asked respondents to indicate if they had a view of the stormwater pond from their residence. Question 3 asked respondents living within a 5-minute walk of a stormwater pond to indicate how important the presence of the stormwater pond was for their decision to move to their neighbourhood using a Likert-type sale. Five-point Likert-type scales were used throughout the survey, as they are a well-established method of measuring values, easy to administer, straightforward for respondents, and can be analyzed using standard statistical methods (Ovadia, 2004). Rating questions were used in this study as opposed to ranking questions, as ranking questions may force respondents to order their preferences even in cases where they value some of the attributes in question equally (Klein et al., 2004). While a rating system allows respondents to assign a value to an attribute irrespective of the other attributes, rating systems can also be susceptible to non-differentiation amongst unmotivated respondents (Ovadia, 2004) and acquiescence bias (van Herk and van de Velden, 2007). Question 4 asked respondents to rate their satisfaction with the amount of open space in their neighbourhood, from very dissatisfied to very satisfied. Question 5 tested whether respondents knew their neighbourhood pond was a constructed stormwater pond, or if they believed the pond was a natural pond or a natural pond that receives stormwater.

Questions 6 to 14 characterized the public's perception and use of the stormwater ponds in their neighbourhood. In Question 6 respondents were presented with nine outdoor activities (plus "none" and "other") and were asked to select which activities they participated in at their local pond. Question 7 asked respondents to indicate how frequently they participated in the activities at the stormwater pond that they identified in Question 6. In Question 11 respondents were asked to rate the importance of 12 different design features of stormwater ponds, in terms of their use and enjoyment of stormwater pond facilities. Question 12 asked respondents to rate their agreement with three statements regarding the level of maintenance, accessibility, and pollution of their neighbourhood stormwater pond. For Questions 7, 11, and 12 the order of options was randomized for each respondent to reduce response order bias (Israel and Taylor, 1990).

An open-ended format was used for Questions 8 and 9, which asked respondents to identify the main advantages/benefits and disadvantages/drawbacks of having a stormwater pond in their neighbourhood, respectively. The use of open-ended questions has been associated with lower completion rates, however they can be useful for exploratory questions where a wide-range of responses are anticipated and to avoid any author bias which may result from limiting respondents to a select set of answer choices (Holland and Christian, 2009). The use of opened-ended questions was useful for this survey given that the public perception of stormwater ponds has not been explored in Canada, therefore a wide range of perspectives may exist amongst the public.

In Question 13 respondents were presented with three photos of stormwater ponds of varying degrees of naturalness. A photo array question was included as responses to photo-based surveys strongly reflect the real-world perception of the same scene (Cottet et al., 2013). The types of stormwater pond images presented ranged from a pond with a fountain and mowed grass up to the shoreline, a pond with moderate shoreline vegetation with a bench and trail, and a pond with no indication of human intervention. The types of photos used in this survey were informed by photo arrays seen in Ngiam et al. (2017), Cottet et al. (2013), and Dobbie (2013). The photos used in the photo array were taken from actual pond sites across the City of Ottawa so the landscape would be familiar to respondents. The order of the photos was randomized for each respondent to reduce response order bias (Israel and Taylor, 1990). In Question 14, respondents were asked to explain their choice of photo in Question 13 in an open-ended format.

Lastly, the five demographic questions in this survey collected information of the respondents' gender, age, household income, and household composition. The questions were designed to be minimally invasive (e.g. by presenting ranges for household income and age) and are important for revealing trends in perception amongst different demographic groups (Glasser, 2012).

Pre-testing is an important part of the survey design process (Umbach, 2004). Prior to ethics review and distribution, the survey was shared with a knowledgeable group consisting of three individuals from academia, one professional consultant in watershed management, and four members of the public from the target communities to ensure that the survey questions were easy to comprehend and could be completed in the estimated amount of time. The community members who completed the pre-test were also asked to complete a short evaluation of the survey where they commented on the level of difficulty of the survey and the amount of time it took to complete the survey (Appendix B). The survey was adjusted based on feedback received during the pre-tests.

The survey was approved by and conducted in accordance with the University of Ottawa's Research and Ethics Board (H-05-19-4069). Consent from respondents was obtained by including an implied consent text read by respondents prior to starting the survey. The full survey and consent text can be found in Appendix A.

3.3 Data collection

The survey was distributed to participants via community associations and remained active for four to six weeks. Individual hyperlinks to the survey were created for each community association to be able to differentiate responses between each community. The links were then shared via the community associations' email newsletters, website, and/or Facebook page/group. Riverside South, BBMG, Kanata Beaverbrook, and Kanata Lakes Community Associations distributed their surveys between June 13 to 18th, 2019. Trailwest and Bridlewood distributed their survey links on June 26th. All surveys were closed July 29, 2019. The surveys for Bridlewood and Trailwest were closed after four weeks as they received an equal or higher number of responses as the other community associations in fewer weeks, therefore it was deemed unnecessary to leave the survey open for an additional two weeks.

Reminders were distributed in weeks three or four of the survey for five of the six community associations. A reminder was not distributed to Bridlewood, as the number of responses received from this community after the initial distribution was more than double the next highest number of responses.

Distributing the survey online via community associations was deemed to be the best form of distribution for a variety of reasons. Having the support of the community associations gave the survey additional legitimacy, which may have made people more receptive to participating. Additionally, alternative modes of distribution, such as in-person or mail surveys, are more energy and time intensive and would have likely resulted in a lower number of responses as the online survey. A limitation of distributing the survey through a community association is that only individuals engaged with the community associations had access to the survey, potentially leaving out others in the community. However, those who are involved with the community association are perhaps more likely to engage on community issues, meaning that they may have been more inclined to respond to a survey than those who are not involved with their association. Another disadvantage of distributing the survey through community associations is that the communities represented in this study depended on the community associations' willingness to participate, thus communities with associations that did not agree to participate are not represented. Two communities in Kanata South and one community in Kanata North failed to respond to multiple requests to participate, and therefore are not represented in this study.

3.4 Data analyses

Analyses of the survey results were conducted using well-established methods (Thomas, 2006; Harpe, 2015). Incomplete survey submissions were included in the final analysis. Descriptive statistics were generated by SurveyMonkey, and the corresponding figures were generated/modified using Microsoft Excel. Where appropriate, inferential statistical analysis was conducted using nonparametric tests in RStudio. The Mann-Whitney U test was used to compare responses between genders (male/female) and households with and without children present. The Kruskal-Wallis test was used to compare responses between age ranges and income levels. An inductive approach was used to code responses to open-ended questions (Questions 8, 9, and 14) into unique categories based on methods by Thomas (2006) (Figure 3). The raw text for each response was divided into segments that represented a distinct theme. Each segment was then assigned a code based on its theme. The codes were amalgamated to reduce overlap and redundancy and further refined to produce a select number of unique categories. The raw text was then re-read and labelled with at least one category to determine the number of responses that referenced each category. Responses could be assigned to multiple categories.

Initial reading of raw text	Identify specific text segments within each response	Assign a code to each segment of text based on theme	Reduce overlap and redundancy among codes	Refine remaining codes into most important categories
Hundreds of responses	Many segments of text	20-30 codes	10-15 codes	<10 categories

Figure 3. The coding process used in the inductive analysis of open-ended survey responses adapted from Thomas (2006).

3.5 Justification of methods

A range of other methods have been used in studies in this field, such as on-site interviews (Volker and Kistemann 2013; 2015), economic analyses such as hedonic pricing (Le and Li, 2009) and discrete choice experiments (Carlsson et al., 2003). While these methods are viable alternatives, an online survey was deemed to be the most appropriate method for this study for several reasons. On-site interviews at stormwater ponds would only capture the perspectives of individuals who already visit the ponds in question, and thus would likely have a positive perception of these facilities. Given that stormwater ponds can be a contentious issue, it is important to capture a wide range of perspectives to get a better understanding of the overall perception of these facilities by the general public. A hedonic analysis would estimate a homeowner’s willingness to pay to live close to a stormwater pond, with the assumption that the perceived value stormwater pond will be reflected in the sale price of the home. However, a hedonic analysis would not address why the stormwater pond would or would not be considered an amenity, information that can be useful for decision-makers and planners when designing these systems. A discrete choice experiment would reveal insights into the preferences of specific attributes of stormwater ponds, but discrete choice experiments can be demanding on respondents and many find the inclusion of a hypothetical payment confusing (Rakotonarivo et al., 2016). A well-designed survey can reveal similar insights into the preferences of stormwater pond attributes as a choice experiment in a way that is more straightforward for the respondent. Additionally, given the somewhat limited timeframe and funding of this research, an online survey was deemed to be the most efficient method in terms of both time and cost.

4 Results

The survey received a total of 285 responses with 249 completed surveys (completion rate=87%). The Bridlewood community had the highest number of responses (n=101), followed by the communities of Riverside South (n=48), Trailwest (n=46), BBMG (n=46), Kanata Lakes (n=23), and Kanata Beaverbrook (n=21).

4.1 Context questions

Of the 285 total respondents, 82.1% of respondents lived within a five-minute walk from a stormwater pond, while 14.7% of respondents did not and 3.61% did not know (Figure 4). Of the proportion of respondents who reported living within a five-minute walk from a pond (n=233), 20.6% reported having a view of a pond from their residence (Figure 5).

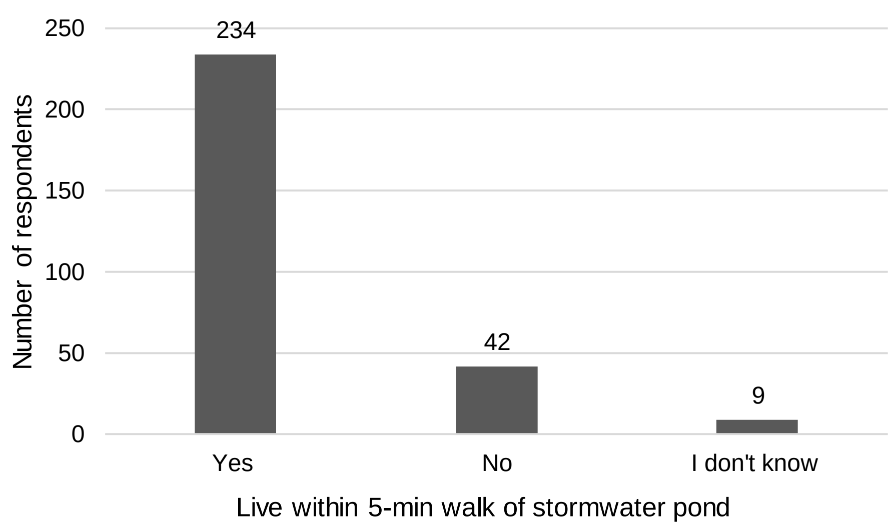

Figure 4. Respondents indicating if they live within a 5-minute walk of a stormwater pond (n=285).

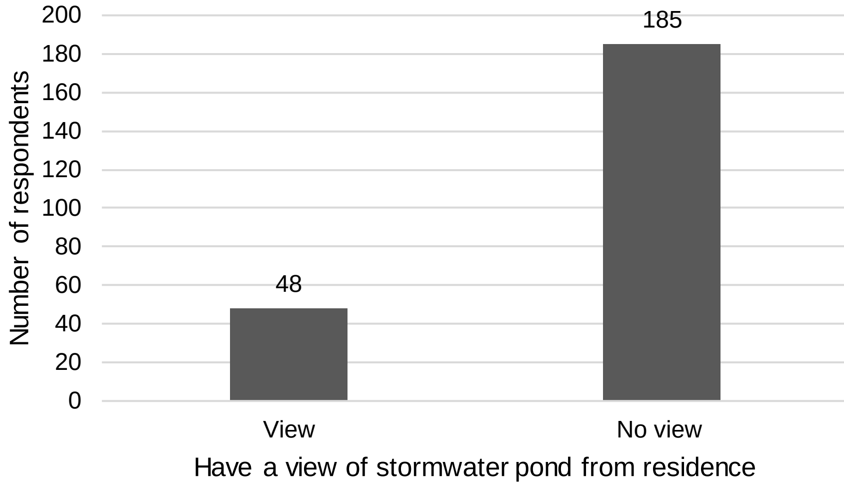

Figure 5. Respondents living within a 5-minute walk of a stormwater pond who have a view of the pond from their residence (n=233).

For 47.2% of respondents living within a 5-minute walk of a stormwater pond, the presence of a stormwater pond was not an important factor influencing their decision to move into their neighborhood (Figure 6). The majority of the other respondents living within a 5-minute walk of a stormwater pond (48.5%) reported that the presence of a pond had some importance when deciding to move to their neighborhood, ranging from slightly important (12.0%) to very important (10.7%). The importance of the stormwater ponds for respondents' choice of neighbourhood was not significantly influenced by gender (W=4251.5, p=0.84), age (χ^2=6.75, df=4, p=0.15), income (χ^2=3.02, df=3, p=0.39), or the presence of children in the household (W=5201.5, p=0.55).

Seventy-three percent of all respondents were satisfied or very satisfied with the amount of open space (e.g. parks, forests, water bodies) in their neighborhood. The level of satisfaction with neighbourhood open space did not significantly differ between genders (W=5606.0, p=0.91) age ranges (χ^2=0.49, df=4, p=0.97), income levels (χ^2=3.70, df=3, p=0.30), or households with or without children (W=6720.5, p=0.50). Over half of respondents were aware that the pond in their neighbhourhood was constructed for stormwater management purposes, while the remaining respondents either did not know (26.48%), thought it was a natural pond (5.93%), or thought it was a natural pond that receives stormwater (11.86%) (Figure 8).

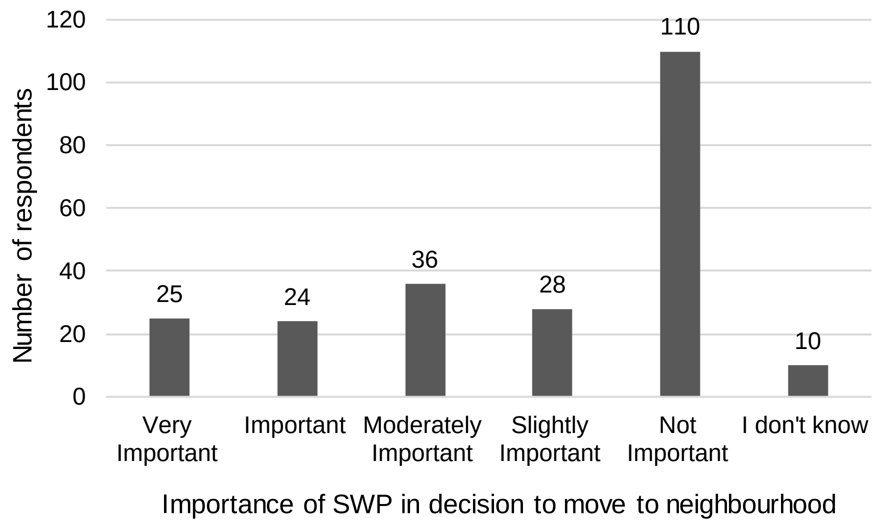

Figure 6. Importance of the stormwater pond (SWP) for the decision of respondents living within a 5-minute walk of a pond to move to their neighbourhood (n=233).

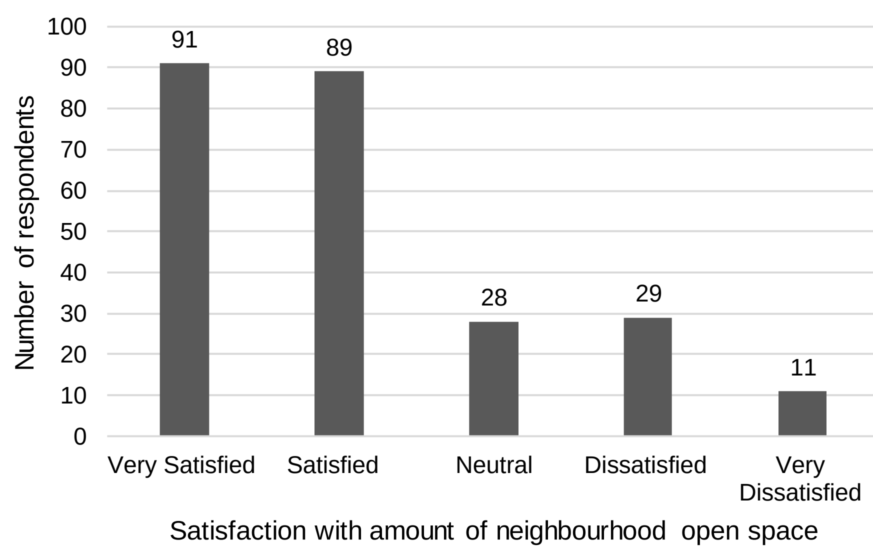

Figure 7. Respondents’ satisfaction with amount of open space (e.g. parks, forests, water bodies) in their neighbourhood (n=248).

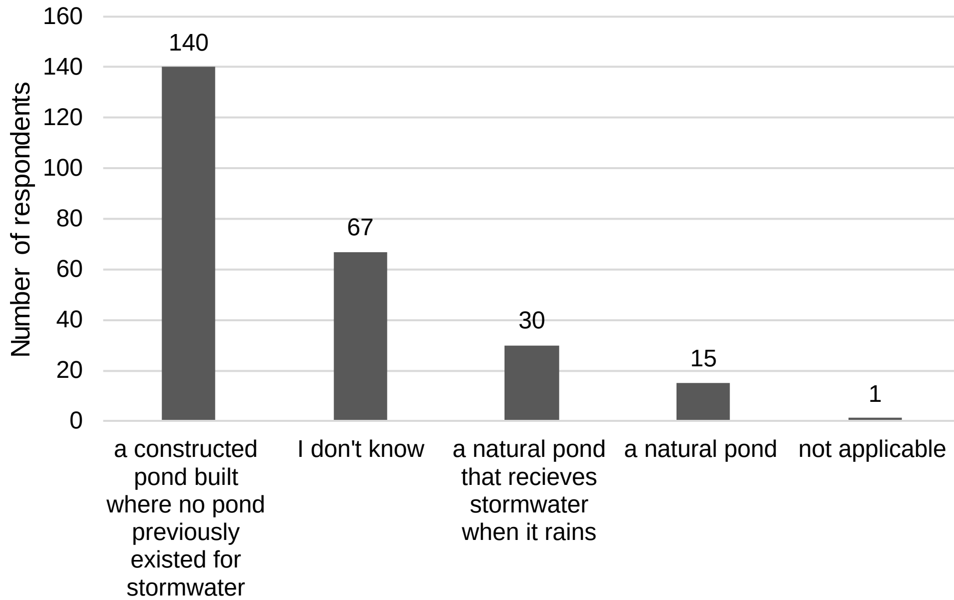

Figure 8. Respondents' classification of their neighbourhood stormwater pond (n=253).

4.2 Perception and use questions

The most common activities conducted by respondents at their local stormwater pond were walking (84.98%), viewing wildlife (e.g. birdwatching) (64.03%) and enjoying nature (61.66%) (Figure 9). Only 8.7% of respondents did not participate in any activities at their local stormwater pond. A majority of respondents conducted activities at their pond on a weekly (38.34%) or daily (22.53%) basis (Figure 10). Thirty percent of respondents visited the pond less frequently, either on a monthly basis or a few times a year. The frequency of pond visits among respondents was not significantly impacted by gender (W=6030.5, p=0.91), age (χ^2=0.65, df=4, p=0.96), income (χ^2=5.84, df=3, p=0.12), or the presence of children in the household (W=6396.0, p=0.42).

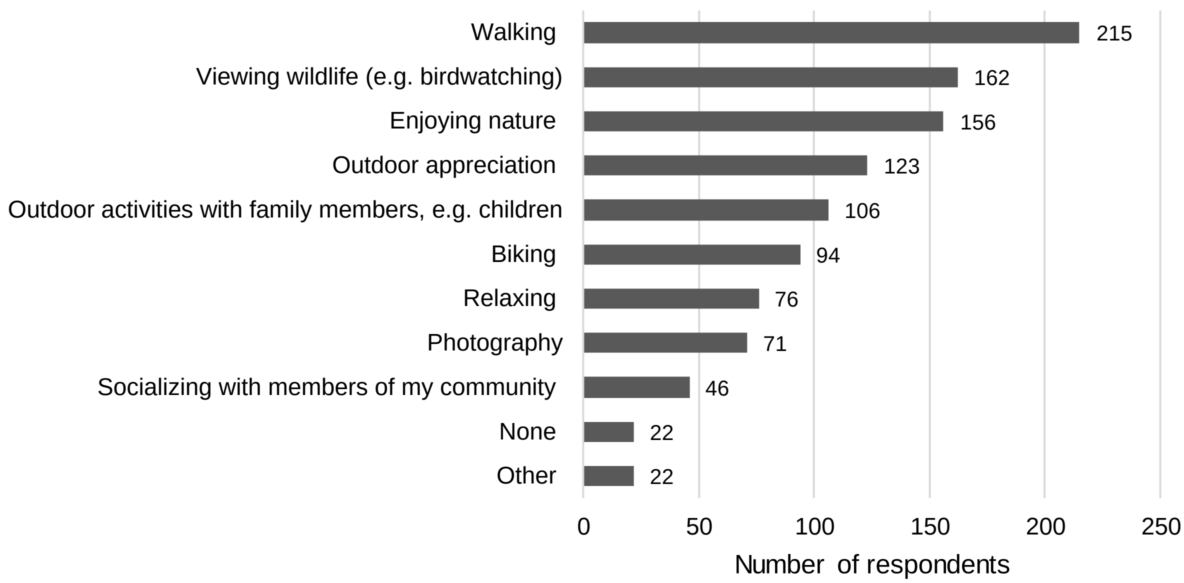

Figure 9. Activities conducted by respondents at their neighbourhood stormwater pond (n=253).

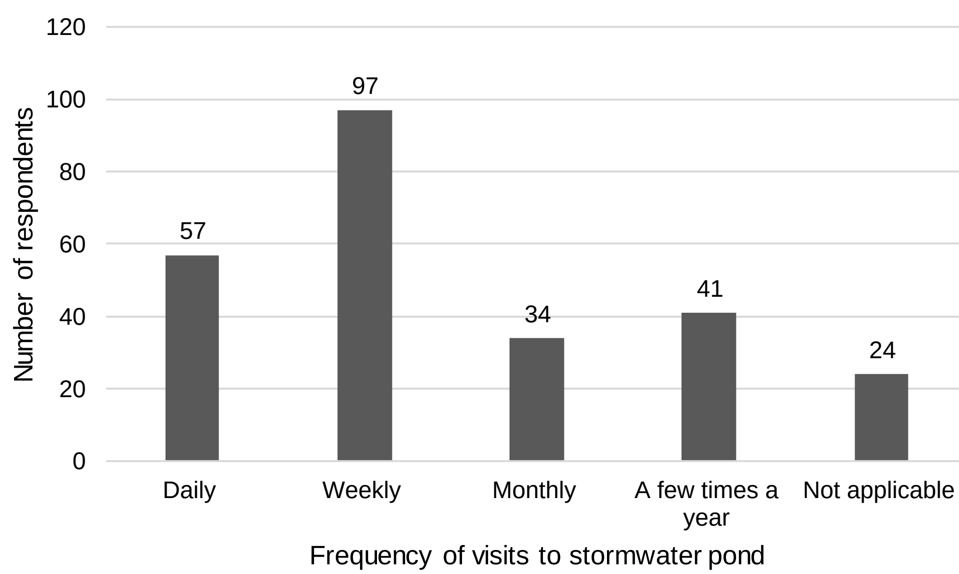

Figure 10. Frequency of respondents' participation in activities at their neighbourhood stormwater pond (n=253).

Questions 8 and 9 used an open-ended response format to collect respondents' opinions on the main advantages/benefits and disadvantages/drawbacks of having a stormwater pond in their neighborhood, respectively. A variety of answers were recorded which could be grouped into several categories (Tables 2 and 3). The most common advantage/benefit of having stormwater ponds in their neighbourhood listed by respondents was that the stormwater ponds support wildlife (50.2%) (Figure 11). Other commonly reported advantages of stormwater ponds include providing access/proximity to nature (32.0%), stormwater management (30.0%), and recreation and education (19.7%). When respondents were asked to specify the most significant disadvantages/drawbacks of having a stormwater pond in their neighbourhood, mosquitoes and other insects (41.8%), none (22.7%), and smell (21.1%) were the most common answers (Figure 12). Despite some notable drawbacks, a majority of respondents (80.2%) agreed/strongly agreed that the advantages of having a stormwater pond in their neighbourhood outweigh the disadvantages (Figure 13).

Table 2. Categories of advantages/benefits of having a neighbourhood stormwater pond extracted from open-ended responses to Question 8.

Advantage/benefit	Description	Response example(s)	Percentage of responses
Supports wildlife	Maximizing urban species richness/diversity by providing habitat for wildlife, such as birds	"Some place to watch birds on the water, hear the frogs, with an occasional otter & beaver"	50.2%
Access & proximity to nature	The public can view and enjoy nature in their own neighbourhood	"Ability to enjoy nature, especially the wildlife, without having to drive to an NCC trail"	32.0%
Stormwater management	Controlling the volume and flow of stormwater runoff and providing protection from flooding	"Keep water out of my basement"	30.0%
Recreation & education	Providing a place for recreational activities (e.g. walking, biking) and outdoor education, especially with children	"Great to have the opportunity to walk in nature" "Having the wildlife close by for my children to learn about and understand their habitat"	19.7%
Aesthetics	Beautifying the neighbourhood	"We can see from all our back windows, it's beautiful!	12.8%
Mental health & well-being	Providing a place for relaxation and creating a sense of calm	"The storm water pond is in view from my house and the view is great for my mental health and relieves my work day stress."	8.9%
Undeveloped space	Maintaining open area within a sprawling peri-urban environment, which helps maintain privacy and buffers in busy neighborhoods	"Green space, breaking up large amounts of new developments."	8.4%
Other services	Other social and environmental services, such as providing a space for socialization, climate change adaptation, and mitigating UHI effects	"…Bonding with family and friends." "Dealing with the increasing varied weather due to climate change." "…Reduction of heat island effect…"	4.4%
No benefits/non-answer	Specified no benefits or their answer could not be interpreted (e.g. "Xx"). Does not include respondents who did not submit an answer to Question 8.	"None" "Bad design, because inlet from creek is too small and creek backs up on our street"	2.5%

Table 3. Categories of disadvantages/drawbacks of having a neighbourhood stormwater pond extracted from open-ended responses to Question 9.

Disadvantage/ drawback	Description	Response example(s)	Percentage of responses
Mosquitoes & other insects	Ponds can act as a breeding ground and habitat for mosquitoes and other insects	"Stagnant water means breeding ground for mosquitoes and other insects."	41.8%
No disadvantages	Specified no disadvantages. Does not include respondents who did not submit an answer to Question 9.	"None."	22.7%
Bad smell	Pond can produce a bad smell	"The water sometimes smells swampy"	21.1%
Pollution & litter	Concerns over polluted water and trash in and around the ponds	"It's a cesspool full of chemicals" "Garbage build-up in and around the pond"	10.8%
Geese and other pests	Pond attracts nuisance wildlife, such as geese and skunks	"Several hundred Canada geese congregate in our pond, which can be very loud/noisy, and their droppings pollute the water." "Occasional smell, rats and skunks."	8.8%
Undesirable vegetation	Vegetation around the pond is overgrown/unmaintained; presence of dangerous plants such as wild parsnip	"Dangerous WEEDS – like plantain, etc." "Poorly maintained surrounding area with benches installed too close that are overgrown and unusable after only 5 years"	5.2%
Other	Response could not be classified into one of the major categories	"Uneducated people not knowing what it is or why it's there" "Potential of flooding with the new development behind the pond"	5.2%
Safety concerns	Water presents a drowning risk; concerns over loitering around ponds	"No protection against children falling into the pond…." "…kids using forested areas for drug use."	4.1%
Unattractive appearance/design	Appearance/features of pond not conducive for use and enjoyment	"Man made appearance, neglect could be unsightly…"	3.6%

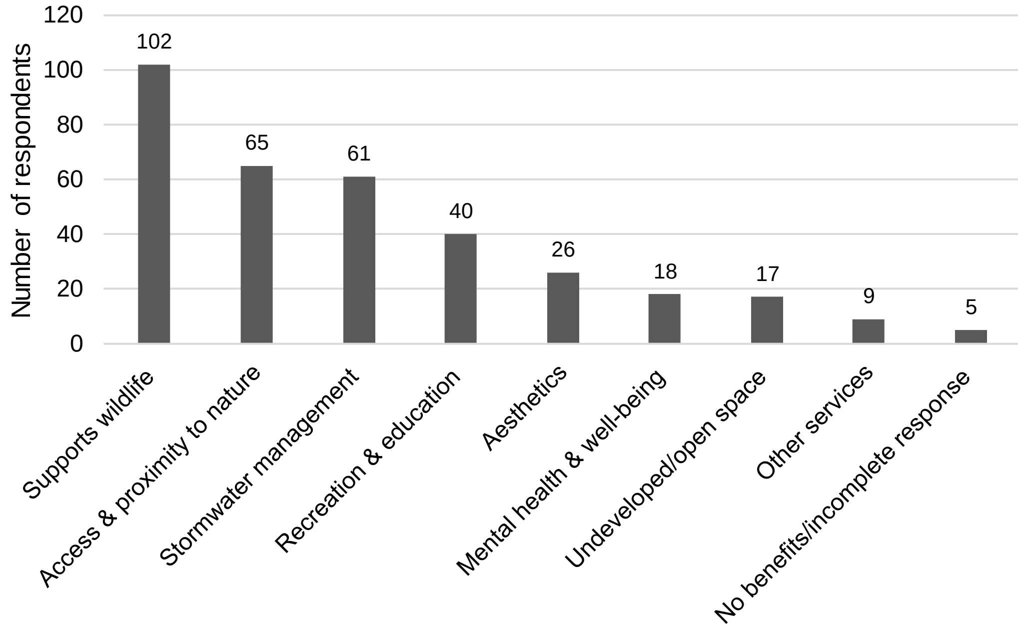

Figure 11. Categories of advantages/benefits of having a stormwater pond in their neighbourhood reported by respondents (n=203).

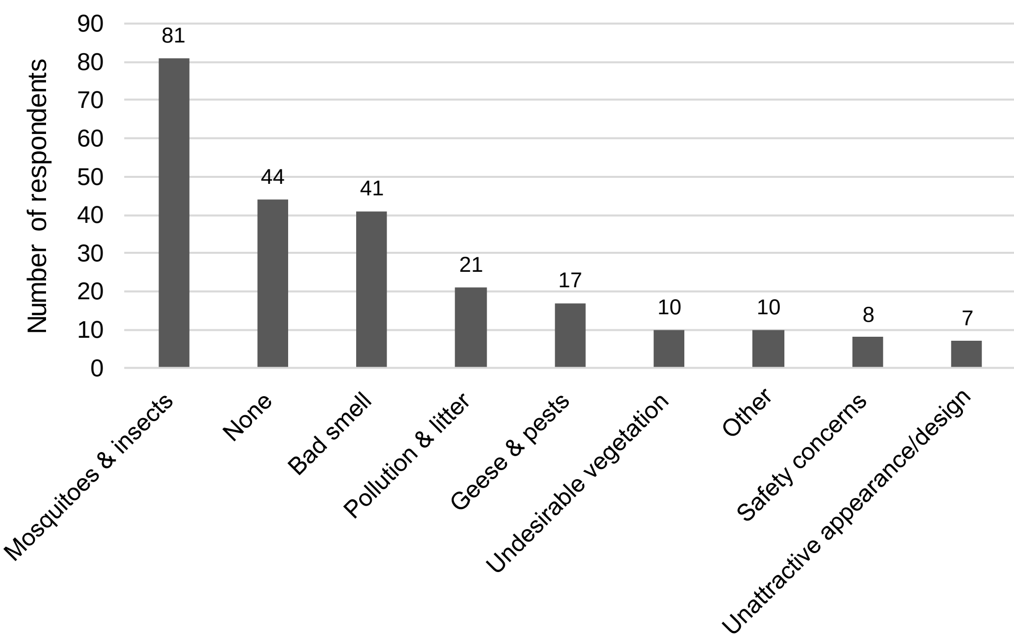

Figure 12. Categories of disadvantages/drawbacks of having a stormwater pond in their neighbourhood reported by respondents (n=194).

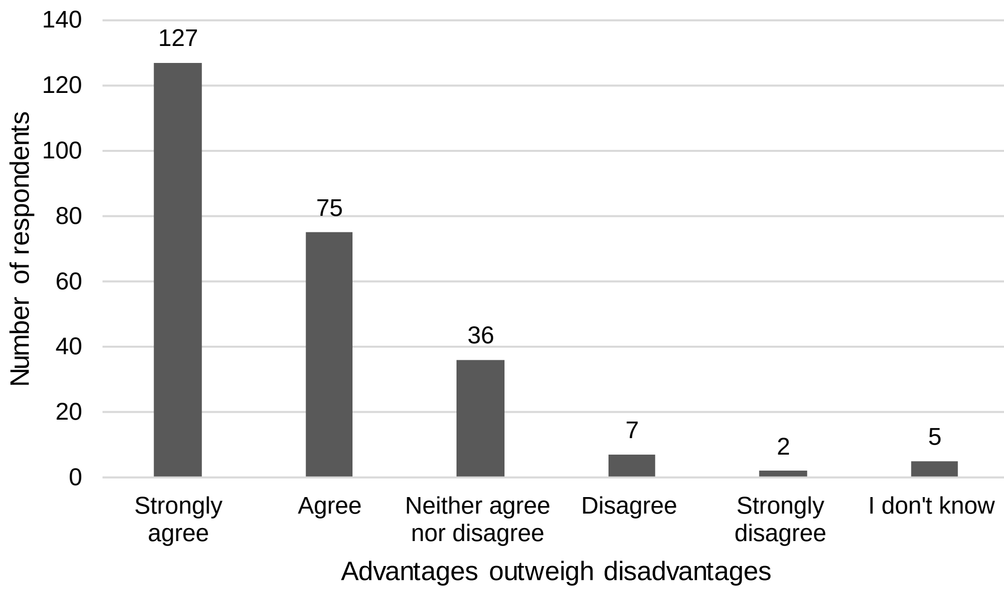

Figure 13. Respondents' agreement with the statement "the advantages of having a stormwater pond in your neighbourhood outweigh the disadvantages" (n=252).

Walking trails were rated as the most important feature of a stormwater pond in terms of respondents' use and enjoyment of the facility, followed closely by the presence of wildlife (Figure 14). Cleanliness and trees were also rated highly. The least important feature for pond use and enjoyment was a fenced shoreline, followed by mowed grass to the shoreline and interpretive signs.

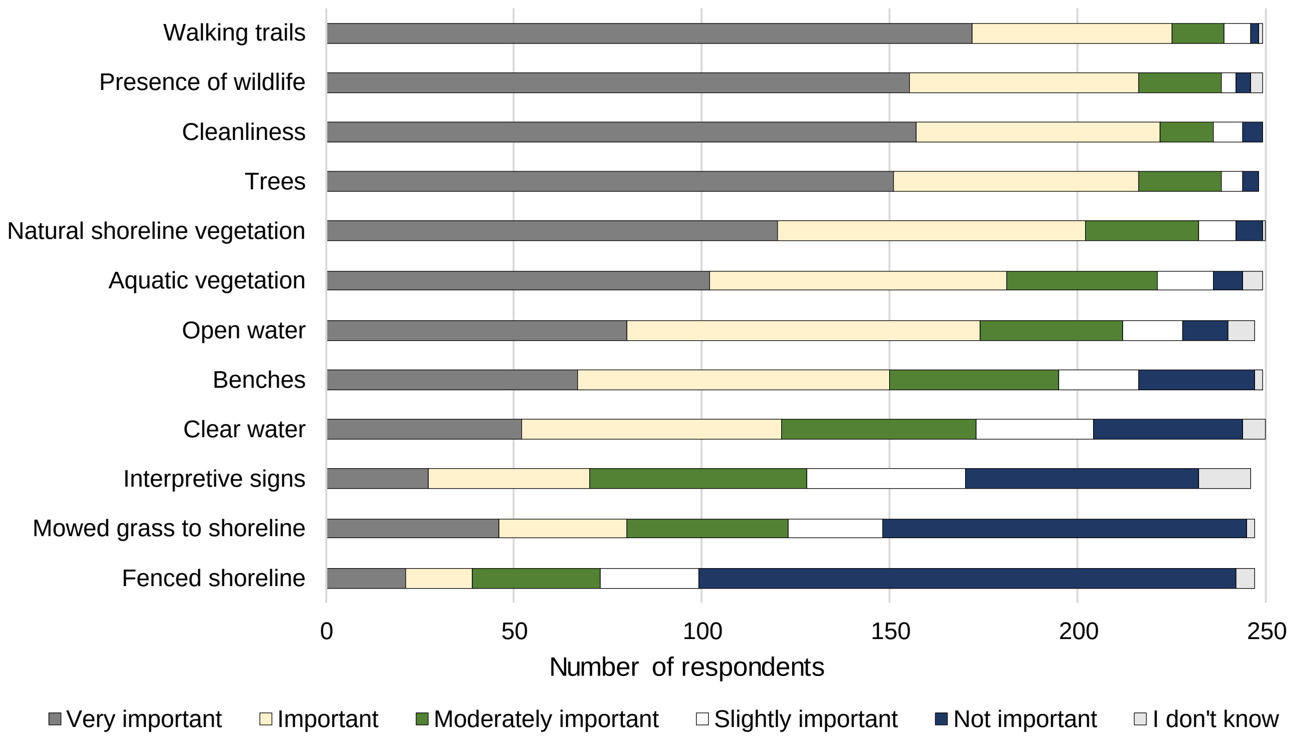

Figure 14. Importance of features of a stormwater pond, in terms of respondents' use and enjoyment (n=250).

Respondents were presented with three statements regarding the level of pollution, accessibility, and maintenance of their neighbourhood stormwater pond. The sentiments of respondents were generally split across the range of possible responses; however, a majority of respondents were neutral or expressed some level of agreement with each statement. (Figure 15). Thirty-five percent of respondents had some level of concern that their neighbourhood stormwater pond was polluted, while 32.5% were not concerned and the remaining 32.3% were neutral or did not know. With regards to stormwater pond maintenance, 44% of respondents wished their neighbourhood pond had better maintenance compared to 18.4% who did not and 37.6% who were neutral. Forty-two percent of respondents wished their pond was more conducive to recreational use and enjoyment, compared to 30.6% who did not and 27.5% who were neutral/did not know.

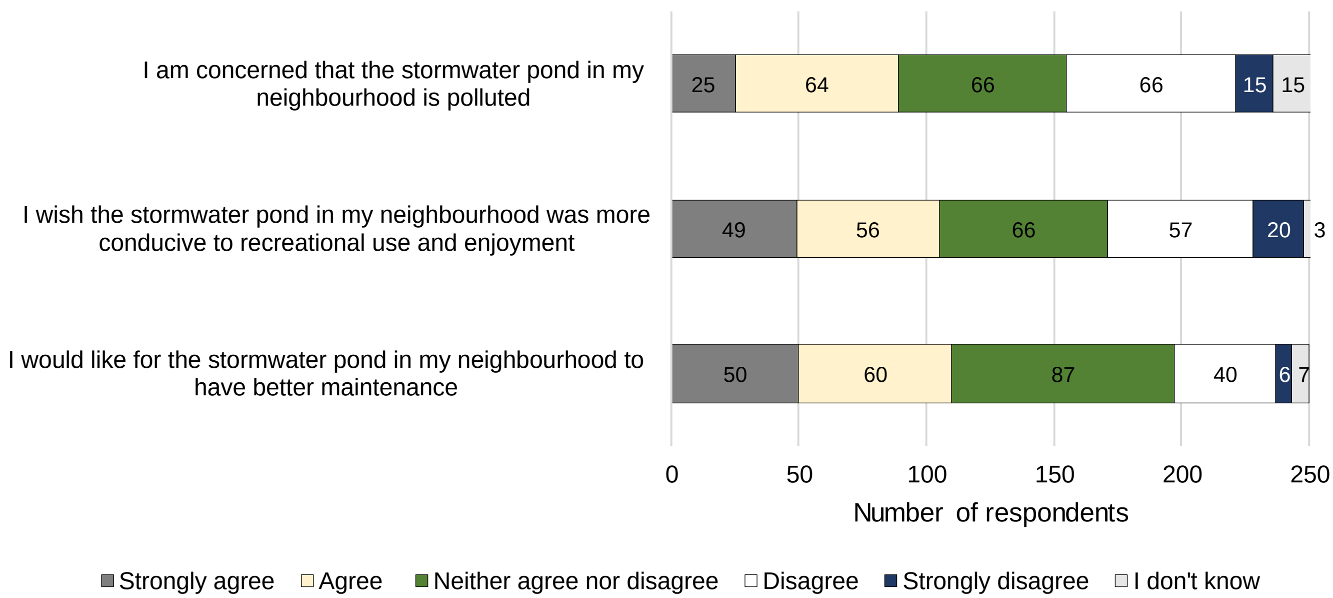

Figure 15. Levels of agreement with statements regarding the level of pollution, maintenance, and accessibility of the stormwater pond in respondents' neighbourhoods (n=251).

The photo preferences in Question 13 were almost equally split between the pond with shoreline vegetation, trail, and bench (Photo A) and the highly naturalized pond (Photo B), selected by 43.8% and 43.4% of respondents respectively (Figure 16). The pond with the mowed grass, fountain, and clear water (Photo C) was the least preferred photo, selected by only 12.7% of respondents. Pond photo preferences were not significantly influenced by gender (W=6290.0, p=0.18), age (χ^2=4.55, df=4, p=0.34), income (χ^2= 1.47, df=3, p=0.69), or the presence of children in the household (W=6699.0, p=0.63).

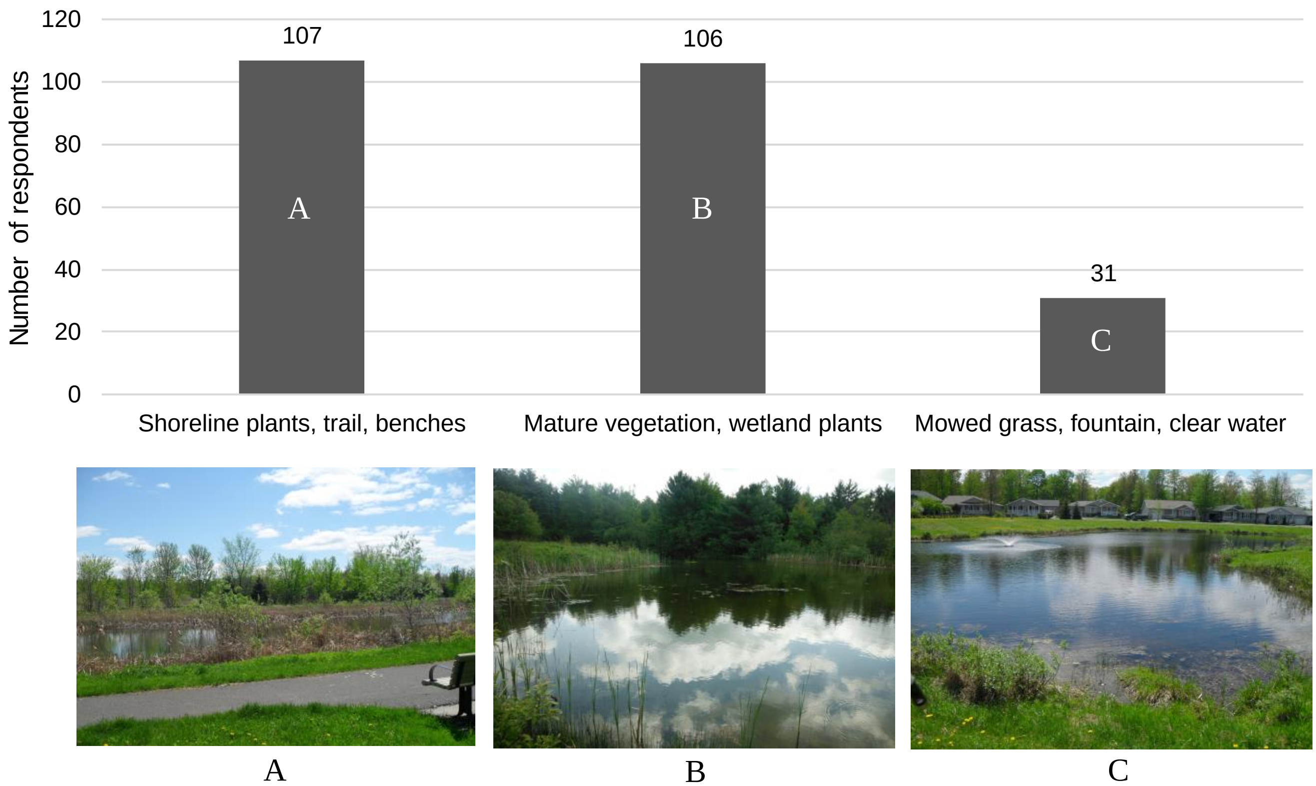

Figure 16. Preferences of respondents when presented with photos of stormwater ponds with (A) moderate shoreline vegetation, a trail, and a bench; (B) high naturalization with mature vegetation and wetland plants; and (C) mowed grass to the shoreline, clear water, and a fountain (n=244).

Of the 244 respondents who answered Question 13, 213 explained their photo choice in Question 14. For respondents who selected Photo A, the main reasons for their choice were that the pond appeared to be conducive to recreation and use (64.2% of responses), had natural elements (24.2%), and was accessible to the community (24.2%) (Table 4). Among respondents who selected Photo B and explained their choice, 77.4% said they preferred this photo because the pond looked the most natural. Respondents also chose Photo B because the pond appeared to be good for wildlife (21.5% of responses) and had trees/vegetation (10.8%). For respondents that selected Photo C, cleanliness and aesthetics were the most common reasons for their choice (42.8% and 28.6% of responses respectively).

Table 4. Responses to Question 14 which asked respondents to explain their photo selection in Question 13.

Photo	Number of responses (n=213)	Explanation for photo selection in Question 13 [Number of responses]
Shoreline plants, trail, benches	95	Conducive to recreation/use [61] Accessible to community [23] Natural elements [23] Maintained [5] Peaceful/inviting [5] Other [2]
Mature vegetation, wetland plants	93	Natural [72] Good for wildlife [20] Trees/vegetation [10] Visually appealing/inviting [8] Tranquil [4] Other [2]
Mowed grass, fountain, clear water	21	Clean [9] Aesthetically pleasing [6] Inviting/accessible [4] No bugs [2] Fountain [1]

4.3 Demographic questions

A majority (66.67%) of the respondents were women. Close to half (46.99%) of the respondents were between 30 and 45 years old, with the next largest age group being 45 to 60 (34.14%). Most (78.51%) of the respondents live in households consisting of two adults. Close to 70% of respondents have a household income (before tax) of over $100,000 CAD. A majority (66.07%) of respondents have at least one child residing in their household on part-time or full-time basis (Figure 17).

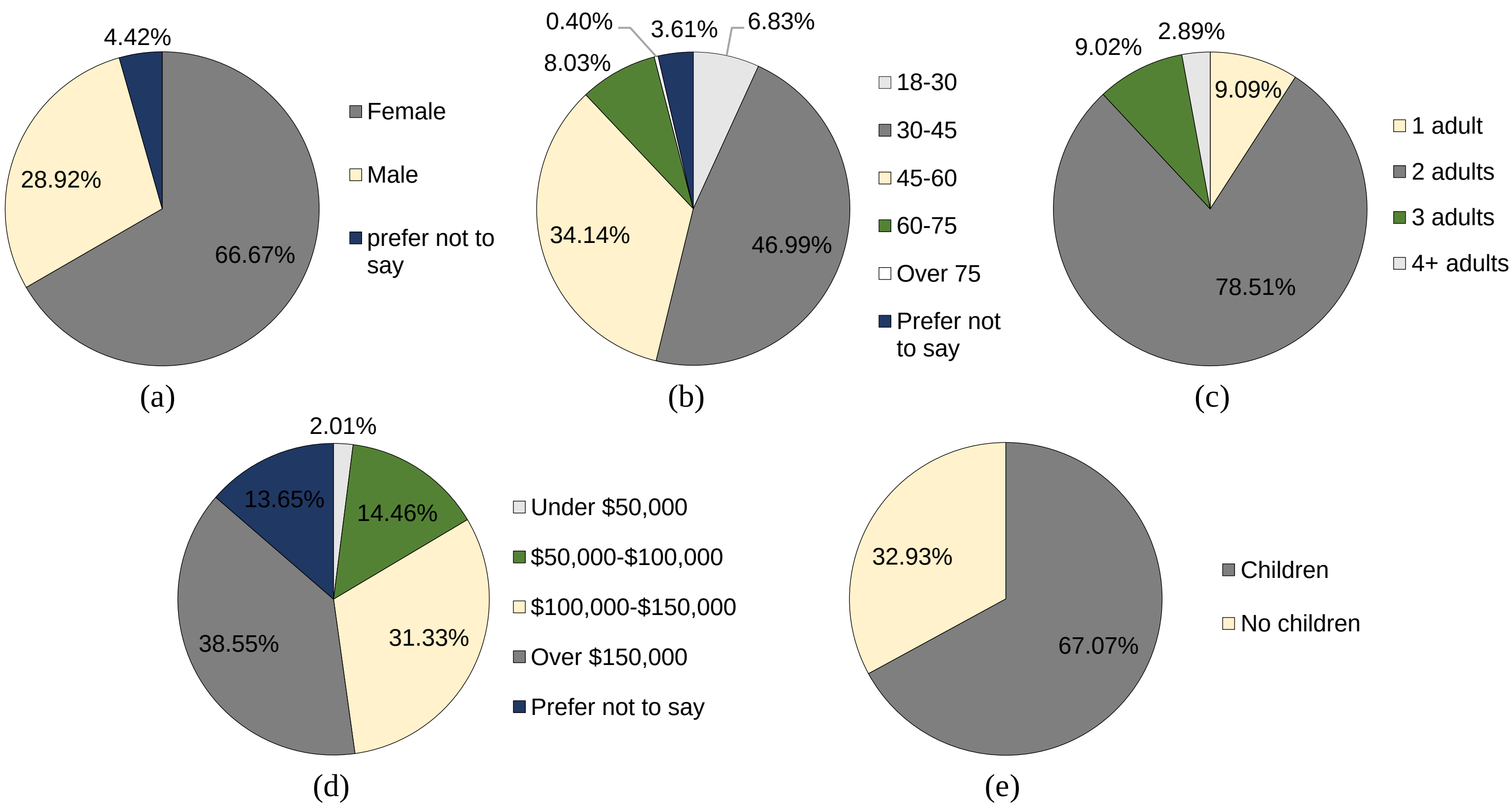

Figure 17. Demographic summary of respondents. (a) Gender (n=249); (b) Age group (n=249); (c) Number of adults residing in household (n=242) ; (d) Household income before tax (n=249); (e) At least one child residing in the household on a full-time or part-time basis (n=249).

5 Discussion

This study is the first to examine the public perception of urban stormwater ponds as environmental and social amenities in Canada. This research was exploratory, with the intention of gathering information and developing a better understanding of a topic which has not been thoroughly investigated. An online survey was successfully used to collect a variety of perspectives from members of the public on the social value of urban stormwater ponds in the City of Ottawa, Ontario. The survey received a satisfactory number of returns comparable with numbers seen in similar survey-based research (Bastien et al., 2011; Jarvie et al., 2017; Ngiam et al., 2017). Additionally, the survey's high completion rate (87%) suggests that the survey length and level of complexity was appropriate for the target audience. The survey results indicated that while their primary purpose is infrastructural, stormwater ponds can also provide valuable social services to surrounding communities, most notably by providing a place for suburban dwellers to experience nature and wildlife. Despite some noted disadvantages, a majority of respondents visited the stormwater ponds regularly and largely appreciated the interactions with nature and recreational amenity (in this order).

5.1 Demographic considerations

It is important to note that the communities surveyed in this study were selected due to the high number of embedded stormwater ponds. As this research was exploratory, it was necessary to target communities where stormwater ponds are present. The survey responses were analyzed collectively, rather than conducting separate analyses for each community. The survey was divided by community associations to facilitate survey distribution, and not for the purpose of comparing responses between communities. Moreover, the socio-demographic conditions of the communities are relatively homogenous (Table 5), which made it possible to examine the survey results as a whole rather than separately by community. A majority of respondents were at or above the median household income for their municipality and above the median income for all of Ottawa ($73,836 CAD) (Ottawa Neighbourhood Study, 2019). Close to half of respondents were between the ages of 30 to 45, which is the age range that encompasses the median ages for all the associated municipalities (Ottawa Neighbourhood Study, 2019). A higher proportion of respondents were female, which is similar to other studies (Bertram and Rehdanz, 2015; Pedersen et al., 2019). This unequal gender distribution may be attributed to the trend that women are more likely to use social media for communicating than men (Kimbrough et al., 2013) and may have been more likely to have seen the survey posted online. The frequency of stormwater pond visits among respondents was independent of their gender, age, income, and household composition. The importance of the stormwater ponds for respondents' decision to move to their neighbourhood and the respondents' satisfaction with the amount of open space in their neighbourhood were also independent of these demographic parameters. Lastly, respondents' preferences for the different pond photos in the photo array question were also independent of gender, age, income, and household composition.

The proportion of respondents who were aware of the ponds' function as stormwater ponds (55%) was higher than levels reported in some studies (Williams et al., 2019) and lower than in others (Bastien et al., 2011). It is possible that the relatively high level of awareness seen in this study is due to the fact that the National Capital Region has experienced two major flood events in the past three years, making residents more aware of stormwater infrastructure in their neighbourhoods. Alternatively, some developers in the City of Ottawa are showcasing the stormwater ponds in their residential developments as neighbourhood amenities (e.g. The Minto Group, 2018), which may increase levels of awareness. Awareness of the role of green infrastructure is important for generating positive public opinions of these systems (Apostolaki et al., 2006). Continued efforts by developers and real estate agents to inform residents of the role of stormwater ponds for flood protection may help sustain residents' appreciation for these systems and generate stewardship.

Table 5. The total population, median age, and median household income (after tax) of the Municipal Jurisdictions corresponding with the Community Associations participating in the online survey. All data accessed through the Ottawa Neighbourhood Study (2019).

Community Association	Municipal Jurisdiction	Total population	Median age	Median household income (after tax) (CAD)
Riverside South	Riverside South – Leitrim	14,020	36	$100,352
Kanata Beaverbrook	Beaverbrook	6,540	43.2	$76,011
Briarbrook, Brookside, Morgan's Grant	Brookside – Briarbrook – Morgan's Grant	15,785	35.3	$98,413
Kanata Lakes	Kanata Lakes – Arcadia	16,475	43.5	$102,008
Bridlewood	Bridlewood – Emerald Meadows	24,240	38	$96,364
Trailwest	Glen Cairn – Kanata South Business Park	11,090	37.2	$78,680

5.2 Perceptions of advantages/benefits of urban stormwater ponds

The findings of this investigation are consistent with other studies which found that people appreciate wetlands and ponds with high biodiversity (Bastien et al., 2011; Jarvie et al., 2017; Williams et al., 2019) and recreational infrastructure (Ghermandi and Fichtman 2015; Moore and Hunt 2012). Half of respondents listed supporting wildlife as one of the main advantages of having a stormwater pond in their neighbhourhood. Additionally, respondents rated the presence of wildlife as the second most important feature of stormwater ponds in terms of use and enjoyment after walking trails, and viewing wildlife was the second most common activity conducted by respondents at the ponds after walking. Collectively, respondents repeatedly distinguished and prioritized wildlife over exposure to nature in general and other forms of "greenness." A few studies have explored potential synergies between biodiversity and public preferences for green space. A study by Wang et al. (2019) suggests that people may perceive urban green space with high biodiversity as more unique, and therefore may place a greater value on their interactions with these environments. Multiple investigations have shown that green spaces with high biodiversity may offer greater psychological health and well-being benefits compared to areas with lower biodiversity (Carrus et al., 2015; Fuller et al., 2007; Wood et al., 2018). As articulated by one respondent of the present study: "[i]t's a sense of peace. The wildlife is amazing. I spend amazing amounts of time looking out my window, on my deck and in my backyard. Interacting with the wildlife and nature is so calming." Other studies suggest that perceived biodiversity is a more significant determinant of the psychological benefits of green space than actual measured species richness (Dallimer et al., 2012; Pett et al., 2016). However, in the present study it seems that respondents have observed high species richness at these sites, with one respondent seeing "…beavers, frog[s], [and] almost 100 species of birds."

Establishing clear linkages between biodiversity and human health and well-being benefits is challenging, as the outcomes of interactions with biodiversity are highly individualistic and context dependent (Pett et al., 2016). For instance, characteristics such as sociodemographic/economic factors, culture, ecological knowledge, the intention of the interaction, and the length of time spent in nature, can all impact the well-being outcomes of an individual's interactions with biodiversity (Pett et al., 2016). Additionally, inconsistency across studies regarding the indicators used to measure biodiversity and mental health and well-being outcomes makes it difficult to establish clear links which are broadly applicable from a planning perspective (Sandifer et al., 2015). Further research using consistent parameters is needed to be able to isolate the cause and effect responses between biodiversity exposure and psychological health and well-being outcomes.

Approaching green/blue space provision through the lens of biodiversity conservation may be an effective strategy for maximizing the ecosystem services provided by these areas. There is a general consensus emerging from the recent ecological literature that maintaining natural biodiversity is fundamental to sustaining the delivery of provisioning, regulating, and cultural ecosystem services which are essential to human welfare (Sandifer et al., 2015). As such, biodiversity may be a useful indictor for measuring the quality of urban green/blue spaces in order to maximize the benefits provided by these areas to surrounding communities. However, it is important for urban planners and developers to consider that not all biodiversity is created equal. For instance, the use of non-native species to enhance biodiversity in urban green/blue space may reduce the ecosystem services provided by these areas (Lyytimaki and Sipila, 2009). Additionally, it is important to consider that high levels of biodiversity may also result in ecosystem disservices, such as attracting nuisance wildlife (von Dohren and Haase, 2015). Lastly, as discussed by Pett et al. (2016), the psychological and well-being benefits provided by biodiversity are highly context dependent. Thus, it is essential for urban-planners and decision makers to treat humans as an integral component of the urban ecosystem and design green/blue spaces that are appropriate for the surrounding communities (Sandifer et al., 2015).

Walking was the most common activity conducted by respondents at the stormwater ponds, and walking trails were rated as the most important feature of stormwater ponds in terms of respondents' use and enjoyment. It is well understood that conducting regular outdoor physical activity is beneficial for one's physical and mental health (White et al., 2019). Beyond appreciating the trails for providing opportunities for recreation, respondents also considered walking trails to be an important infrastructural element for increasing the accessibility of the stormwater ponds for use and enjoyment by the community. For instance, one respondent who selected Photo A (pond with a trail and bench) did so because it "[s]eems to best represent itself as a natural water feature, but is also accessible via the path and bench," while another thought that "[the pond] is in a city, so it should be enjoyed by the community." Another respondent also preferred Photo A because it could be enjoyed by people of all ages and abilities, saying the pond was the "[b]est of both worlds. Most amount of people to be able to enjoy, including young, elderly and disabled."

Goal 11.7 of the UN Sustainable Development Goals is to "provide universal access to safe, inclusive, and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities" (UN General Assembly, 2015). Bierbacka and Kronenberg (2018) identify three levels of institutional barriers which prevent the use of urban green space: availability (does the green space exist), accessibility (are there physical and/or psychological obstacles preventing the use of the green space), and attractiveness (does the user want to spend time there; does the green space correspond to the needs and preferences of the user). The presence of a stormwater pond in a neighbourhood is not enough to classify it as urban green space; it must also have features which make it accessible and attractive to users. The inclusion of walking trails and other recreational infrastructure (i.e. benches) is one way of eliminating barriers that limit the accessibility and attractiveness of the space. For instance, a walking trail may remove a physical barrier for people with limited mobility who would otherwise not be able to access a stormwater pond with highly naturalized surroundings. A trail may also encourage people to spend time at a stormwater pond, thus making it more attractive for use. If stormwater ponds are to be integrated within the urban and suburban landscape as an environmental amenity, it is important that they have features that make them accessible and attractive for use by the surrounding community.

UN Goal 11.7 specifically references the need for universal access to green space for children. Sixty-seven percent of respondents had at least one child in their household on a full- or part-time basis, and the opportunity for outdoor education with children provided by the stormwater ponds was a reoccurring theme throughout the survey responses. For instance, when describing the main advantages of having a stormwater pond in their neighbourhood, one respondent stated that they appreciated "[h]aving the wildlife close by for my children to learn and understand their habitat." There is a growing concern that our increasingly urbanized and technology-dependent society is causing people, especially children, to become disconnected from nature, leading to an "extinction of experience" (Soga and Gaston, 2016). One study from Japan found that the degree of urbanization within a landscape had a significant negative influence on the frequency of children's interactions with nature (Soga et al., 2018). In their investigation into approaches to mitigate the extinction of experience, Soga and Akasaka (2019) found that increasing the number of public green spaces within a landscape can increase the probability of green space use, while increasing the quality of green spaces (i.e. vegetation heterogeneity) is important to facilitate the repeated and prolonged use of green spaces. Stormwater ponds can be used in both landscape management approaches, by both increasing green space availability and featuring diverse vegetation (e.g. wetland plants) which is typically not present in conventional green spaces, such as parks. As such, stormwater ponds may be useful sites to conduct outdoor education and appreciation with children and help prevent an extinction of experience among children living in urban/suburban communities.

5.3 Perceptions of disadvantages of urban stormwater ponds

An overwhelming majority considered the disadvantages of having a stormwater pond in their neighbhourhood to be marginal compared to the advantages. Interestingly, safety concerns over the potential drowning risk of stormwater ponds was not a major concern for respondents as seen in similar studies (Bastien et al., 2011). A fenced shoreline is a common way to mitigate potential drowning risks, however respondents rated this as the least important feature of a stormwater pond in terms of use and enjoyment. Few residential stormwater ponds within the City of Ottawa have fenced perimeters (M-A. Perron, University of Ottawa, personal communication, 2019).

The greatest concern among respondents was presence of mosquitos and other insects at the ponds, with 42% of respondents considering this issue to be a major disadvantage of having a neighbourhood stormwater pond. Stormwater ponds can be favourable habitat for mosquitoes, as their larvae develop in shallow, stagnant, and nutrient rich waters (Jackson et al., 2009). In Canada, there is a growing concern over the spread of mosquito-borne diseases such as West Nile virus (WNv) and malaria, as rising temperatures caused by climate change may lead to the northward range expansion of disease-carrying mosquito species (Hongoh et al., 2012). While one 2009 study from British Columbia indicates that mosquito species which are vectors for WNv may prefer constructed water bodies over natural habitats for reproduction (Jackson et al., 2009), there is little additional evidence demonstrating links between mosquito populations and stormwater management sites in Canada. It is unknown whether the stormwater ponds in the study communities experience a higher mosquito abundance compared to the rest of the area. For instance, Kanata North, where three of the participating community associations are located, has had a perceived mosquito problem over the past several years attributed to the high water table, flat topography, and large number of wetlands in the area (GDG Environment, 2019). To combat this problem, the City of Ottawa implemented the Kanata North Nuisance Mosquito Control Program starting in 2016, which involved contracting an independent environmental firm to spray biological larvicides (*Bacillus thuringiensis israelensis* (*Bti*) and *Bacillus sphaericus* (*Bs*)) on wetlands and marshes during the spring to control snow melt mosquitoes (GDG Environment, 2019). No reports have been published demonstrating the success of the 4-year trial program at reducing mosquito populations. Should the program be renewed in January 2020, it will cost Kanata North residents an additional $20 on their tax bills (CBC News, 2019).

Despite respondents' concerns over the potential for stormwater ponds to be mosquito breeding grounds, proper design and maintenance of these facilities should prevent them from becoming suitable breeding habitat for mosquitoes (EPA, 2005; Valdenlfener et al., 2018). The aquatic larval stages of mosquitoes require 7 to 10 days in standing water (EPA, 2005), while stormwater ponds in Ontario are designed to have a detention period of 24 hours (MECP, 2003). Moreover, mosquito breeding typically occurs in water bodies with depths of less than one meter (EPA, 2005), whereas the average depth of stormwater ponds in Ontario is 1 to 2 meters (MECP, 2003). Additionally, the strategic use of vegetation, including submerged macrophytes, emergent plants, and shoreline trees, can provide habitats for predators that can help manage mosquito populations (Jackson et al., 2009). For instance, stormwater ponds with higher obligate wetland plant species richness may support a higher abundance of mosquito predators such as dragonflies and damselflies compared to ponds with lower species richness (Perron and Pick, 2019).

Odour was a commonly cited issue surrounding the stormwater ponds, mentioned by 21% of respondents as a major disadvantage of having a pond in their neighbourhood. In Riverside South in particular, a stormwater pond with recurring odour issues caused residents to be apprehensive about the construction of additional stormwater ponds in the community (Willing, 2018). The odour was caused by hydrogen sulfide gas, which can be emitted when stormwater ponds experience hypoxic conditions as a result of improper design and/or maintenance (Chen et al., 2017). To address this problem, the city invested in a $150,000 aeration system to increase levels of dissolved oxygen and prevent the production of hydrogen sulfide gas (Willing, 2018). This case from Riverside South illustrates the importance of proper design and maintenance of stormwater management systems to prevent odour issues, which can be a major deterrent to the public use and enjoyment of these sites.

Concerns among respondents over the pollution and litter in and around the stormwater ponds highlight the ongoing challenge of balancing pond maintenance with pond "naturalness." One respondent cited "[p]oor ongoing maintenance by the City and/or land developer. Garbage blows in and is left; grass not cut and plants not maintained/plants overgrown." Respondents rated cleanliness as the third most important feature of stormwater ponds in terms of their use and enjoyment, which is consistent with other studies in which survey participants rated neatness and cleanliness highly for ponds and other types of blue/green infrastructure (Ngiam et al., 2017; Suppakittpaisarn et al., 2019; Williams et al., 2019). Despite rating cleanliness highly, there was a lack of consensus over the need for increased pond maintenance, with a greater proportion of respondents who were neutral/did not want any additional maintenance compared to those who wanted better maintenance. This discrepancy is likely due to concerns that increased levels of maintenance would jeopardize the "naturalness" of the ponds. One potential solution to manage pond maintenance and increase community satisfaction with their neighbourhood stormwater pond is to implement an "Adopt-A-Pond" program. This type of program has been successfully implemented in other Canadian cities, such as the City of London, Ontario. The City of London's program is a partnership between the City and residents, where community members volunteer to help "maintain, beautify, enhance and keep the [stormwater] pond safe for all to enjoy." (City of London, 2018). With support from the City, pond adopters host a minimum of two pond clean-ups per year (spring and fall), observe conditions at the pond and report any problems, and share information with other homeowners (City of London, 2018). An Adopt-a-Pond program may be an effective solution to address residents' concerns over pond maintenance, while also providing citizens with an opportunity to participate in community-led environmental stewardship that can foster a sense of community and improve their well-being (Dennis and James, 2016).

5.4 Multifunctionality

The concept of multifunctionality has gained popularity in urban green infrastructure planning as an effective strategy to enhance the sustainability and resilience of cities (Sussams et al., 2015). As urban centres continue to densify and green/blue space becomes more limited, it will likely be impossible to maintain green space dedicated for single-use purposes such as recreation (e.g. parks, sports fields), food provision (e.g. gardens), or flood management (e.g. swales). Single-use green/blue space can lead to fragmented and unevenly distributed ecosystem services in an urban area, resulting in the inequitable allocation of the benefits provided by these services. Rather, increasing the capacity of urban green/blue spaces to provide multiple provisioning, regulating, and cultural services to the surrounding community can help make cities more resilient (Demuzere et al., 2014). The results of the present study clearly demonstrate that urban stormwater ponds have the capacity to be multifunctional urban blue/green spaces that provide social benefits to communities in addition to their hydrological functions. For the multifunctional capacity of urban green/blue space to be fully realized, Hansen et al. (2019) recommend (1) assessing existing green/blue space for their ecological, social, and economic functions; (2) developing guidelines and standards for multifunctionality in city-planning; (3) recognizing that not all green/blue spaces must deliver the same ecosystem services; (4) considering the role of urban green/blue space in the wider green infrastructure network; and (5) fostering collaboration across sectors. Combining recreational and social amenities with stormwater management functions, as exemplified by the stormwater ponds in this study, is an excellent opportunity to create multifunctional green/blue spaces that provide environmental and social sustainability benefits to their surrounding communities.

5.5 Policy Implications

Several policy implications can be drawn from this study, which should be considered by developers and/or municipalities as they continue to build stormwater ponds. Guidelines and standards should be included in stormwater management policies for the use of features that maximize the cultural ecosystem services provided by stormwater ponds. These guidelines should be informed by further research that builds upon the present study examining the social benefits provided by stormwater ponds. The most highly valued features of stormwater noted by respondents in this study (wildlife and walking trails) would likely be amenities in communities outside of the study area. However, it is also important for developers and planners to consider the needs of their communities and include features that are relevant and appropriate. Therefore, when designing stormwater ponds and other forms of green infrastructure, it is important to consider humans as an integral part of the landscape and include design elements which maximizes the health and well-being of urban residents.

Collaboration is needed across sectors in order for stormwater ponds to be successfully integrated as environmental amenities into the urban landscape. While the design of stormwater ponds is primarily lead by hydrologists and engineers, it is important to involve municipal planners in the design process in order to situate the pond within a city's broader green space network. Additionally, local community leaders and public health experts may provide specialized insight into how the design of stormwater ponds can be improved to provide health and well-being benefits to surrounding communities. Thus, this research provides evidence in support of an interdisciplinary approach to stormwater management, taking into account the environmental, social, and economic benefits that may be derived from strategic green and blue infrastructure planning.

This research also highlights the importance of including provisions for multifunctional green and blue infrastructure within broader sustainability policies. Many federal, provincial, and municipal jurisdictions are developing sustainability policies/strategies to maximize community resilience and increase climate change adaptation capacity. These policies often include measures to preserve natural capital and maximize the benefits of urban green space. For instance, Canada's Federal Sustainable Development Strategy includes an action to "support the development of green space in urban areas to increase opportunities for residents to connect with nature" (ECCC, 2019). Ontario's Environment Plan outlines goals to protect natural areas and update land use policies to help communities be more adaptive to climate change, such as improving stormwater management practices (MECP, 2018). Within the National Capital Region, the National Capital Commission (NCC) and the City of Ottawa have each developed sustainability/resilience plans that detail current and future actions to address urban sustainability goals (City of Ottawa, 2012). An aim of NCC's strategy is to make green space more accessible to the public (National Capital Commission, 2018) and the City of Ottawa's plan includes actions to enhance green space and improve the City's green space network (City of Ottawa, 2012). The City of Ottawa's plan specifically notes an action to "[l]ook for new opportunities to develop or maintain natural areas in public parks and adjacent to stormwater management ponds and other public infrastructure" (City of Ottawa, 2012).

This research presents stormwater ponds as one solution to fulfill the green space requirements of sustainability and resilience policies that has potentially been overlooked in urban landscape planning. The findings of this study illustrate that in order for stormwater ponds to function as urban green and blue space, not only do they have to be present within a landscape, but they have to be accessible and attractive for use. Not all green/blue space is created equal, and this research shows that some features of stormwater ponds are more attractive for public use and enjoyment than others. Additionally, this research indicates that certain barriers, such as the presence of mosquitos, smell, and improper maintenance, would prevent stormwater ponds from being used as green space. These barriers should be considered by planners and developers in the design and maintenance of these facilities to ensure they are prevented. The findings of this research illustrate the potential benefits of incorporating the concept of multifunctional green infrastructure into sustainability and resilience policies in order to maximize the ecosystem services provided to urban communities.

Lastly, increasing levels of awareness on the co-benefits provided by stormwater ponds and other forms of green/blue infrastructure is essential for generating widespread support of these systems (Apostolaki et al., 2006). This increased awareness must happen not only amongst the public, but also amongst landscape planners and decision-makers in order for them to be knowledgeable proponents of multifunctional green/blue infrastructure. Therefore, interdisciplinary research examining the ancillary benefits of green/blue infrastructure must continue to be published and shared across sectors, and an information exchange of practical lessons for multifunctional green/blue infrastructure design must occur within the professional planning network and across municipalities.

5.6 Limitations

It is important to address the various limitations of this study. First, there are inherent limitations associated with survey-based research, most notably the introduction of biases. Online surveys such as the one used in this research can be subject to self-selection bias, which is bias introduced by the fact that survey respondents select themselves to participate in the survey, thus creating a non-random sample (Bethlehem, 2010). Self-selection bias is related to non-response bias, which is when the results of a survey become non-representative as the opinions of survey respondents differ from those of non-respondents (Billiet and Matsuo, 2012). Individuals who feel neutral toward a topic may be less inclined to participate in a survey, and thus the results may not represent the true spread of opinions.

Another limitation of this study is that the method of survey distribution prevented calculating a response rate. Response rate is an important metric for determining the representativeness of a sample population (Baruch and Holton, 2008). In this case, using social media platforms like Facebook groups/pages made it challenging to track the survey's reach and thus calculate a response rate. Additionally, collecting the necessary data to calculate a response rate would have placed an even greater burden on the community associations, which already dedicated a generous amount of time and effort to assist with distributing the survey. While providing a response rate would have strengthened the results of the survey, the exploratory nature of this research means that the results can still reveal important insights even in the absence of this metric.

Another limitation of this study is that the socio-economic demographics of the surveyed communities are relatively homogenous, with a large proportion of the respondents having a household income above the City of Ottawa average. The lack of low-income communities in this study is notable, especially given that marginalized communities often lack access to quality green/blue space compared to more affluent communities (Wolch et al., 2014). The findings of this research would have been strengthened by including perceptions from residents living in lower-income communities to determine if stormwater ponds in these neighbourhoods have an equal capacity to provide social benefits as the stormwater ponds located more affluent communities.

5.7 Areas for Further Research

This research illustrates that stormwater ponds can provide many of the same social services as other forms of urban green space, such as parks, by providing communities opportunities for immersion in nature and outdoor recreation. However, one element that this research did not address is whether when given the option, people would prefer to recreate at a stormwater pond facility or at a park. Some studies suggest that people may prefer to spend time in outdoor areas with water features over areas without water (White et al., 2010; Volker and Kistemann, 2011). While the results of this survey illustrated that people value the recreational and social amenity provided by stormwater ponds, no conclusions can be made as to whether respondents prefer recreating at stormwater ponds over other forms of green space. The findings of this study would be complemented by additional research that investigates the public's preferences for different types of green/blue space, thus revealing which features of green/blue space are the most valued by the public.

6 Conclusion

Prior to this research, the capacity of urban stormwater ponds to provide ancillary benefits to communities had not been investigated in Canada. This exploratory study successfully used an online survey to collect a range of perspectives on the social value of urban stormwater ponds in six communities in the City of Ottawa, Ontario. This research is extremely relevant to current landscape management priorities across the City of Ottawa, as seen in campaigns to protect green space lead by local non-profits such as Ecology Ottawa's Living City Program (Ecology Ottawa, n.d.) and the Kanata Greenspace Protection Coalition (2019). The results of this research reveal that stormwater ponds have the capacity to provide cultural ecosystem services to suburban communities in addition to their main hydrological functions. For this capacity to be maximized, design features which support native wildlife and provide opportunities for outdoor recreation (i.e. trails) are recommended. The methods used in this research can and should be replicated in other Canadian municipalities, with researchers making an effort to include perspectives from low-income and marginalized communities. This research is useful for developers, as it demonstrates that stormwater ponds can add value to neighborhoods beyond their intended infrastructural purpose if their design includes features which support public use and enjoyment. Designing stormwater ponds to be multifunctional urban green/blue spaces that provide both environmental and social benefits to surrounding neighbourhoods will help maximize the sustainability and resilience of urban and suburban communities.

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Appendices

Appendix A: The survey questions used in the online survey with the implied consent text.

PAGE 1

Title of the study: Public perception of urban stormwater ponds as environmental amenities

Supervisor: Dr. Frances Pick, Professor, Department of Biology, University of Ottawa, Ottawa, ON

Student - Researcher: Charlotte Heller, M.Sc. in Environmental Sustainability Candidate, Institute of the Environment, University of Ottawa, Ottawa, ON

Invitation to Participate: You are invited to participate in the abovementioned research study conducted by Charlotte Heller, who is being supervised by Dr. Frances Pick. This research is being conducted as a part of Charlotte Heller's Master's Thesis.

Purpose of the Study: From this research we wish to learn how stormwater ponds in suburban neighborhoods of Ottawa are perceived by residents and how the attributes of the stormwater ponds influence the public's perception of these facilities.

Participation: Participating in this study requires completing an online survey that should take less than 10 minutes. You do not have to answer any questions that you do not want to answer. If you wish to participate in this study, please complete the following survey. Your decision to complete and submit this survey will be interpreted as an indication of your consent to participate.

Benefits: The information collected in this study will provide useful insight into how stormwater ponds can be designed to offer both environmental and social benefits to urban communities. The results of this study can be used by decision-makers and planners when designing new stormwater ponds to maximize the public's enjoyment of these facilities.

PAGE 2

Confidentiality and Anonymity: The information that you will share will remain strictly confidential and will be used solely for the purposes of this research. The only people who will have access to the research data are the primary investigator and her supervisor. Your answers to open-ended questions may be used verbatim in presentations and publications but you will not be identified. In order to minimize the risk of security breaches and to help ensure your confidentiality we recommend that you use standard safety measures such as closing your browser and locking your screen or device when you are no longer using them or when you have completed the study.

Results will be published in pooled (aggregate) format. Anonymity is guaranteed since you are not being asked to provide your name or any identifying personal information.

Conservation of the data: The survey data will be stored temporarily online during the data collection and analysis period, after which it will be securely downloaded and deleted from the internet and stored indefinitely on a password protected computer.

Voluntary Participation: You are under no obligation to participate and if you choose to participate, you may refuse to answer questions that you do not want to answer. Completion and submission of the survey by you implies consent. Once you submit the survey, you will be unable to withdraw your data from the study as the researchers will be unable to retrace individual data sets. Participants should print a copy of the consent form to keep for their personal records.

Information about the Study Results: Upon successful completion of this master's thesis, this study will be made available on the University of Ottawa's Institute of the Environment website.

If you have any questions or require more information about the study itself, you may contact the research supervisor at the number mentioned herein.

If you have any questions with regards to the ethical conduct of this study, you may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5, tel.: (613) 562-5387 or ethics@uottawa.ca.

Thank you for your time and consideration.

Charlotte Heller
Dr. Frances Pick

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Introduction: Stormwater is water that originates from rainfall and melting snow and ice. This water can soak into the soil, get absorbed by plants, evaporate, or become runoff which eventually enters sewers. Stormwater ponds are typically designed to receive the stormwater runoff from sewers and protect neighborhoods from flooding. One such type of pond has a permanent pool of water; these ponds are quite common across the City of Ottawa, especially in newer residential areas. In this survey, "stormwater pond" refers to ponds with a permanent pool of water which may resemble small lakes that are present in residential or industrial areas.

1. Do you live within walking distance (5-min walk) of a stormwater pond?
   - ☐Yes
   - ☐ No
   - ☐ I don't know

   (Respondents who answered "No" or "I don't know" were sent directly to Question 4.)

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2. Do you have a view of a stormwater pond from your residence?
   - ☐Yes
   - ☐No
   - ☐I don't know

3. How important was the presence of the stormwater pond for your decision to move in to your residence?

Very important ☐	Important ☐	Moderately important ☐	Slightly important ☐	Not important ☐	I don’t know ☐

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4. How satisfied are you with the amount of open space (e.g. parks, forest, water bodies) in your neighborhood?

Very satisfied ☐	Satisfied ☐	Neutral ☐	Dissatisfied ☐	Very dissatisfied ☐	I don’t know ☐

5. The stormwater pond in my neighborhood is *(please select one)*:
   ☐A natural pond that can be affected by rainfall
   ☐A natural pond that receives stormwater when it rains
   ☐A constructed pond built where no pond previously existed for stormwater
   ☐I don’t know

6. What type of activities do you do at the stormwater pond closest to your residence? *(Please select all that apply)*:
   ☐Walking/physical activity
   ☐Viewing wildlife (e.g. birdwatching)
   ☐Photography
   ☐Outdoor appreciation
   ☐Outdoor activities with family members, e.g. children
   ☐Socializing with members of my community
   ☐Relaxing
   ☐Enjoying nature
   ☐None
   ☐Other *(please specify)*:

   Click or tap here to enter text.

7. How often do you participate in the activities at the stormwater pond you identified in question 6?
   ☐Daily
   ☐Weekly
   ☐Monthly
   ☐A few times a year
   ☐Not applicable

8. What would you consider to be the most important benefits of having a stormwater pond in your neighbourhood (if any)? Please write your response below:

Click or tap here to enter text.

9. What would you consider to be the greatest disadvantages of having a stormwater pond in your neighbourhood (if any)? Please write your response below:

Click or tap here to enter text.

10. The benefits of having a stormwater pond in your neighborhood outweigh the disadvantages:

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	I don't know
☐	☐	☐	☐	☐	☐

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11. Rate the importance of the following features of a stormwater pond, in terms of use and enjoyment of the facility:

	Very important	Important	Moderately important	Slightly important	Not important	I don't know
Open water	☐	☐	☐	☐	☐	☐
Clear water	☐	☐	☐	☐	☐	☐
Shoreline vegetation	☐	☐	☐	☐	☐	☐
Trees	☐	☐	☐	☐	☐	☐
Walking trails	☐	☐	☐	☐	☐	☐
Cleanliness	☐	☐	☐	☐	☐	☐
Aquatic vegetation	☐	☐	☐	☐	☐	☐
Fenced shoreline	☐	☐	☐	☐	☐	☐
Benches	☐	☐	☐	☐	☐	☐
Interpretive signs	☐	☐	☐	☐	☐	☐
Presence of wildlife	☐	☐	☐	☐	☐	☐
Mowed grass to shoreline	☐	☐	☐	☐	☐	☐

12. Please indicate your level of agreement with the following statements:

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree	I don't know
The stormwater pond closest to my residence is healthy	☐	☐	☐	☐	☐	☐
I am concerned that the stormwater pond closest to my residence is polluted	☐	☐	☐	☐	☐	☐
I would like for the stormwater pond closest to my residence to have better maintenance	☐	☐	☐	☐	☐	☐
I wish the stormwater pond closest to my residence was more conducive to recreational use and enjoyment	☐	☐	☐	☐	☐	☐

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13. Which of the following stormwater ponds appeals the most to you? Please select one image:

Mature vegetation, wetland plants

Shoreline plants, trail, benches

Mowed grass, fountain, clear water

14. Please explain your choice for question 13:

Click or tap here to enter text.

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15. What is your total household income, after tax?
    - ☐ $0-$50,000
    - ☐ $50,000-$100,000
    - ☐ $100,000-$150,000
    - ☐ Over $150,000
16. What is your age?
    - ☐ 18-30
    - ☐ 30-45
    - ☐ 45-60
    - ☐ 60-75
    - ☐ Over 75
17. What is your gender?
    - ☐ Male
    - ☐ Female
    - ☐ Other gender identity
    - ☐ Prefer not to say
18. How many adults reside in your household?

    Click or tap here to enter text.

19. Does at least one child reside in your household on a full-time or part-time basis?
    - ☐ Yes
    - ☐ No

END OF QUESTIONNAIRE

Appendix B. Evaluation of the draft survey completed by individuals who participated in the survey pre-testing process.

SURVEY EVALUATION

1. How long did it take you to complete this survey?
   Click or tap here to enter text.

2. How would you rate the level of difficulty of this survey?
   ☐Very difficult
   ☐Difficult
   ☐Moderately difficult
   ☐Slightly difficult
   ☐Not difficult

3. Was there any terminology used that you did not understand? Please specify below:
   Click or tap here to enter text.

4. Were there any questions you found confusing? Please explain your response below:
   Click or tap here to enter text.

5. Were there any questions you could not answer? Please explain your response below:
   Click or tap here to enter text.

6. Any other comments:
   Click or tap here to enter text.

Thank you for your participation. Please email this completed survey pre-test to Charlotte Heller.