Urban Pond Management for Improved Stormwater Control and Biodiversity

Trade-offs, Practices, and Roles in Urban Contexts

Mohamed Ehab Zarifa

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Swedish University of Agricultural Sciences, SLU
Faculty of Natural Resources and Agricultural Sciences
Landscape Engineer Programme – Uppsala
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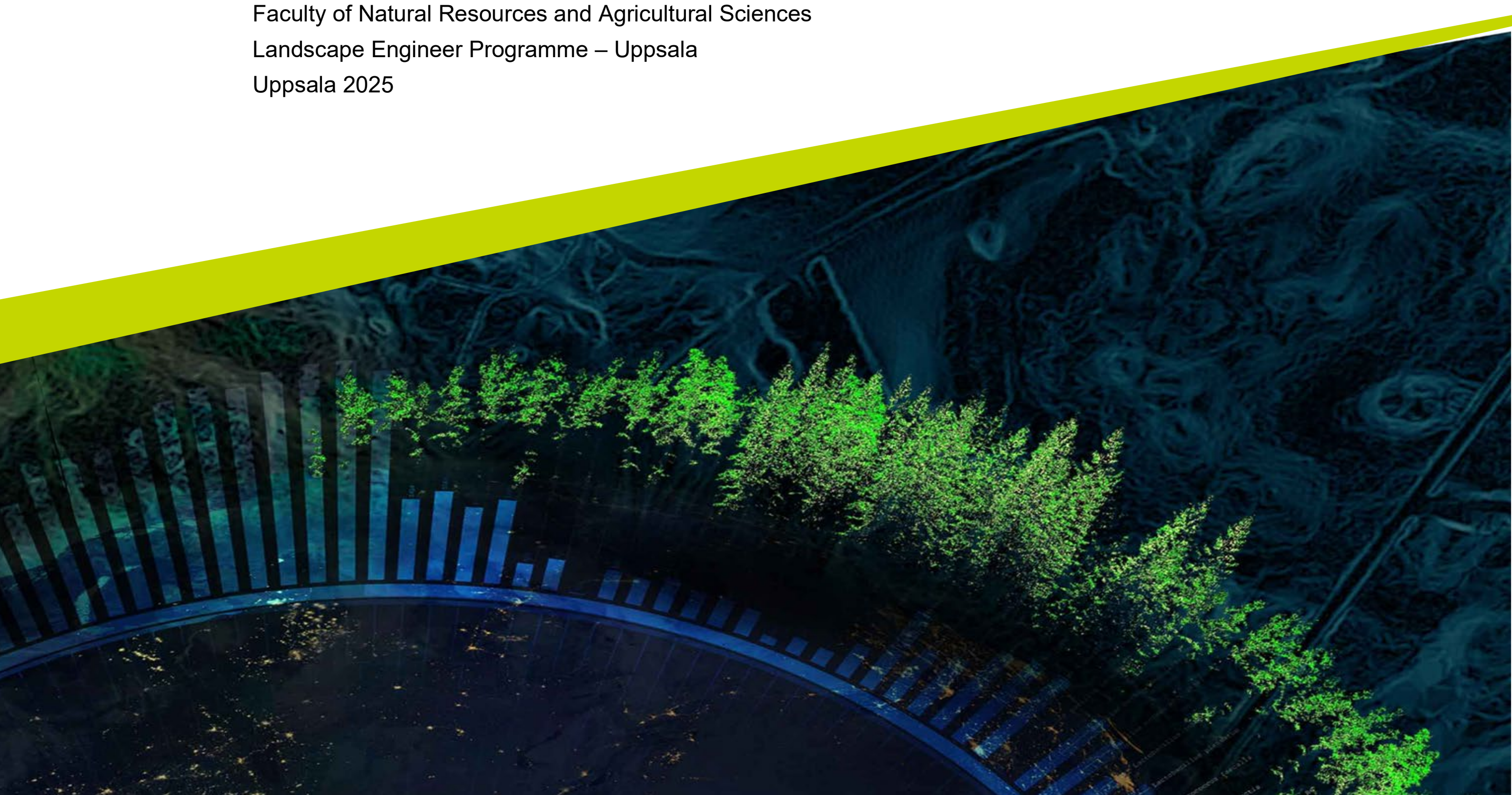

Urban Pond Management for Improved Stormwater Control and Biodiversity – Trade-offs, Practices, and Roles in Urban Contexts

Förvaltning av stadsdammar för förbättrad dagvattenhantering och biologisk mångfald – Avvägningar, praxis och roller i urbana sammanhang

Mohamed Ehab Zarifa

Supervisor:	Anna Lundvall, Swedish University of Agricultural Sciences, Department of Urban and Rural Development
Examiner:	Vera Vicenzotti, Swedish University of Agricultural Sciences, Department of Urban and Rural Development

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Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Urban and Rural Development
Division of Landscape Architecture

Abstract

The focus of the study is on pond management in urban areas for the better control of stormwater runoffs, as well as increasing biodiversity in urban areas. Although there is an increasing number of implementations of the concept of urban ponds, there is scant literature available on the management aspects of these structures once the pond is constructed. The question the study seeks to answer is: What roles and management practices support stormwater mitigation and biodiversity enhancement in urban ponds?

A qualitative method is used, with the study depending on secondary sources from the academic literature. The secondary data is systematically analyzed, with the six steps provided by Braun & Clarke followed in the process of determining the themes from the study. The themes emanating from the study are the role of urban ponds in the conservation of freshwater biodiversity, the management of stormwater runoff, as well as sustainability in the urban environment.

The themes that emerged from the analysis are three: (1) the ecological role of urban ponds in the support of freshwater biota, (2) the technical management practices necessary to maintain stormwater regulation, and (3) the social aspects of the maintenance process, which establish the nexus with policy support.

The importance of maintenance, the control of water quality, and the involvement of specialized equipment or personnel is made clear by the study results. Good management practices, including the prevention of pollution or the provision of habitat, are necessary for the achievement of stormwater management, as well as the protection of biodiversity.

Keywords: Urban pond, Biodiversity, ecosystems services, Stormwater management, Retention Pond, Urbanization.

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Abbreviations

EU	European Union
GI	Green Infrastructure
GBI	Green–Blue Infrastructure
EPA / US EPA	Environmental Protection Agency (United States)
BMP	Best Management Practices
N / P	Nitrogen / Phosphorus
CBM	Community-based monitoring
RQ	Research question

1. Introduction

Urbanisation has increased the importance of urban ponds, both in city planning and in research (Higgins et al., 2019). These ponds, together with lakes, comprise a part of what is commonly termed green-blue infrastructure (GBI).

Basically, GBI is a network of natural and semi-natural areas that cities try to manage in order to provide services such as flood control, water cleaning, and habitat for different species (European Commission, n.d.). This infrastructure may incorporate green elements like parks, forests, and even green roofs, but also blue features such as rivers, lakes, wetlands, and ponds.

Ponds and lakes can be differentiated based on one basic characteristic, that is, size and depth. According to Freshwater Habitats Trust (n.d.), any water body that is below two hectares (or 20,000 square meters) and shallow enough for sunlight to reach the bottom is typically considered a pond. Oertli and Parris (2019, p. 6) describe the distinctive characteristics of urban ponds as follows:

> In synthesis, compared to natural or rural ponds, urban ponds are often smaller, shallower, younger, with a more regular shoreline; they include artificial structures (bottom or margin), and they are located within a built environment. Water quality is often poor due to pollution, and urban ponds commonly support exotic species (including plants, fish, and ducks).

Green infrastructure, as it is used within this context, refers to the integration of vegetated and water-based features in the urban environment. The purpose is to increase biodiversity, manage stormwater, in addition to creating spaces that can be enjoyed in a recreational way (Li et al., 2017; Persson, 2012).

Increasingly, developers are acknowledging this value, and ponds are one of the features being built to support ecosystem services and make urban areas more resilient.

Some studies have been conducted involving ponds and biodiversity, though most of those studies are focused on wider issues of pattern or ecosystem service in general (Krivtsov et al., 2022). For instance, there is evidence that ponds and green spaces help in the conservation of fauna, climate change adaptation, as well as enhancing the quality of water (Krivtsov et al., 2022). What is not well documented is the management of ponds after construction, and which practices help sustain these benefits over time.

Still, the issue of managing stormwater in cities is a challenge. Ponds in urban areas act as one of the solutions in the overall GBI system that assists in this process in several ways, including reducing flood risk, enhancing water quality, as well as assisting in urban biodiversity (Krivtsov et al., 2022; Hill et al., 2016). This rainwater often contains nutrients as well as pollutants from the impervious surface in cities, and ponds help store this water before it reaches downstream systems (Krivtsov et al., 2022).

In the last years, research about urban ponds has increased. This is a sign of a rise in the number of ponds in cities, as well as the importance of ponds in terms of both ecological and social factors (Krivtsov et al., 2022; Hill et al., 2018).

Even with this progress, there are still gaps in knowledge. A key missing topic is the post-construction management of ponds, as well as the optimal means of maintaining them in order to continue to enjoy the benefits over time (Oertli & Parris, 2019). Knowledge of pond ecology and pond management is significant for policymakers, planners, as well as the public. Local authorities, in particular, need clear knowledge about the services that ponds can provide. This is imperative in situations where urbanisation continues to exert more stress on biodiversity, as well as in situations where sustainable development is a goal in urban areas (Hassall & Anderson, 2015).

This thesis will aim to outline the roles, responsibilities, and practices that are part of urban pond management. The main focus is on how ponds contribute to stormwater control and biodiversity in urban areas. By addressing these issues, it is believed that this will help in enhancing the understanding of pond ecology, as well as offer contributions that will help towards increased acceptance of ponds in cities (Oertli & Parris, 2019; Spotswood et al., 2021). Good management is required if ponds are to retain their ecological function in order to ensure that cities are resilient and biodiverse (Oertli & Parris, 2019).

1.1 Problem statement

Despite the prospective benefits, there needs to be more research on urban pond management, considering their role in stormwater runoff mitigation and biodiversity enhancement. Spotswood et al. (2021) explain that there is scarce literature focusing on urban ponds management. There is a need to examine the management of urban ponds after implementation due to their role in increasing biodiversity movement in urban areas.

While there may not be a wealth of literature specifically focused on managing water ponds for stormwater runoff mitigation and biodiversity enhancement, the responsible actors, such as municipal authorities, urban planners, environmental agencies, and utility companies (who often maintain water infrastructure and stormwater systems) can still apply many general principles and best practices. Additionally, regional and state agencies may contribute oversight, and local communities, citizens, and NGOs often play a role in stewardship and monitoring (European Commission, n.d.; Esmail et al., 2022; Oertli & Parris, 2019; Hill et al., 2016; Krivtsov et al., 2022).

Stormwater runoff is a primary concern for urban areas as it can cause flooding, water degradation, and biodiversity loss. To address this issue, this study will focus on how these collective management approaches can improve stormwater runoff mitigation and enhance urban biodiversity, aiming to provide practical insight informed by both literature and real-world practices.

1.2 Purpose of the Study

The purpose of this study is to investigate the role of post-constructed urban pond management in improving stormwater control and enhancing biodiversity. The focus in it will be on cities where urban ponds are designed from the beginning as part of green blue infrastructure but still require the active management to function as intended.
After being constructed, ponds depend on management to monitor their operation. Through tasks such as maintenance, monitoring, pollution control, and habitat care, management can determine the long-term success or failure of these systems.

Therefore, this study will highlight and evaluate how current practices align with responsibilities set out in municipal regulations, environmental policies, and scientific frameworks (Oertli & Parris, 2019; Hassall, 2014; Hill et al., 2016; Krivtsov et al., 2022; Esmail et al., 2022; European Commission, n.d.).

1.3 Research questions

1-What does existing research reveal about how urban pond management affects water quality and the ecosystem's health?

2-Which management tools and techniques are identified as effective, with various climates and habitat types?

3-What are the best practices and main challenges described in the literature for maintaining urban ponds during their operational phase?

2. Methodology

For this study, I have selected various articles and reports that are available, and having an approach that gives me some flexibility with the way in which I analyze the evidence is sensible in these circumstances. I chose to go with a qualitative literature review with my own interpretation and comparing a range of sources dealing with urban pond management and its effects on stormwater and biodiversity.

The method of thematic analysis I used was Braun & Clarke's from 2006. The process began with familiarizing myself with the literature, which included extensive readings, taking notes, and even some revisit readings if something wasn't fitting just right there. Following the initial steps, the process moved on to the organization of the codes, grouping them until some clear themes emerged. There was some review and refinement involved before the main points began to be clear, then working to pull everything together to explain just how pond management post-construction actually works.

Regarding the sources, I tried to be organized in my search, starting with peer-reviewed articles, major reports, or documents that centered on the more practical side of managing ponds in the urban area. There were also some articles that featured valuable information on maintenance, surveillance, or the problems encountered in taking care of the habitat.

With each research question as a guide, I noticed that different authors took varied approaches. Investigating water quality and ecosystem health meant focusing on ecological outcomes, but for tools and techniques, I paid attention to how strategies changed across different environments. Best practices and challenges came up often in the literature and sometimes led me to rethink how I grouped my findings.

All the while, I used thematic coding to keep data organized. This enabled me to develop a qualitative synthesis that went beyond answering the study questions to pointing out the existing questions that had yet to be addressed. To be sure, I opted to synthesize qualitatively because the question is complex, context-dependent, and cannot be encapsulated in numbers alone.

This method helped me gain perspective on the work that is already out there without having to do my own field study, which makes my plan practical and, hopefully, informative.

2.1 Research design

While selecting a study design, the researcher's methodological assumptions guide the choice and explain the researcher's traits (Kothari, 2004). The current study employs a qualitative methodology and descriptive design, with assumptions guiding data collection and analysis.

These assumptions guided how data were collected and interpreted, and even more, they shaped the conclusions that emerged from the analysis. I considered two key aspects: the need of topic specificity and the use of inductive reasoning (Daniel and Sam, 2011). Inductive reasoning and gathering general meanings allowed me to develop particular knowledge using qualitative methodology.

The descriptive design assumes that detailed data are needed to provide rich descriptions, requiring large amounts of data to apply findings to similar situations. I focused on the issue at hand, analysed it, and drew broad generalisations (Daniel and Sam, 2011). This design helps describe research challenges and can be a springboard for further study.

Interpretivism lets the researcher interpret and generate meaning from collected information through interaction between the researcher and the data (Alharahsheh and Pius, 2020). Since this investigation involves interpreting information, the research process inevitably affects the problem. Gathering ideas and applying data helps understand management of urban ponds in urban environments, considering their roles in stormwater mitigation and biodiversity enhancement (Alharahsheh and Pius, 2020).

2.2 Data collection

The following stage of my plan was to identify and select the appropriate materials from the available articles and reports, starting from the systematic process previously described. I have needed an approach that allows flexibility to examine the evidence. The focus was neither on acquiring all the available information nor on material, but rather on identifying those that could provide information about how to manage post-constructed urban ponds and in which way this affects stormwater and biodiversity.

I relied on peer-reviewed sources to ensure reliability but also included policy reports that offered practical data. Some of these texts described daily practices, such as routine maintenance, water quality monitoring, or dealing with pollution and habitat pressures. I was lucky to find a broader policy or planning perspective, which helped to place those practices in context. Both analysing and studying sources presented detailed descriptions on the one hand, with broad, higher-level information on how to tackle the questions raised in the study on the other.

Once I located the desired materials, I worked through them using an iterative process: close reading, note-taking, and revisiting earlier choices when a source revealed relevance to more than one research question—for instance, a study on algae control was more than just related to water quality but also about long-term maintenance challenges. Fortunately, these overlaps were beneficial because they illustrate how different aspects of management are often connected in practice.

Regarding the management strategies or techniques, I narrowed my search to those that involved different climate or habitat conditions. For best practices and challenges, I noted cases where ponds succeeded, but also those where problems such as lack of funding or poor coordination caused limitations for their effectiveness.

However, the method of sourcing information had some challenges—in the form of regional imbalance, some regions were overrepresented in the literature, while others had little to contribute; nevertheless, it allowed me to build a diverse base of evidence. The method will also give me the entire range necessary to establish the areas covered or the areas with significant information deficits.

2.3 Data Analysis

For this study, I conducted a hands-on, systematic approach to analyze the data, relying on the six steps of Braun & Clarke's thematic analysis procedure, as described by Charalambous (2022). Since all my information came from existing literature, I didn't use any statistical tools—instead, the focus was on interpreting the texts thoughtfully and qualitatively.

It began with me familiarizing myself with the information and the material, meaning going through the articles and reports, taking notes, sometimes going back to areas that weren't clear yet, etc. Next came the process of coding, wherein I highlighted areas of the information that seemed crucial to the points covered in the study.

Starting with these initial codes, I began looking for some pattern, some way in which the themes kept reappearing, linking different pieces of the data together. This wasn't always easy, you understand—I had to refine my themes a couple of times, checking that indeed the themes that emerged accurately represented the messages the data was trying to convey to me before setting about developing them into the narrative or coherent story.

Using thematic analysis helped me organize a lot of information in a way that made sense, revealing compelling relationships between and trends around urban pond management, stormwater control, and biodiversity. In the end, this method allowed me to build a logical argument, all grounded in carefully coded qualitative evidence (Charalambous, 2022).

2.4 Scope, Criteria, and Limitations

Scope. This study is focused on published research and reports dealing with the management of constructed urban ponds. The main focus is on how post-construction practices contribute to stormwater control and biodiversity in the urban context. Studies on constructed ponds in rural context, aquaculture, or other non-urban water bodies were not considered, as they fall outside the study's objectives.

Criteria. The sources used consisted of mainly academic sources from publications, reports, grey literature, or academic sources related to the involvement of urban ponds in stormwater mitigation or biodiversity. Only sources with English publications have been used, hence consistency in the meaning of interpretation is ensured.

Searches were carried out in several databases, including Web of Science, Science Direct, Primo, SpringerLink, and Google Scholar, using keywords such as *urban ponds*, *pond management*, *stormwater runoff*, *biodiversity*, and *urban cities*. Articles were screened in stages: duplicates removed, titles and abstracts checked for relevance, and then full texts reviewed against the criteria. Sources that lacked sufficient or relevant information were excluded, while those that contributed to at least one of the research questions were retained.

Limitations. Like all literature reviews, some limitations had to be accepted within the context of the current study. The reliance on English-language sources excluded potentially valuable studies published elsewhere. Access to full texts and time available for review also limited the breadth of material that could be covered within the scope of a bachelor's thesis.

In addition, interpretation of qualitative data is not entirely free from subjectivity. The current study is also taken from the personal background, beliefs, and experiences, meaning there is the possibility of influencing the study. Complete neutrality is unlikely, but steps are taken to be self-conscious and reflective to minimise bias and present the findings as fairly as possible.

2.5 Ethical Considerations

This research is grounded on a systematic literature review, using only publicly available documents and published sources, not original data from human subjects (Grinyer, 2009).

No direct ethical approval was required for the review process.

Data integrity was maintained by providing the entire result without copying or modifying the original material.

The requirement for originality, citation, was also maintained throughout, consistent with the requirement for academic secondary data analysis.

3. Literature Review

This chapter will focus on the key areas that define the study on managing urban ponds. To begin with, I will explore some of the current practices that emerge in the process of trying to manage ponds in urban areas (Section 3.1). The next section will then reveal why these ponds are so important for supporting biodiversity in the midst of the city itself (Section 3.2). Finally, I explore how urban ponds tie into bigger environmental goals—connecting what happens in these small patches of water with urban planning, development pressures, and policy issues (Section 3.3).

By bringing together these perspectives, the chapter lays out the groundwork for understanding how thoughtful management of urban ponds can help cities become more resilient and biodiverse. Hopefully, this review helps answer the questions raised earlier and makes a case for why urban pond management deserves more attention.

3.1 Urban Pond Management

Urban ponds receive scant attention, yet their significance cannot be ignored within the urban environment. Most of these ponds are human-made, meaning that to be beneficial, they must receive constant maintenance to ensure their functionality is optimized. When managed well, they are able to prevent floods, purify the effluent, or create mini-environments for the survival of animals in hostile areas (Ramaiah & Avtar, 2019; Zuniga-Palacios et al., 2021).

The challenge is that ponds are not always as safe as they appear to be to the naked eye. Birds and other animals may be drawn to them, but pollution or repeated disturbance can turn them into poor habitats. These situations, known as ecological traps, show that simply creating ponds is not enough. Careful monitoring and flexible management are needed if they are to remain reliable refuges (Oertli & Parris, 2019).

Pond ecology in urban areas also impacts the adaptation among the species existing in that habitat. For example, amphibians exhibit strong adaptability abilities to chemicals or water changes in their surroundings. Although adaptation is beneficial for the survival of the species, the adaptability of the species can be seen as an indicator of stress or reduction in the population, which is important for the conservation of the species by the managers of the environment (Lambert & Donihue, 2020).

The biggest pressure is from urban living itself. The runoffs from the roads, gardens, and residential areas bring oils, fertilizers, and other chemicals into the pond. Big sewerage systems alleviate some of the burden, but community efforts are also necessary. Planting plants that will absorb pollutants, cleaning the sediment, or analyzing the pond water are some measures that can be taken to care for the pond effectively (Price, 2011; Bhat et al., 2020).

Not all cities have the capacity required to control these systems. In European countries, there are stricter rules, resources, and capabilities to engage in active management practices. However, budget constraints, along with the lack of necessary skills, are some challenges, especially for rapidly developing cities, to maintain ponds efficiently in good condition, according to Schmadel et al. (2019). In some countries, such as Sweden, ponds are accounted for in the stormwater design plans for residential areas, but unsupervised ponds are common in other countries with fewer rules.

More recent uses have involved the connection of ponds to wider green and blue infrastructure. When integrated into the network in green areas, such as parks, rivers, or wetlands, the pond can be connected to the regeneration of the environment, allowing citizens to enjoy the outdoors within the heart of the city itself (Donati et al., 2022; Hill et al., 2016).

3.1.1 Historical Evolution and Management Approaches

Urban ponds have been of interest to humans since ancient times and have therefore been relied upon as components of water resources management (Oertli, 2018). The need to create ponds has led to a focus largely on hydraulic functions such as detention and water quality improvement, with less attention being given to ecological values (US EPA, 2011). As since human life has evolved, pond systems have evolved from simple collection basins to complex and multifunctional systems for water management within the urban environment (Hassall and Anderson, 2015).

In the modern era, especially since the early 20th century, due to the increasing movement of people from the countryside to cities, the municipalities have increasingly integrated stormwater management into their frameworks, with large-scale installations in cities across North America, Europe, and beyond (Hill et al., 2016; Oertli and Parris, 2019). New studies emerged to explore the role of these engineered ponds in sustaining various biotic communities. Research conducted in Europe and the USA indicated the creation of biotic communities for amphibians, macroinvertebrates, or birds, some of which are even comparable to those within natural wetlands, according to Hassall & Anderson (2015) and Hill et al. (2018).

The shift brought about by the development was represented in the approaches of the Management, which have widened correspondingly. This is because the integration of traditional engineering activities with ecological restoration was made possible with the help of activities such as habitat enhancement, vegetation buffers, the control of invasive species, and community outreach (Oertli & Parris, 2019; U.S. EPA, 2021).

3.1.2 Examples of Urban Pond Management Techniques

Pond maintenance in urban areas also involves more than just maintenance, with the focus on the selection of the appropriate mechanisms for solving the problems occurring in the pond. Among the techniques used is phytoremediation, involving the planting of plants or buffer strips surrounding the pond to assimilate nutrients, remove pollutants, and stabilize the shores of the pond. Such practices help improve the quality of the pond water while providing additional habitat for species (Bhat et al., 2020; Zuniga-Palacios et al., 2021).

Another approach is dredging, clearing out sediments that build up with contaminants. Removing this layer restores depth and oxygen levels, which are crucial for fish, insects, and other aquatic life (Flanagan et al., 2021; Price, 2011). Ponds can also be tied into larger stormwater systems, so they help manage flooding while giving polluted runoff more time to filter naturally (Donati et al., 2022).

Long-term care also involves monitoring unwanted species, also known as invasives, in addition to involving the surrounding community. Monitoring these unwanted species is crucial in preventing the problem of ecological imbalances from going beyond control, while the involvement of the surrounding community invites them to contribute to the surveying process, hence allowing the community to develop ownership of the ecological system (Márton et al., 2025).

Together, these methods show how management can directly shape whether ponds thrive or decline. They are also closely tied to the management challenges this research is exploring.

3.2 Urban Ponds as Stormwater Management Infrastructure

To match the rate of urban development and ensure prosperity for the land, there are many land-use changes occurring within urban areas, including the replacement of the permeable and green surface cover with impermeable surface cover, leading to increased stormwater runoff volumes and peak discharge (Fletcher et al., 2015). However, with the advancement in science and technology and engineering developments, ponds in the urban context have emerged as an important part of stormwater management, with the main responsibility of dealing with the problem of floods by regulating the quality, quantity, or even managing the runoff process. The pond system serves as an efficient tool in the reduction of peak runoff levels, offering holistic benefits related to water quality aspects. (US EPA, 2011).

Apart from their efficiency in hydraulic functions, stormwater ponds also play a significant role in stormwater quality enhancement. Through the sedimentation and biological uptake processes, suspended solids are trapped, while nutrients such as nitrogen and phosphorus, as well as heavy metals and hydrocarbons from road runoff, as vegetation around and within ponds further enhances these processes by acting as natural filters (Marques & Mandrak, 2024).

Over time, unfortunately, these treatment processes cannot be undertaken without risks and challenges. Due to the constant runoff, the sedimentation material with high concentrations of metals, pesticides, and organic compounds settled on the bottom surface, hence increasing the reduction in the volume due to the reduction in the pond's depth (Flanagan et al., 2021). Things can go from bad to worse if the phosphorus is cycled internally, leading to its release back into the water, fuelling algal blooms, creating oxygen deficits, or even leading to the transformation of pond areas from pollution sinks to secondary pollution sources, and it becomes a source of problems instead of being a solution. (Williams et al., 2013). These challenges will result in the reduction of the performance, and without managerial interventions.

These problems will sharply decline the performance, and without adaptive interventions from managers. A stormwater pond, if it is to maintain its functions effectively, also needs specialised processes for its management, which could be the removal of sediment, evaluation of inflow/outflow structures, or the consistent monitoring of water quality, according to Heal et al. (2006) and U.S. EPA (2021).

These steps will help ensure that the urban ponds continue to offer stormwater detention and pollutant reduction services throughout the operational lifespan of the ponds (Marques & Mandrak, 2024).

3.3 Urban Ponds as Vital Components of Biodiversity Conservation

Urban ponds aren't just pretty features scattered through cities—they're key players in making urban landscapes more diverse and resilient. Even though many of these ponds are small, together they add up to a big impact, supporting all kinds of life—including rare and threatened species—even if their biodiversity doesn't quite match that of rural ponds (Alikhani et al., 2021). Because most urban ponds are artificial and often located between fragmented habitats, they serve as stepping stones for wildlife, by helping plants and animals move across the city. Ponds also help clean water and trap carbon, offering their benefits for both ecosystems and the communities nearby (Alikhani et al., 2021).

These urban ponds aren't just valuable for wildlife—they offer people real benefits, too. Firstly, they help keep city temperatures comfortable by cooling the air, provide pockets of green for relaxation, and make neighbourhoods more inviting places to live (Song et al., 2020). The "urban heat island" effect, caused by all the concrete and pavement, can make cities unpleasantly hot; healthy urban ponds help counteract this problem, saving energy and improving public health.

Secondly, urban ponds are essential for keeping cities vibrant and livable (Esmail et al., 2022). More than just physical spaces, urban ponds open up chances for learning. They offer everyone—from schoolkids to curious adults—a real-world window into how natural systems work. At the same time, urban expansion challenges these habitats, changing natural cycles and cutting up habitats so wildlife has to work harder to survive (Li et al., 2022). Getting a grip on these pressures is the first step towards better city planning, helping communities weave green and blue spaces throughout urban neighbourhoods for the benefit of both biodiversity and climate resilience (Aram et al., 2019; Esmail et al., 2022).

As more people move to cities, it's more important than ever to protect these urban pond hotspots. They face constant threats, yes, but they offer remarkable shelter for biodiversity even under tough conditions. By restoring and maintaining urban ponds and surrounding green spaces, cities can become more robust in the face of climate change, and support wildlife on a broader, regional scale (Alikhani et al., 2021; Esmail et al., 2022).

While urban ponds are shown to help maintain regional species richness, most studies note declines in sensitive taxa due to habitat fragmentation and poor water quality (Alikhani et al., 2021). This highlights a need for further investigation into habitat restoration and corridor creation—topics directly addressed by my research objectives.

3.4 Impacts of Urbanization on Urban Pond Ecosystems

Urban areas have expanded enormously over the last hundred years, transforming the face of cities across the globe (Williams et al., 2013). With the increasing number of people migrating to urban areas, the water bodies in these areas, particularly urban ponds, are also being impacted. With the growth of cities and the increase in the population, the pressure on urban ponds from construction, pollution, and other sources is also on the increase, making the management of freshwater biodiversity in these areas even more difficult, with green spaces shrinking due to human activity (Hassall & Anderson, 2015).

Besides their ecological importance, there are several other aspects in which urban ponds are valuable to city life. They contain water, which is much required, be it for the vendors, factories, or the inhabitants in the more populated areas. Furthermore, ponds are also valuable in reducing temperature and providing green patches in the otherwise crowded city, which become ideal locations for social gatherings, be it cultural or recreational, providing attractive places in the urban landscape (Heal et al., 2006).

Despite all these advantages, urban ponds are often left on the sidelines when managing water resources in urban areas. Urbanization and the increasing population mean that these ponds are experiencing strain, with the pressure to provide for different needs sometimes having had detrimental consequences. Mismanagement has resulted in poorer water quality and shrinking pond resources (Villasenor et al., 2017). For cities to keep thriving, it's essential to recognize how important these ponds really are—and to manage them smartly before they slip away for good (Villasenor et al., 2017).

Although much is known about water quality degradation in urban ponds, less is documented about long-term remediation effectiveness, as highlighted by Flanagan et al. (2021). Few studies offer comparative evidence on policy-driven restoration versus community-led initiatives, a gap this research will explore.

To conclude, research shows that urban ponds are much more than just aesthetic components of the urban landscape. They are human-made structures, requiring intelligent management to ensure they continue to work well. However, if well managed, urban ponds are capable of providing benefits to the community, from flood protection to cleaner water sources, among others. But these systems, which are under constant pressure due to the rapid rate of urbanisation, are facing new challenges, and many questions are yet to be answered, such as how well restoration methods work in the long run and how different governance models, from government-led programmes to community efforts, affect outcomes.

Such knowledge gaps inform the scope of the study. Through its focus on pond management within the context of biodiversity conservation under the conditions of ongoing urbanization, the study intends to demonstrate how cities can effectively support the conservation of these small but important bodies of water.

3.5 Ecosystem Services of Urban Ponds: Trade-offs and Synergies

The studied literature indicates that urban ponds can provide different levels of services, going beyond the minimum stormwater regulation, by sharing common attributes in the intersection of the hydrologic, ecological, and urban spheres. That is why, nowadays, they are more often recognized in the context of multifunctional eco-systems, merging the technical needs with the possibilities of ecology (Hill et al., 2018).

Evidence showed that, aside from having beneficial hydrologic functions, the design of urban ponds must be made multi-functional to maximise these benefits, including their uses in biodiversity, recreation, culture, or even the cooling effect on climate through local cooling and carbon uptake (Hamel & Tan, 2021). Hill et al. (2018) emphasize that with the broad suite of services that ponds can provide, they become unique features in urban planning, where few infrastructures have the ability to provide the urban areas with different ecological, social, and technical benefits simultaneously. Vegetated ponds, for example, can support amphibian and bird populations while also enhancing water quality (Oertli & Parris, 2019; Hamer & Parris 2011). Networks of connected ponds enhance biodiversity and resilience against floods simultaneously (Hassall & Anderson, 2015; Donati et al., 2022).

However, "trade-offs" are also inevitable. The design optimised for hydraulic efficiency, may result in the simplification of habitats, leading to the reduction of species diversity. Within the same context, dredging enhances the quality of water, but its benthic communities are disrupted temporarily. The linking of ponds to create bigger aquatic networks boosts the resilience of the system but also poses greater threats of invasive species distribution (Clevenot et al., 2018; Oertli & Parris, 2019). Such tensions show the need for adaptive management that weighs short-term efficiency against long-term ecological integrity. (Gebreselassie et al., 2022)

Policy and planning frameworks such as the EU Green Infrastructure Strategy (2013) and the EU Biodiversity Strategy 2030 increasingly prioritise nature-based solutions. So, integrating ponds within green-blue infrastructure networks can ensure resilience, improve quality of life, and support biodiversity within dense urban landscapes (European Commission, 2013; Oertli & Parris, 2019).

4. Results

In this chapter, I am sharing what this study has uncovered through reviewing existing research and case studies. This chapter walks you through the main findings grouped around the three key questions at the heart of the research: 1-how pond management influences water quality and ecosystem health; 2-which management tools and techniques actually work well in different climates and habitats; and 3-what the best practices and biggest challenges are when it comes to keeping urban ponds healthy over time.

Each section pulls together insights from several sources rather than focusing on single studies. The aim is to give a clear sense of what researchers and practitioners already know, where practices seem to work, and where gaps still exist. This way, the results build a foundation for the discussion that follows in the next chapter.

4.1 Management Effects on Water Quality and Ecosystem Health (RQ1)

The urban ponds are usually designed small and scattered; at the same time, they carry a weight far bigger than their size. There are some studies that show they support biodiversity and help keep ecosystems working inside cities (Flanagan et al.2021, Gallagher et al., 2011).

We can infer the effectiveness of the pond in managing stormwater, pollution and the surrounding surfaces, from its condition (Márton et al., 2025). One of the most common indicators is nutrient build-up. Often, the Nitrogen and phosphorus from runoff, fertilisers, detergents, and wastewater collect in ponds and trigger eutrophication. Causing algae blooms, oxygen drops, and aquatic life suffering (Flanagan et al., 2021; Márton et al., 2025).

Retention ponds can significantly reduce nutrient concentrations, with one study reporting phosphorus and nitrogen removal rates between 10-47% over a one-year monitoring period (Yazdi et al., 2021). Similarly, ponds with heterogeneous design—featuring varied depths and macrophyte cover—support higher macroinvertebrate and amphibian diversity compared to simplified designs (Hassall & Anderson, 2015; Hill et al., 2021). Some research points to a simple but effective fix: plants. Vegetative working as buffers (reed beds, aquatic plants, and green strips) soak up excess nutrients fast before they reach the water (Pandey & Tripathi, 2019; Bhat et al., 2020). Incorporating ponds in wider green-blue infrastructure systems, including wetlands and riparian areas, improves the ecosystem service values of ponds as well as their performance contribution to urban flood resilience (Donati et al., 2022).

These results thus verify that properly maintained ponds can effectively support both stormwater management and biodiversity conservation. That is why monitoring is important since it assists in detecting those issues earlier on.

Unfortunately, the greatest factor affecting the pond's condition remains human activity. Pollution sources include factories, roads, gardens, as well as recreational activities (Price, 2011; Bhat et al., 2020). Some of this is taken care of by the city-wide systems; however, local activity is also important, planting filtering vegetation, dredging out sedimentation, and monitoring water quality periodically (Worcester, 2024; Bhat et al., 2020). Nevertheless, some studies highlight that ponds built fundamentally for hydraulic purposes do not necessarily offer the same results in an ecological perspective. Steep-banked or frequently dredged ponds often simplify habitats, which in the second hand will impact species richness negatively and reduce secure breeding for amphibians and birds (Clevenot et al., 2018; Gebreselassie et al., 2022). So, Dredging improves water quality by removing accumulated sediments, on one side, and it temporarily disrupts benthic communities and may even cause damage if performed during breeding seasons (Clevenot et al., 2018).

Furthermore, urban ponds can act as ecological traps, seeming nice in the surface, but attracting species to apparently suitable habitats that are in fact contaminated or subject to frequent disturbance (Oertli & Parris, 2019). Some studies documented accumulation of heavy metals and hydrocarbons in stormwater ponds, which stresses aquatic organisms and potentially transfers pollutants along the food chain (Gallagher et al., (2011).

In summary, managers need to be more aware of the steady challenges facing urban ponds management, including, among other things, nutrient buildup, surface runoff, and ecological traps, and at the same time, be aware of the preventive measures that can maintain cleaner conditions and stronger ecosystems. In the following section, we will look more closely at the tools and techniques identified in recent studies as effective measures.

4.2 Effective Management Tools and Techniques for Urban Ponds (RQ2)

The challenges presented above have forced researchers and practitioners to inspect and introduce a variety of management strategies to tackle these challenges. This section highlights several approaches—such as vegetative buffers, sediment removal, and Integrating Ponds into Green–Blue Urban Networks -whose effectiveness varies by climate and ecosystem type.

4.2.1 Vegetative Buffers and Phytoremediation

Some studies highlight the function of using plant buffers—reeds, sedges, and floating mats, which remains one of the simplest but most reliable tools for urban pond management. They have a very reliable role in intercepting nutrients such as nitrogen and phosphorus before these reach the open water, which are so effective in damping algal blooms and maintaining oxygen levels for fish and amphibians. At the same time, they be used for their aesthetic value (Petrova et al., 2022). Wang et al. (2012) demonstrated in his field research in China that root-channel wetlands planted with macrophytes have the ability to retain significant amounts of heavy metals in both sediments and plant tissues, helping to reduce pollutant loads even under slightly contaminated conditions. In addition, case studies from Europe show that buffer strips and green patches around road networks accumulate heavy metals and act as sustainable phytoremediation zones, highlighting their role in protecting adjacent ponds (Petrova, 2022).

Species choice matters. Macrophytes such as Typha and Eichhornia have proven effective at nutrient and metal uptake, but results are most consistent when managers use locally adapted species (Wang et al. 2012, Petrova 2022). Results are best when species are locally adapted; in heavily industrial or polluted sites, however, outcomes have been mixed, which shows the need for repeated monitoring (Wang et al., 2014).

4.2.2 Sediment Management and Dredging

The sediments in city ponds often consist of a lot of substances besides the soil. The stormwater and runoff to the ponds carry with them everything from human activities they can find in their way through the roads and surfaces around the ponds. They often carry pesticides, hydrocarbons, and heavy metals (Flanagan et al., 2021).

Clevenot et al. (2018) explained in their article that the harmful effects of these sediments on the ecosystem in the pond, such as road salts and nitrates, can cause sub-lethal effects on amphibians, but at the same time, they lead to slow death in the long term. Even though the harmful effects are shown on the surface, it can be delayed or subtle, because these pollutants are often released slowly from the sediments at the bottom of the pond, and by the time the effects are clearly visible on the surface, the damage to the oxygen and the pH of the water has already occurred, which can described as ecological trap. (Clevenot et al., 2018).

The dredging of the pond rids it of the sediments, can restore the requested depth, and the perfect conditions for oxygen and pH, though costs and ecological disturbance mean it has to be carefully timed, the best results balance habitat protection with the removal of accumulated pollutants (Zhang et al., 2021).

4.2.3 Integrating Ponds into Green–Blue Urban Networks

Finally, ponds from the beginning designed as part of stormwater management and it would work best when they are not isolated. Linking them with other green and blue structures—streams, wetlands, parks— will improves connectivity for wildlife and enhancing the ecosystem by creating Ecological corridors and makes water systems more resilient to both pollution and floods control. and no doubt that strongest results come from the Integrated planning between all stockholders in urban planning such as municipalities, ecologists, and local communities (Oertli & Parris, 2019).

4.3 Effective Practices for Maintaining Urban Pond Structures (RQ3)

While Section 4.2 highlighted a broad range of tools and techniques available to be applied to urban ponds, such as vegetation buffers or sediment removal, this section turns attention to daily routine operations, which managers rely on taking place after those techniques are applied. Here, we can distinguish between the operational practices, which refer to the daily routine as behind-the-scenes tasks to maintain these systems daily for long-term performance, such as inspection schedules, maintenance routines, water quality monitoring, and practical responses to problems as they arise, while tools and techniques represent methods chosen for thoughtful pond management depending on varying ecological and institutional conditions.

By drawing a clear line between what you install and what you do, enables us to make sense of urban pond management. It becomes easier to focus on the day-to-day realities and obstacles of maintaining urban ponds' functioning, rather than only on initial design or tool selection. (EPA, 2021)

4.3.1 Monitoring and Adaptive Management

One of the most widely cited practices is the routine monitoring of water quality and ecological indicators. Continuous measuring of water quality parameters, including dissolved oxygen, turbidity, pH, nutrient concentrations, and contaminants, helps the managers to take crucial decisions and timely interventions (Oertli & Parris, 2019).

Several studies have emphasised that adaptive management, in other words, adjusting maintenance strategies in response to these outcomes, as central to maintaining the ponds' functionality under varying climates and land-use conditions (Oertli & Parris, 2019; Skovira & Bohlen 2023).

Community science initiatives, such as (local residents and volunteers, have enhanced monitoring capacity by collecting and sharing environmental data, contributing valuable data that improves responsiveness and taking adaptive management decisions (Kuitert & van Buuren, 2022).

4.3.2 Vegetation and Invasive Species Control

Management of the Vegetation growth in the ponds is another recurring practice to preserve pond function and biodiversity. Routine tasks include controlling invasive species, maintaining native plant cover for nutrient filtration. Supporting native species and keeping them in balance between aesthetic and ecological aspects, while keeping invasives under control, is highlighted as a best practice (Alikhani et al., 2021). Gallagher et al., (2011) present in their study how the pollutants, such as road salts and nitrates, can negatively impact ponds' vegetation by stressing or eliminating sensitive plant species, reducing the effectiveness of vegetative buffers for nutrient filtration and habitat support. Furthermore, this loss of vegetation function can convert the ponds into ecological traps—there, the habitat appears suitable for wildlife, but it actually exposes amphibians and other species to harmful conditions (Clevenot et al., 2018).

4.3.3 Community Engagement and Education

Citizen and neighbourhood participation in the management process is long-term beneficial and is therefore a crucial component in pond management. Long-term pond health improves when residents feel a sense of ownership and increased vigilance with regard to changes within and around the pond (Oertli and Parris, 2019).

The benefits are not only technical, but it is often the everyday choices of nearby residents are also crucial for the pond's fate. Their participation builds a sense of stewardship among community members, which makes them more likely to support long-term management actions, which also creates faster responses to new problems (Conrad, C. C., & Hilchey, K. G., 2011).

One of the strongest ways to make this involvement real is community science. There, ordinary residents such as students, retirees, nature groups—have more opportunity to participate physically on the site than any city staff ever could (Conrad & Hilchey 2011). When people understand why a scruffy patch of plants matters for biodiversity, or why dredging is needed sometimes for water quality, they are more inclined to support management decisions and even contribute to pond care (Oertli & Parris, 2019). No matter what they are practising around the pond, their eyes and ears often spot changes before managers do. Whether they are studying animals and vegetation or analysing soil and water clarity with simple kits, their observations provide early warnings and create stronger datasets for long-term planning. (Oertli & Parris, 2019; Buytaert et al., 2014). Of course, there are challenges, such as communication gaps between volunteers and city officials.

Nevertheless, studies and evidence show that the more the community is engaged, the healthier ponds are, the earlier problems are spotted, and communities feel more powerful and responsible than if the entire management were left to experts alone (Spotswood et al., 2021).

5. Discussion

In this chapter, my focus is to discuss the outcomes that were presented in the previous Chapter 4 and connect them to the broader context of urban pond management. The aim is to explore the implications of the results, highlighting trade-offs, and positioning them within existing research.

After studying the results we have obtained, it is evident that management of urban ponds includes stormwater and different ecological, technical, and social aspects and challenges, which are both complex and interconnected. To reflect the interdisciplinary nature of the topic, the discussion goes beyond the RQs and will be divided into three parts. The first addresses the ecological dimensions, focusing on biodiversity, ecosystem services, and resilience. The second examines the technical tools and management approaches, evaluating how interventions perform across different contexts. The third considers the social and governance practices, emphasising the role of community engagement, institutional arrangements, and education in long-term pond management.

5.1 Urban Ponds as Ecological and Stormwater Infrastructure

The results already showed that urban ponds provide benefits far beyond their size, functioning both as stormwater infrastructure and as ecological habitats, by retaining and detaining runoff, reducing peak discharges, and at the same time, trapping sediments and pollutants.

Yazdi et al. (2021) in their study confirmed the effectiveness of urban ponds in nutrient control. They reported reductions of 10-47% in nitrogen and phosphorus within retention ponds over one year, highlighting their importance in improving water quality. And it's worth noting that they emphasise that nutrient removal efficiencies vary throughout the year due to biological and environmental factors, highlighting their relevance while acknowledging the seasonal variability and limits of single-pond studies.

The results from the reviewed studies similarly indicate that ponds with vegetated buffers and heterogeneous depth zones performed better in nutrient capture and pollutant reduction than simplified designs focused only on hydraulic efficiency. These findings support earlier evidence that macrophyte cover and shoreline complexity improve both pollutant removal and ecological conditions (Oertli & Parris, 2019; Hassall & Anderson, 2015).

At the ecological level, ponds act as important biodiversity nodes within urban landscapes. They provide habitats for amphibians, macroinvertebrates, and birds, especially when macrophyte cover and shoreline heterogeneity are present (Oertli & Parris, 2019; Hassall & Anderson, 2015). Integration into wider blue–green infrastructure networks further amplify these benefits by creating ecological stepping-stones and dispersal corridors (Donati et al., 2022).

However, the results also underline that these synergies are not guaranteed. Poorly designed or maintained ponds can lead to eutrophication, oxygen depletion, and pollutant accumulation, creating ecological traps where species are attracted to degraded habitats (Oertli & Parris, 2019; Márton et al., 2025). The trade-offs identified in Chapter 4 align with those reported in the literature. Hydraulic efficiency, which comes through steep bank designs and simplified structures, improves flow regulation but reduces habitat complexity, which can lower species richness. In the same context, the dredging, which can be used to remove sediments and restore storage capacity, will disrupt benthic life and amphibian reproduction if conducted during sensitive seasons (Clevenot et al., 2018). Similarly, green corridors and connectivity across ponds contribute to increasing hydrological resilience and ecological diversity, but on the other hand, will facilitate the spread of invasive species, posing a management dilemma. These patterns emphasise the importance of taking not only hydrological efficiency into account, rather their ecological consequences when assessing the urban ponds. (Havel et al. 2015).

5.2 Technical Management and Maintenance Practices

The ecological benefits described in the previous section rely fundamentally on how well urban ponds are managed and maintained (Oertli and Parris, 2019; Hill et al., 2016). Results described in chapters 4.2 and 4.3, with supporting findings from recent international studies referenced in this thesis, demonstrate that pond management requires a combination of practical engineering skills, including sediment removal to maintain pond performance, as well as pond water quality monitoring, with natural management strategies such as the use of aquatic vegetation to absorb or biodegrade detrimental pollutants (Flanagan et al., 2021; Pandey & Tripathi, 2019).

In this part of the discussion, we will examine these results in more detail to see how technological approaches help in achieving cleaner water, better stormwater systems, and healthier pond ecosystems, as well as touch on the practical issues and challenges that often come into play in managing ponds in cities (US EPA, 2021; Donati et al., 2022; Skovira & Bohlen, 2023).

Technical Tools and Their Effectiveness. Vegetative buffer systems, as well as phytoremediation techniques, could be identified as one of the most inexpensive techniques that could be effectively used to preserve water quality in ponds in urban areas. Recent findings on this process include that root-channel wetlands, as well as macrophytes, possess the ability to remove nutrients as well as heavy metals, thereby leading to increased water clarity (Pandey, 2019; Petrova,2022). Moreover, even the type of species selected is of utmost importance in this process. It has been found that native species, such as Typha/Eichhornia, are found to be most effective, while non-native species often show variable results and require more maintenance. (Pandey, 2019).

Sediment management and dredging. Dredging is a crucial process in reinstating the depth and oxygen level in a pond required by aquatic life by eliminating the contaminated sediment in the pond (Clevenot et al., 2018; Heal et al., 2006; Zhang, 2021). Nevertheless, we must not disregard the consideration that excessive dredging done at improper timings can result in achieving a converse effect that affects benthic fauna and breeding of amphibians; thus, the best way to avoid this, and minmize the ecological harm is scheduling dredging activities outside reproductive seasons (Clevenot et al., 2018).

Integrated practice. Through the integration of biological filtering with dredging, we shall be able to optimise pond functions, as this will also exemplify that low-cost ecological approaches are beneficial in conjunction with those of engineers (Donati et al., 2022).

It is important to state that, despite the fact that sometimes institutional issues in urban pond management come to the fore, there are still financial constraints in pond management that lead to a delay in the important sediment removal process (Donati et al., 2022). These technical tools alone will not ensure effective management of the urban pond, as there is a factor of follow-up on the performance and adjusting it over time.

Here we come to the adaptive management, which is a critical feedback-based process of monitoring and adjusting practices in maintenance, as well as contributing to pond performance under rainfall and pollution impacts (Oertli & Parris, 2019; Skovira & Bohlen, 2023. We also obtain data from the persistent monitoring of nutrients as well as dissolved oxygen, which trigger early signals/warnings of the onset of either eutrophication or water quality decline. These data offer such a high level of quality that one can rely on in making decisions, that maintenance activities can transition from a cleaning response to a planning activity or, in other words, from reactive cleaning to proactive planning in a way that minimises ecological damage. (EPA, 2021).

Nevertheless, in practice, financial constraints do affect the municipalities at times such that they struggle to ensure that there is continuity in monitoring, as well as a response from management (Donati et al., 2022). It is important to recognise that there has been a positive experience in community-based monitoring in increasing shared responsibility towards pond management through expanding the local data coverage and filling the gap in spatial data (Conrad & Hilchey, 2011; Buytaert et al., 2014).

Apart from what is already mentioned, integrating urban ponds into wider blue–green infrastructure systems can add to the overall efficiency of hydraulic regulation, pollutants removal, as well as resistance to urban flooding (Hamel & Tan, 2021; Donati et al., 2022). This aligns well with the EU Green Infrastructure Strategy and the EU Biodiversity Strategy 2030, which both advocate multifunctional water infrastructures as a means of addressing climate change. This integration is ensured by a successful collaboration of various disciplines such as water engineering, ecology, and planning in a way that minimises conflict between hydraulic optimisation, on one hand, and ecological efficiency, on the other. (European Commission, 2013; European Commission, 2020).

In conclusion, the management of urban ponds needs equal consideration of both technological and ecological issues to end with improved water quality and management of stormwater but can also lead to increased ecological resilience (Donati et al., 2022; Flanagan et al., 2021; Pandey & Tripathi, 2019). In addition to these technological solutions, it needs continuous monitoring, adjustment, as well as interdisciplinarity between technological, ecological, and urban planning expertise (US EPA, 2021; Donati et al., 2022). As will be evident in the next section, this kind of coordination is most effective when technical approaches are integrated with governance practices as well as urban policies.

5.3 Social and Governance Practices

Section 5.3 shifts focus from how urban ponds are managed technically to who manages them and how governance decisions shape their effectiveness. Social factors such as policy frameworks, institutional cooperation, and community participation are significantly influential in determining success related to technical and ecological approaches.

Urban ponds often function within a fragmented institutional framework where responsibilities are shared between municipal water departments, environmental agencies, and other contractors, leading to issues of coordination and lack of accountability (Kuitert & van Buuren, 2022). Wihlborg et al. (2019) applied a transition theory framework to explain the forces influencing the implementation of blue–green infrastructure by Swedish municipalities. Their study revealed that fragmented governance and slow institutional transitions continue to constrain effective stormwater management. The authors have identified through semi-structured interviews with municipal stormwater practitioners growing demands for recreation, biodiversity protection, and climate adaptation as key drivers of BGI adoption. Nevertheless, internal challenges, such as organisational rigidity, and external challenges, such as a lack of awareness about e-government, remain as obstacles that slow down its implementation. Findings indicated that pilot projects cannot trigger systemic transformation on their own, and that changes need to be made at a legal and financial system level that favours institutional learning and cooperation on a long-term scale. Moreover, Bohman et al. (2020) point out that equal progress is still lacking in achieving more comprehensive and cooperative stormwater management, as they stress that formal and informal institutional changes are required to enhance sustainability transitions. Based on workshops, interviews, and surveys, they propose incorporating stormwater risk evaluations on a catchment scale into planning and having a centralised leadership coordinating efforts towards common goals.

Collectively, these studies have made it clear that genuine governance reform through legal, financial, and organisational change is essential for embedding sustainable stormwater and pond management within municipal policy structures. Policies such as -EU Green Infrastructure Strategy (European Commission, 2013), and EU Biodiversity Strategy for 2030 (European Commission, 2020) identify integrated planning and governance that links ecological and technical objectives as essential. However, local implementation of such frameworks is still a challenge because of administrative silos and short-term procurements that prevail.

Thus, adequate pond governance entails institutional, funding, and interdepartmental considerations and cooperation. Going beyond institutional reform, social engagement is essential for maintaining effective governance of ponds. Community-based monitoring and citizen science projects can help address capacity issues by expanding data-gathering efforts and community responsibility for pond maintenance (Conrad & Hilchey, 2011; Buytaert et al., 2014).

On the other hand, the urban water-management domain has to build compelling new relationships with the private sector and civil society, as BGI is typically constructed above the surface and is, therefore, sometimes located on private property. Initiatives aimed at public awareness, such as workshops and community stewardship campaigns, can help people become more knowledgeable about ponds ecosystem role and build public support for pond maintenance. (Kuitert & van Buuren, 2022). By incorporating these participatory methods into formal structures of governance, this gap can be bridged and reinforced on all fronts, including ecologic accomplishment as well as public trust.

6. Conclusion

The study evaluated how to manage urban ponds to fulfil their role in stormwater control and biodiversity enhancement. Results show their providing services in mitigating stormwater and enhancing biodiversity; even though they face large challenges in the form of urban pollution inputs, nutrient loading and limited maintenance.

Urban ponds require efficient management techniques that help maintain water quality and minimise biological risks, such as reducing household pollutants and pesticides. Besides routine dredging and debris removal activities, these practices, therefore, need to be integrated into governance planning frameworks and be synchronized with community social engagement as well. It is clear, based on available evidence, that urban ponds cannot be effectively managed if they are considered as minor landscape elements. They are essential components of urban stormwater infrastructure and biological networks. They need to be considered as multifunctional infrastructure elements, and this will be indispensable for sustainable urban development.

Overall, based on their effective and vital role in urban cities, they should be considered as multifunctional infrastructure, and treated as vital components for urban stormwater systems, and supported adaptive framework to ensure long-term performance.

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