In Deep Waters

Exploring Appropriate Maintenance Strategies for Urban Wetland Biodiversity in Swedish Municipalities

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In Deep Waters. Exploring Appropriate Maintenance Strategies for Urban Wetland Biodiversity in Swedish Municipalities

På Djupt Vatten. Lämpliga Skötselstrategier av Urbana Våtmarker för Främjandet av Biologisk Mångfald i Svenska Kommuner

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Abstract

Urban Wetlands (UWs), defined as bodies of water receiving urban runoff, remain essential to urban ecology, although they are threatened by anthropogenic activities, particularly those related to urban hydrology. For rich biodiversity to thrive in these systems, effective maintenance strategies are necessary. This study aimed to investigate proper maintenance strategies for promoting UW-biodiversity by interviewing Biologists/Ecologists (Bio/Eco) and Stormwater Managers/Urban Planners (SM/UP) in Swedish municipalities and analyzing their responses statistically. Results indicate that relatively few Swedish municipalities employ such established maintenance strategies, with larger municipalities and SM/UP overrepresented among those having maintenance plans and experiencing problems, including organizational and design-related obstacles. Cleaning/de-clogging of outlets and inlets, as well as removal of excess debris, appear relatively frequently, likely benefiting biodiversity. While, emptying UWs of water occurs infrequently, potentially hindering biodiversity along with infrequent monitoring routines. Trade-offs involve balancing stormwater treatment efficiency and biodiversity as well as choosing between maintenance actions and timing to strike the right level of disturbance, favoring selected species. UW-biodiversity follow-ups in Swedish municipalities are scarce and vague, with an unclear association with maintenance strategies. Therefore, optimal maintenance strategies for biodiversity should be based on contextual research, recommending water table monitoring, weeding, removing in/outlet debris, and incorporating a multi-cellular design with a pre-sedimentation basin, allowing for full maintenance access and emptying, as well as complex littoral fringe structures and varied bottom terrain. Further research clarifying the symbiotic relationship between stormwater treatment efficiency and biodiversity, accompanied by contextual outreach to municipalities, is needed.

Keywords: Urban, wetland, biodiversity, maintenance, strategies, Swedish, municipalities

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Abbreviations

CW	Constructed Wetland
Eco/Bio	Ecologists/Biologists
SM/UP	Stormwater Managers/Urban Planners
UW	Urban Wetland

1. Introduction

1.1 Background

Wetlands are currently in deep water, as evidenced by a considerable decrease in their numbers (Asselen et al. 2013). Wetland loss varies significantly globally, but the trend is clear: since 1700, humans have drained 50-90% of wetlands in the industrialized world (Ibid; United States Environmental Protection Agency 2001). Globally, this figure amounts to 35% (Ramsar 2018; Fluet-Chouinard et al. 2023). Pertaining to Sweden, 25% of its original wetland area was lost during the 19th and 20th centuries (Goverment Offices of Sweden 2021).

Land-use change, overexploitation of water resources, and agricultural activities, are the primary drivers for wetland reduction, directly linked to urbanization, with its associated anthropogenic activities and demographic characteristics (Convention on Wetlands 2021; Fluet-Chouinard et al. 2023). The Swedish scenario exemplifies this trend well, with the establishment of "diking companies" in the 19th century. These were supported by the government and corresponding legislation, aimed at expanding arable land to feed a growing population through drainage efforts (Håkansson 1997). However, forestry has been the primary driver of wetland loss in Sweden, accounting for 45% of the total reduction (Fluet-Chouinard et al. 2023). This unfortunate development constitutes a significant threat to the establishment of sustainable cities (Veselka & Anderson 2013).

Wetlands are recognized as one of the most productive ecosystems on the earth (Gibbs 2000; Ramsar 2018). Referred to as biological hotspots (Contreras MacBeath et al. 2020; Dertien et al. 2020), the kidneys of nature (Eklöf et al. 2023), ecosystem nurseries (Whitfield 2017), and species libraries (Ye et al. 2018), wetlands serve as vital components of global ecological health. Accordingly, they provide essential ecosystem services, including water detention, water purification, flood protection, carbon sequestration, food production, biodiversity, recreational opportunities (The Swedish Society for Nature Conservation 2023), and prevention of coastal erosion (Bevan 2020).

Wetlands also mitigate global warming through carbon sequestration (Were et al. 2019). Given that wetlands cover approximately 6% of the Earth's surface (Mitsch & Gosselink 2000) and constitute about 15% of Sweden’s total area (Eklöf et al. 2023), their reduction contributes to increased greenhouse gas emissions (Elfström 2022). Re-wetting wetlands in Sweden could potentially reduce carbon emissions by 20%, which is equivalent to the annual total emissions from Swedish vehicle traffic (Sveriges Television 2023). Moreover, the reduction in wetlands results in decreases in groundwater recharge and biodiversity loss (The Swedish Society for Nature Conservation 2023).

Currently, there are clear and rapid demographic changes occurring, with the current global population of 8 billion people (United States Census Bureau 2023) expected to increase to 8.5 billion by 2030, 9.7 billion by 2050, and 10.4 billion by 2100 (United Nations 2022b). This rise is closely linked to urbanization, with the United Nation (United Nations 2022a) estimating that 58% of the world's population will reside in cities by 2075. These demographic shifts accelerate climate change, alter land use, disrupt local ecosystems, and threaten urban ecology through the displacement of natural (Lehmann 2014; Alikhani et al. 2021; University of Helsinki 2023).

As an integrated part of urbanization, urban hydrology is heavily modified by these factors (Alberti 2008; Douglas 2020b; McIntyre 2020), hence wetlands, situated within the urban matrix experience reductions, fragmentation and functional disturbances due to the aforementioned factors (World Wetlands Day 2018; Alikhani et al. 2021). Urban managers need to recognize this situation to adapt and adjust urban planning sustainably, to make the city of the future resilient and robust towards climate change, not least by addressing interconnected stormwater challenges (Metcalfe et al. 2018; Bevan 2020; Qi et al. 2020; Ribbe et al. 2024; Rousseau et al. n.d.).

As a result, Urban Wetlands (UWs) (see figures 1-3) have gained popularity during the last 30-40 years. Today, they are globally recognized as an integrated component of green/blue infrastructure by various governmental agencies (Shutes et al. 1997; Hunt et al. 2011; Gorgoglione & Torretta 2018; Palta & Stander 2020). Consequently, they have been increasingly implemented in urban settings for stormwater management (Rousseau et al. 2008). Subsequently, several programs, policies and laws have been established to promote urban wetlands, including the “Green Street Program” in Portland (Bevan 2020), the “Urban Wetland Laws” in Chile (Rojas et al. 2022), the Wetland City Accreditation (Ramsar 2023), Australia’s Index of Wetland Condition, and Ireland’s Integrated Constructed Wetland program (Veselka & Anderson 2013).

Figure 1. UW, Ranagård, Halmstad Municipality (photo: Mikael Brocki).

Figure 2. UW, Kristianstad Municipality (photo: Patrik Olofsson).

Figure 3. UW, UK (photo: Sam Stafford).

Such initiatives acknowledge the importance of the multitude of ecosystem services provided by UWs, including reducing concentrations of pharmaceuticals (Verlicchi & Zambello 2014), lowering levels of microplastics (Wang et al. 2020), performing nutrient reduction to lessen eutrophication (Hansson et al. 2005; Harrison et al. 2011; Hung et al. 2021), counteracting the urban heat island phenomenon (Sun et al. 2012), promoting health and well-being (Bevan 2020; Alikhani et al. n.d.), and enhancing biodiversity (Ye et al. 2018; Bevan 2020; Zhang et al. 2020).

This thesis focuses on the latter aspect, investigating how maintenance strategies of UWs influence biodiversity within these ecosystems.

1.2 Rationale for Study

In comparison to other stormwater plants, wetland systems offer relatively more advantages for treatment of urban runoff (Larm & Blecken 2019). Indeed, UWs (here, referred to as Constructed Wetlands (CWs)) are more effective in reducing effluent wastewater compared to natural wetlands (Alikhani et al. 2021). Consequently, CWs are regarded as Best Management Practice for urban stormwater management (Carver et al. 2015).

However, proper maintenance actions are needed, for these systems to function optimally and provide their intended ecosystem services adequately. (Hunt et al. 2011; Blecken 2016; Gorgoglione & Torretta 2018). But, there is insufficient understanding of how to meet this requirement (Rousseau et al. n.d.). Although more attention is being paid to appropriate maintenance approaches for UW-systems (Alikhani et al. 2021), there is an increasing demand for guidelines regarding maintenance strategies for stormwater units in general (Larm & Blecken 2019) and for UWs in particular (Blecken et al. 2017). Therefore, future research is needed to investigate this issue further (Gorgoglione & Torretta 2018), because we do not yet fully understand how human disturbances either benefit or harm these systems (Palta & Stander 2020).

As the kidneys of the city (Ye et al. 2018), UWs are key components for making cities livable (Ramsar Convention on Wetlands 2018), thereby facilitating the development of sustainable urban areas (WWT Consulting 2018). By supporting various vital functions for urban biodiversity (Zhang et al. 2020), they now have become integrated parts of urban ecology (Sievers et al. 2019). Under favorable circumstances, UWs can function as primary habitat providers within the urban matrix (Hui et al. 2009), even having the potential to even serve as refuges for endangered species (Chovanec 1994).

Hence, healthy UWs are necessary for maintaining and promoting urban biodiversity (Hui et al. 2009; University of Helsinki 2023). However, urbanization is threatening the existence and health of UWs (Ramsar Convention on Wetlands 2018; WWT Consulting 2018), causing them to become "patchy" and fragmented (Alikhani et al. 2021:5). As a consequence urban biodiversity is damaged (Ye et al. 2018). The fact that research on how urbanization affects UWs is scarce (Rojas et al. 2022), aggravates this negative trend.

Authors suggest an interdependency between UW-maintenance and UW-biodiversity (Hansson et al. 2005; Zhang et al. 2020), as indicated by a decline in biodiversity in UWs as these system age (Herrmann & Yoshiyama 2014). However, research on this symbiosis is still limited (Hansson et al. 2005; Zhang et al. 2020), which highlights the need for better understanding of this connection (Hui et al. 2009).

Yang et al. (2021), studied UW-maintenance routines among stakeholders in Melbourne. However, to the best of my knowledge, there is currently no study investigating the relationship between UW-biodiversity in association with UW-maintenance strategies in Swedish municipalities. Consequently, this thesis aims to address this research gap.

1.3 Aims

In light of the current academic knowledge of urban wetlands with its related research gaps (described in chapter 1.2), the primary aim of this essay is to investigate and describe appropriate maintenance regimens for promoting biodiversity in UWs. By understanding how Swedish municipalities perform their maintenance of these systems, it is intended to facilitate thoughts for future research. Hopefully, this will render in practical suggestions for UW-maintenance for the promotion of biodiversity in Swedish municipalities.

1.4 Reserach Questions

To achieve the aims the following questions function as a framework for description and analysis of urban wetland maintenance.

- How should maintenance of UWs be performed in order to promote their biodiversity?
- How do Swedish municipalities perform their maintenance of UWs?
- Which trade-offs should be considered when maintaining UWs for the enhancement of biodiversity?

1.5 Scope and Delimitations

The scope of this study is best understood in relation to the definitions provided in chapter 1.7.8, which explain the broad usage of the term "urban wetland." Therefore, contextually, both natural wetlands and CWs have been included in the UW-category. The determining factor has been set to, whether the waterbody receives urban runoff, which can be considered as an appropriate distinguishing feature[1]. Figures 4 to 9, display representative photographs of corresponding units included in this study.

Figure 4. Stoby Wetland, Hässleholm Municipality (photo: Thomas Johnsson).

Figure 5. Pond 3, Kungälv Municipality (photo: Kungälv Municipality).

Figure 6: Mensätra Wetland, Nacka Municipality (photo: Marika Zetterström).

Figure 7. Flygstaden Stormwater Pond Halmstad Municipality (photo: Mikael Brocki).

Figure 8. Herrebro Wetland, Norrköping Municipality (photo: Medins Havs och Vattenkosulter AB).

Figure 9. Snusdosan, Kungälv Municipality (photo: Kungälv Municipality).

Contextually, the significance of the adjective "urban" as a description of a wetland may be questioned. However, it is important to emphasize that the term "urban" alone is not easily defined, highlighted by a lack of consensus on its true meaning (see chapter 1.7.1). Furthermore, all municipalities surveyed in this study are

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[1] Godecke-Tobias Blecken, professor, Luleå University of Technology, email 2024-02-23.

classified as urban areas by the Swedish Association of Local Authorities and Regions (Sveriges Kommuner och Regioner 2022). Therefore, it seems reasonable to consider the wetlands investigated in this study as either urban or peri-urban.

1.6 Method

The results and data presented in this study are derived from information provided by Swedish municipalities regarding their maintenance practices for UWs. Between January 15 and April 1, 2024, 65 municipalities were contacted. Initially, a standardized contact form explaining the purpose of the study (see appendix 1), was emailed to municipality customer services. Thereafter, conversations were forwarded to the department interpreted as relevant by the customer service representatives. Respondents were categorized into two groups according to professional affiliation: “biologists/ecologists (Bio/Eco)” and “stormwater managers/urban planners (SM/UP)”. In cases where occupational affiliation was unclear, respondents were estimated to belong to one of these groups. There was a tendency for customer services to assign cases to Bio/Eco, potentially resulting in a biased representation of respondents. As urban ecology management involve a wide range of professionals who collectively shape the urban landscape (Marzluff et al. 2008; McIntyre 2020), SM/UP were actively sought and contacted for counterbalance.

The sequence of events related to the questionnaire process is depicted in figure 10. Upon contact, professionals were informed of the purpose of the thesis using the same contact form as provided to customer services. As questionnaires are a suitable method for data collection, applying to both qualitative and quantitative information (Lantz 2011), a questionnaire was subsequently presented to professionals (see appendix 2). This approach has been employed before, with both (Yang et al. 2021) and (Östberg et al. 2018) using questionnaire-based methods in their studies of urban open space maintenance. Yang et al.'s study directly aligns with this thesis as it focuses on urban wetlands, whereas Östberg et al.'s study shares a similar methodological approach by examining tree inventory routines among Swedish municipalities.

When respondents expressed uncertainty about the definition of "urban wetland", they were provided with a follow-up explanation of this (see appendix 3).

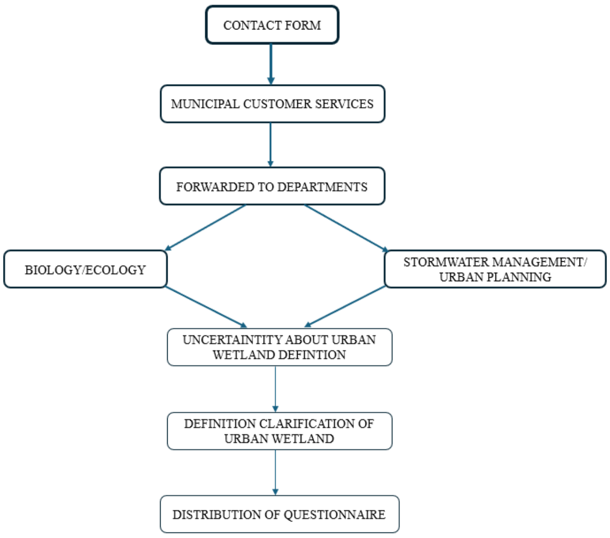

Figure 10. Sequence of Events related to the Questionnaire Process.

Question 1 ("Does/do the wetland/wetlands receive urban runoff?") served as the criterion for study inclusion. Questionnaires indicating "no" were excluded from analysis, resulting in 49 valid questionnaires from 37 municipalities. The geographical locations of respondent municipalities according to their sizes are seen in figure 11.

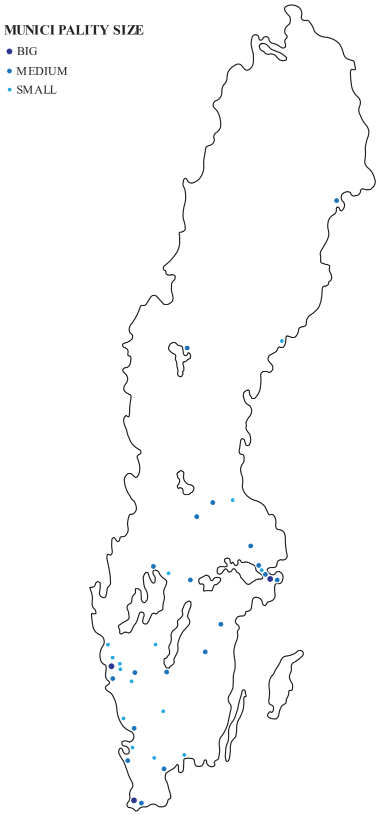

Figure 11. Geographical Location and Size Distribution of Included Municipalities.

Given that the field of UWs in relation to maintenance and biodiversity is relatively new with many areas of uncertainty, it was deemed appropriate to include both binary and open-ended questions in the questionnaire. This approach allowed for responses to provide a more comprehensive and diverse reflection of the situation within Swedish municipalities.

Answers were coded in Microsoft Excel 2021, with most variables being categorized as binary. However, "municipality size," "constructed UWs," and "within organization maintenance" were assigned three values each. Specifically, "municipality size" was divided into big, medium, and small categories, "constructed UWs" into constructed, natural, and both, and "within organization maintenance" into within organization, outside organization, and both. Figure 12 and 13 in appendix 4, respectively illustrate the coding process.

The categorization of municipalities according to population presented some challenges. While the Swedish Association of Local Authorities and Regions (Sveriges Kommuner och Regioner 2022) does not explicitly categorize all municipalities by size, some are described based on their status as commuting hubs in relation to urban centers. Consequently, to code data by size, certain municipalities had to be converted into numerical values comparable to other municipalities of similar population size, as categorized by the Swedish Association of Local Authorities and Regions (Ibid.). Estimations were necessary for the values “medium” and “small,” with the lower limit for the former set at 52,400 inhabitants, which also served as the upper limit for the latter. This conversion was aligned with the size limits defined by the Swedish Association of Local Authorities and Regions (Ibid.). Furthermore, the "size" variable was recoded separately (“size_recoded)”, combining "big" and "medium" into one category.

In instances where different professional categories (i.e. both Bio/Eco and SM/UP) completed the same questionnaire, the variable "profession" was coded as N/A. However, when two respondents from the same professional category (as defined above) completed the same questionnaire, the variable was coded as either 0 for Bio/Eco or 1 for SM/UP. This coding methodology indicates that values were recorded based on the number of questionnaires rather than the number of individual respondents.

Upon coding, descriptive statistics were analyzed in Microsoft Office Excel version 2021. Inferential statistical analysis was conducted using IBM SPSS version 29.0. The Pearson chi-square test of independence was primarily employed for analysis. When the sample size was insufficient for this method, the Fisher’s exact test was utilized. This approach aligns with the previously mentioned studies of Yang et al.

(2021), who used descriptive statistics, and Östberg et al. (2018), who conducted differential statistical analysis.

The contextual literature used for association with the topic (i.e. UWs) and analysis in this thesis was evaluated based on whether it referred to UWs, as defined in this study (see chapter 1.5). Consequently, few studies explicitly mentioned “UWs” but instead referred to CWs. However, they were evaluated to exist in the urban context as described in chapter 1.7.1. Additionally, some literature not explicitly related to UWs, was also used if it was deemed conceptually appropriate and relevant for application.

1.7 Definition of Terms

1.7.1 What is Urban?

What is urban is by no means scientifically surrounded by consensus. Its contextual implementation is broad and arbitrary, varying between academic disciplines, often being beset by confusion (Dijkstra et al. 2019; McIntyre 2020).

The lack of rigor and a coherent international standard for the definition of the term “urban”, underscores the necessity for an academic terminological unity (Ibid.). Therefore, to ensure reliability and validity, it is essential for every author to clearly define how they are using the term in their specific context (McIntyre et al. 2008).

Since there is no benchmark or absolute starting point for urban analysis, a multitude of parameters exist for measuring urbanicity. The most popular and conventional approach, is to employ a binary framework, contrasting rural landscapes with urban areas. However, this approach is problematic as it is linked to a gradient perspective, where urban and rural areas are delineated based on a radius drawn from the city center towards the agricultural landscape. The borders of where these geographical units begin and end lack clear and absolute points (Ibid.).

Accordingly, (Dijkstra et al. 2019:1), recommend categorizing urban areas based on their level of constituting "functional and economic units," exceeding conventional metrics such as population size and density. Furthermore, city size is often used as a variable to explain the degree of "urbanness". However, this approach is also complex and can lead to misconceptions because it is relative and varies depending on the criteria used by different countries in relation to their total population size (Ibid.). The Swedish Association of Local Authorities and Regions also adopts this 'hub-centered' viewpoint by describing certain municipalities from a commuter perspective rather than solely based on size (Sveriges Kommuner och Regioner 2022).

Demographics are not only measured in numbers but also stem from socio-economic and cultural factors that influence human behavior (Goode 2020). This applies also to ecological behavior, as evidenced by diverse perspectives and practices in lawn management, which have been linked to differing levels of education and income (Burr et al. 2018). Additionally, the urban character can also be studied in relation to decision-making processes, where geographical concentrations of political power, as commonly found in capital cities, are considered to constitute a high degree of urbanness (Goode 2020).

Given this context, it could be more appropriate to proceed from anthropogenic activities and their impacts on land, with subsequent alterations of associated ecosystems. This line of thinking, suggests that an area, even if situated far from the city center, could still be classified as urban due to the extensive reach of anthropogenic activities.

Considering this, cities are areas with urban syndromes caused by biotic and abiotic drivers, where biodiversity decline is one of the most dominant features of this phenomenon. Even though this progression facilitates modified, and in many ways synthetic ecosystems, urban environments can still serve as vital habitats for a wide range of organisms (McIntyre 2020). This topic is further explored in chapter 1.7.3.

In summary, the term “urban” lacks a precise definition. Therefore, its usage and interpretation require adaptation to the specific field of study and the contextual circumstances distinguishing it.

1.7.2 What is Biodiversity?

In landscape studies, biodiversity is a frequently used term, referring to species richness, evenness and abundance (Bock et al. 2007) in conjunction with genetic variability (University of Gothenburg 2020), ecosystem amplitude/plasticity (Beaugrand 2023), habitat complexity (National Research Council 1999) and functional ecosystems variations (Tilman 2001).

It is a broad and inclusive concept treating: “…all forms, levels and combinations of natural variation, at all levels of biological organization " (Gaston 2010). Scientifically, it is defined as: “The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems” (Dıaz et al. 2015:12).

Since decreased urban biodiversity stems from destructive human influence, logically human actions such as constructive maintenance efforts can contrarily be used as a tool to enhance it (Novacek & Cleland 2001). This principle extends to wetlands located within the urban matrix as well (Vermonden et al. 2009; Hsu et al. 2011).

1.7.3 What is Urban Ecology?

Urban biodiversity cannot be studied separately from urban ecology. As its name suggests, it is directly linked to altered ecosystems caused by anthropogenic activities in the urban landscape (Aronson et al. 2014; Ouyang et al. 2018). The recognition of increasing atmospheric CO_2 levels in the 1960s accelerated the academic advancement of urban ecology (McDonnell & Niemelä 2011) and in contemporary times, there has been a notable surge in scientific interest in this discipline (Small et al. 2019). Being an interdisciplinary field, encompassing ecology, economics, sociology, psychology, and other scientific disciplines, urban ecology generates a broad definition of the term, influenced by academic affiliations as a bias (McDonnell & Niemelä 2011).

Although, “…urban ecology is far more than urban biodiversity…” (Douglas 2020: LVIII), biological richness remains an inseparable component of the concept. Hence from an ecological perspective, urban ecology can be defined as “…the study of the relationship between living organisms and their environment, their distribution and abundance, the interactions between the organisms, and transformation and flux of energy and matter, in an urban area” (Verma et al. 2020:4). Or as stated by (Alberti 2008: LVII): “…urban ecology is the study of the ways that human and ecological systems evolve together in urbanizing regions”.

Thus, it provides a comprehensive view of nature found within urban areas (Alberti 2008), incorporating a vast variety of habitats, ranging from natural ones (Niemelä 1999) to synthetic ecosystems, resulting from anthropogenic factors (McIntyre

2020). In many ways, the urban landscape displays high species diversity, (Niemelä 1999), often demonstrating richer biodiversity than monocultures such as agricultural landscapes (Goode 2020). However, scholars (Niemelä 1999; Evans et al. 2011) advise against adopting a rural-urban gradient framework for analyzing urban ecology, as its multifaceted nature does not align with a binary approach.

That is to say, urban ecology is intricately connected to urbanization, transforming cities into ecosystems with urban symptoms, driven by disturbed or modified abiotic and biotic factors (McIntyre 2020; Verma et al. 2020). Specifically, stressors such as elevated temperatures, pollution (from light, noise, and air), nutritional additives (junk food), as well as pathogens and parasites (Isaksson 2015), along with hydrological changes caused by impervious surfaces, accelerate the evolution of urban biodiversity (McIntyre 2020; Fenoglio et al. 2021).

Consequently, urban ecosystems are often homogenous in species composition, favoring generalists like rats, pigeons, and exotic and invasive vegetation (Pickett et al. 2001; la Morgia 2020; Langellotto & Hall 2020). Human activities such as leaving food scraps, installing bird feeders, and planting exotic species in private gardens and parks enhance this tendency (McIntyre 2020). Furthermore, land-change drives species and individuals within the urban landscape to become spatially disconnected, through fragmentation. Therefore, steppingstones in the form of green-/blue corridors are needed for reconnection (Soulé 1991; Marzluff & Ewing 2008; Haase et al. 2020).

The term "urban metabolism" (Giurgiu et al. 2023) is fitting here as it pertains to the accelerated biological processes and progression occurring in ecosystems within urban areas. Nevertheless, The full impact of this gradual evolution on urban ecosystems is not yet fully understood (McIntyre 2020).

1.7.4 What is Urban Hydrology?

To understand the concept of "urban hydrology", it is imperative to grasp the essence of "urban", a term marked by vagueness, ambiguity, and wide-ranging scientific applications (see chapter 1.7.1.). In itself, contextual hydrology is an abiotic factor that undergoes significant alterations due to anthropogenic activities (Douglas 2020b; McIntyre 2020).

In the urban landscape, it takes on a so called flashy character (Douglas 2020b), where water flows exhibit drastic characteristics, such as high velocities, intense peak flows, high total runoff volumes, low infiltration rates, and reduced groundwater recharge (Ibid.), additionally loading municipal stormwater management.

This phenomenon is in turn induced by the constructed grey infrastructure, characterized by high levels of impermeable surfaces such as roads, pavements, roofs, and parking lots. These surfaces reduce the interception of rainfall, while the infrastructure's uniform slopes and pipes with low roughness factors, further contribute to the flashy character of urban hydrology (Liu et al. 2015). Consequently, modern urban drainage systems have paradoxically become "too effective", resulting in reduced times of concentration, potentially leading to a 30-100% increase in total runoff volumes (Ibid.).

Micropollutants including polycyclic aromatic hydrocarbons (PAHs), pharmaceutical active compounds (PhACs), metals (Douglas 2020b), plastics, per- and polyfluoroalkyl substances (PFAS) (Nguyen et al. 2019; Bodus et al. 2023; Goukeh & Alamdari 2024), nutrients especially in the form of nitrogen and phosphorus (Andoh 1994), pesticides, and organic carbon (Liu et al. 2015) are commonly found in urban runoff water discharge. Furthermore, pollutants from various sources such as traffic, industry, commercial activities, building construction, surface corrosion, spills, waste disposal, and sewer leakages alter the composition of urban runoff water (Ibid.).

During heavy rainfall, stormwater treatment plants become heavily overloaded, resulting in overflows Douglas (2020). Exceeding system capacities, foul water then damages downstream receiving water bodies through eutrophication and contamination (Liu et al. 2015; Douglas 2020b). These overflows can further increase the water concentration of organic carbon, which in turn decreases dissolved oxygen due to microbial oxidation. As a result, urban aquatic ecosystems are seriously disrupted with depletion of habitats and death of organisms (Ibid.).

1.7.5 What are Urban Aquatic Habitats?

Like UWs, urban aquatic habitats are broadly defined. According to (Wagner et al. 2008:9), they include "natural or constructed freshwater bodies, defined by their physical features" and include "urban streams, canals, rivers, ponds, impoundments, reservoirs, and lakes." Presently, they are under decline (Kozlowski & Bondallaz 2013) and are categorized among the most threatened ecosystems (Price et al. 2014). This vulnerability extends to UW-aquatic habitats, which are particularly susceptible to the detrimental effects of anthropogenic activities associated with urbanization (Ibid.).

Many traits described in chapter 1.7.3 regarding urban ecology, apply to urban aquatic ecology and its habitats as well. Accordingly, urban aquatic environments favor generalist species over specialists, as they are more resilient to abiotic stressors resulting from anthropogenic activities, such as pollution, eutrophication, anoxic conditions (Crowe & Rotherham 2019) and elevated water temperatures (Wagner et al. 2008). This trend promotes the displacement of native, more sensitive species by aggressive ones, often in the form of invasive and exotic species (Vermonden et al. 2009), thereby driving a simplification and homogenization of the monocultural character often observed in urban aquatic habitats (Hynes 1963 in Crowe & Rotherham 2019). Furthermore, similar to urban green spaces in general, land changes associated with urbanization also lead to the fragmentation of urban blue spaces (Alberti 2008). In this scenario, urban waterbodies play a crucial role as natural infrastructure in creating connections between clustered green and blue spaces, enabling species mobility and thereby promoting biodiversity (Douglas 2020a; Haase et al. 2020).

To comprehend the nature of urban aquatic biodiversity, it is essential to understand the characteristics of urban hydrology as outlined in chapter 1.7.4 (Alberti 2008; Price et al. 2014). Accordingly, high proportions of impervious surfaces distinctive to the urban matrix, is pointed out as a main stressor for urban aquatic habitats, contributing to their decline (Alberti 2008; Crowe & Rotherham 2019).

Despite the challenges and negative impacts outlined above, urban aquatic waterbodies remain crucial components of urban biodiversity. In a study on urban aquatic macroinvertebrates Vermonden et al. (2009), found that under favorable conditions, urban stormwater habitats can sustain biodiversity comparable to those found in rural areas. Additionally, Price et al. (2014), cite multiple studies indicating that fish, amphibians, and reptiles are frequently observed in urban water bodies. However, the implementation of proper maintenance measures is necessary to support the health of ecosystems within urban waterbodies (Ibid.; Vermonden et al. 2009).

Indirectly, the destructiveness of impermeable surfaces is linked to various harmful effects on urban aquatic ecosystems. These include increased effluent temperatures, greater discharge of water, pollutants, and waste, alterations in morphology, decreased dissolved oxygen levels, elevated nutrient levels, and changes in pH levels (Wagner et al. 2008). Directly, it is connected to alterations in flow regimen (see chapter 1.7.4), highlighted by Ibid. (2008) as the main factor contributing to the degradation of urban aquatic habitats.

Naturally, there are periods of fluctuations in water flow that control levels of dissolved oxygen and regulate connectivity between urban aquatic habitats through the mobility of species. Flow regimen in turn, is influenced by the physical characteristics of a waterbody. These variations include benthic topography features such as steps and falls, backwater eddies, and plunge pools, which contribute to the creation of macro habitats. Additionally, micro habitats are influenced by factors such as substrate type, hydraulic conductivity, and current velocity. The biodiversity observed in urban aquatic settings is a direct result of the heterogeneity in the physical structure of habitats (Wagner et al. 2008).

Additionally, healthy and diverse urban aquatic ecosystems depend on various physical attributes such as cover (provided by overhanging branches to shield from excessive sun radiation), rocks, debris, and a diverse composition of macrophytes (including emerged, submerged, and floating species). These features offer urban aquatic organisms essential resources like food, refuge, shelter, egg-laying nests, and nursery areas, which enable them to complete their life cycles. Additionally, aquatic flora plays a crucial role in enhancing water quality by regulating pH and oxygen levels and reducing pollution through phytoremediation (Ibid.).

However, human disturbances such as maintenance procedures alter this balance and create habitat simplification. This occurs through the uniformity of flow regimen, facilitating anoxic conditions and habitat fragmentation. The effects of this can initiate a downward spiral of urban aquatic habitat quality, where primary and secondary production become disrupted, leading to alterations in species composition between predators and prey. Subsequently, this results in disturbed food webs, alterations in organism life cycles, outbreaks of disease (Ibid.) and ecological traps (Hale et al. 2015). In the worst-case scenarios, this can result in trophic cascades exceeding thresholds for population survival and ecosystem recovery (Ibid.; Wagner et al. 2008).

1.7.6 What is a Wetland?

Determining the nature of wetlands is complex (National Research Council 1995; The Swedish Society for Nature Conservation 2023), and there is “no single, correct, indisputable, ecologically sound definition” (Federal Geographic Data Committee 2013:5) of these systems. Dry and wet environments exist along a gradient, with no clear distinction between these terrains (Federal Geographic Data Committee 2013). Furthermore, wetlands cannot be classified as purely aquatic or terrestrial (National Research Council 1995). Hence, applying a comprehensive definition of the term that suits all conditions and circumstances in which wetlands exist is challenging (The Swedish Board of Agriculture 2004).

Accordingly, there is no universally accepted definition of wetlands, and different nations and agencies provide various and differing explanations of its meaning (U.S. Fish & Wildlife Service 1993). As broadly defined, it encompasses many types of natural and constructed bodies of water (Federal Geographic Data Committee 2013; Alikhani et al. 2021). Furthermore, they can also be rehabilitated wetlands that were previously degraded (National Resources Conservation Service 2010), ideally restored to their former or natural state (United States Environmental Protection Agency 2004). However, this is not always possible (National Resources Conservation Service 2010). This allows for flexibility in the use of the term, reflecting the diversity and complexity of these systems (Tiner N.d.), which is depicted in table 1, presenting an overview of wetland definitions.

In terms of land, some authors refer to wetlands as the area existing in the transitional zone between land and water, also known as the ecotone or the littoral zone (United States Environmental Protection Agency 2004; Hui et al. 2009; Yarrow 2009). However, other attributes besides land cover, such as hydrological characteristics, nutrient cycling (Brinson 1993), and substrate composition (United States Environmental Protection Agency 2004; Yarrow 2009; Federal Geographic Data Committee 2013), can be utilized to define wetlands.

In summary, wetlands are defined by specific characteristics related to space, size (area) substrate (material and saturation), hydrology (depth and inundation), time (duration of inundation), ecosystems, habitats, and vegetation. Nevertheless, there is no clear consensus on what constitutes a wetland, rendering it an arbitrary concept.

Table 1. Wetland Definitions.

Author	Definition
Australian Government 2013:1	“Wetlands are aquatic ecosystems with plants animals and soils that are adapted to wet conditions which often require and can survive permanent or periodic inundation. Water in wetlands can be still or flowing; it can be fresh, salty or brackish. Wetlands do not have to be continuously wet…”
Australian Government 2013:1	“Wetlands may be natural or constructed or a mixture of both. Lakes, swamps, dams, marshes, mudflats, mangroves and coral reefs are all examples of wetlands. Inland rivers and coastal or marine with water up to six metres deep at low tide are also examples of wetlands”
Federal Geographic Data Committee 2013:6	“In general terms, wetlands are lands where saturation with water is the dominant factor determining the nature of substrate development and the types of plant and animal communities living in the substrate and on its surface. The single feature that most wetlands share is a substrate that is at least periodically saturated with or covered by water”
National Research Council 1995:3	“A wetland is an ecosystem that depends on constant or recurrent, shallow inundation or saturation at or near the surface of the substrate. The minimum essential characteristics of a wetland are recurrent, sustained inundation or saturation at or near the surface and the presence of physical, chemical and biological features reflective of recurrent, sustained inundation or saturation”
Ramsar Convention Secretariat 2004:6	“Areas of marsh fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres”
The Swedish Board of Agriculture 2004:11	“Wetlands are areas where the hydrology supports the growth of hydrophilic (water-loving) vegetation, which covers more than 50 percent of the vegetated area”
Swedish Environmental Protection Agency 2023:n.p.	“A wetland is an area where water is present either just above or just below the soil surface for a significant portion of the year”
Swedish Environmental Protection Agency 2023:n.p.	“Areas at the bottom of lakes, oceans, and other water bodies that temporarily dry up and lack vegetation are also considered wetlands”

Samuelsson 2023:n.p.	“Wetlands are defined as areas where water is present for a significant portion of the year, either under, on, or near the soil surface. Even vegetated water areas are classified as wetlands”
United States Environmental Protection Agency 2015:n.p.	“Areas that are inundated by surface or ground water with frequency sufficient to support a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth or reproduction”
United Nations 2021:8	“…”wetlands” might not be understood to include standing water bodies”
United States Environmental Protection Agency 2004:1	“Although wetlands are often wet, a wetland might not be wet year-round. In fact, some of the most important wetlands are only seasonally wet. Wetlands are the link between the land and the water. They are transition zones where the flow of water, the cycling of nutrients, and the energy of the sun meet to produce a unique ecosystem characterized by hydrology, soils and vegetation…”
United States Environmental Protection Agency 2015:n.p.	“Wetlands are areas that are inundated or saturated by surface or ground water at frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil condition. Wetland generally include swamps, marshes, bogs and similar areas”
Tiner N.d.:n.p.	“”Wetland” is a generic term for all the different kinds of wet habitats- -implying that it is land that is wet for some period of time, but necessarily permanently wet”
Bevan 2020:13	“Wetlands are unique ecosystems that are either permanently or seasonally inundated with water. They include lakes, rivers, swamps and marshes, wet grasslands, estuaries, saltmarshes and human-made sites such as ponds and reservoirs. They range in size from garden ponds to the Pantanal in Brazil, Bolivia and Paraguay, which is three times the size of Ireland”
Yarrow 2009:1	“Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. Most people recognize wetlands as a transition between aquatic environments and uplands where: the water table is at or near the surface of the land, or the land is covered by water to a depth of no more than 6 feet”

1.7.7 What is a Constructed Wetland?

At the far end of the wetland spectrum (Palta & Stander 2020), CWs seem to have clearer definitions compared to NWs and UWs. table 2 illustrates this, by demonstrating relatively fewer variations in defining the term.

However, they display considerable variations in size, ranging from 10 m^2 to 2-5 km^2 (Ibid.). Additionally, they may not always fit into commonly predefined hydrogeomorphic wetland categories (LePage 2011). Rooney et al. (2015) highlight four main distinctions between CWs and NWs: 1. CWs typically have steeper slopes; 2. CWs have less contact with groundwater; 3. Unlike NWs, CWs maintain a basic minimum water table level; 4. CWs exhibit higher nitrate-nitrite levels and chloride concentrations.

Furthermore, when comparing different types of stormwater management systems, Blecken (2016) contends that CWs are more effective treatment facilities than stormwater ponds, particularly in the removal of soluble pollutants, as they leverage soil and vegetation more efficiently. However, this context is complex because stormwater ponds can also incorporate wetland areas (Ibid.). Additionally, CW:s often work in conjunction with pre-sedimentation basins, which are designed to alleviate the constructed wetland from excessive nutrients and pollutants (McNett & Hunt 2011).

In summary, CWs can be viewed as man-made copies of natural wetlands. By harnessing biological, chemical, and physical processes (Rousseau et al. 2008, 2021), as well as sedimentation (Blecken 2016), their primary purpose is to enhance the retention, detention, infiltration, and purification of urban stormwater runoff (Blecken 2016; Palta & Stander 2020). Moreover, they serve multiple purposes (Fitzgerald 2018; Metcalfe et al. 2018; Liao et al. 2020), including the facilitation of ecosystems and the increase of biodiversity (Liao et al. 2020).

Table 2. Constructed Wetland Definitions.

Author	Definition
Australian Government 2006:n.p.	“Constructed wetland systems are shallow, extensively vegetated water bodies that use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from stormwater”
Blecken 2016:36	“Constructed stormwater wetlands (in the following text only referred to as wetlands) provide a hybrid solution combining elements of ponds and sedimentation basins and so called green infrastructure (which employs vegetation for stormwater treatment)”
Hammer 1989:12-13	“…designed and man-made” complex of saturated substrate, emergent and submergent vegetation, animal life and water that simulate natural wetlands for human use and benefit”
Liao et al. 2020:1	**“**CWs are artificial functional systems comprising wetland vegetation, beds, and shallow ponds or trenches that can be engineered for multiple purposes, such as wastewater treatment and wildlife habitat restoration”
Metcalfe et al. 2018:3	“Constructed wetlands are purpose-built systems that are engineered to achieve one or more of the functions of natural wetlands”
Rogerson 2022:39	“An artificial or constructed urban wetland is a new or restored marsh area within a city designed to manage anthropogenic discharge such as wastewater, stormwater runoff, or sewage treatment and to assist in land reclamation after ecological disturbances associated with mining and urban development”
Rousseau et al. 2008:181	“Constructed wetlands (CWs) are man-made copies of natural wetlands that optimally exploit the biogeochemical cycles that occur in these systems for the purpose of wastewater treatment”
Rousseau et al. 2021:273	“…Manmade wetland ecosystems, engineered in such a way that they make optimal use of the biological, physical and chemical processes offered by wetland vegetation, microorganisms and soil to purify water”
Vymazal 2007:48-49	“Constructed wetlands are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation soils, and their associated microbial assemblages to assist in treating wastewater”

Yang et al. 2021:1443	“Constructed wetlands (CWs) are human-made land areas covered by shallow water throughout or at certain periods of a year, and use natural vegetation, soil and microbial communities for water purification”
Zhang et al. 2020:2	“Constructed wetlands (CWs) are artificial ecosystems that simulate biogeochemical processes occurring natural wetlands to optimize their water purificaton”

1.7.8 What is an Urban Wetland?

Table 3, demonstrates that urban wetlands, like natural wetlands, are also broadly defined (Dooley & Stelk 2021). This is further intensified by the rapid evolution of stormwater management in modern times, leading to the development of an entirely new terminology (Fletcher et al. 2015). Inconsistencies in the usage of the term create conceptual barriers among stakeholders (Dooley & Stelk 2021), exemplified by jargon rather than linguistic integration (Fletcher et al. 2015). As a result, this generates overlaps and confusion (Ibid.).

As a relatively new phenomenon, urban wetlands are no exception to this trend, showing significant variations in definitions nationally, regionally, and locally (Ibid.). (Dooley & Stelk 2021:2) accurately illustrate this by stating that the definition of a wetland within the urban context: “could depend on who created the wetland, why they created the wetland, where the wetland is sited, whether the wetland is able to maintain a natural ecosystem balance on its own or requires maintenance, and other variables”.

In popular usage, natural wetlands (NWs) and urban wetlands (UWs) are often perceived to be mutually exclusive (Sexson n.d.). In fact, urban wetlands share many characteristics with natural wetlands, but there are some tangible differences. The common factor in this seems to be urbanization. Unfortunately, this is also linked to indistinctness, as the term "urban" itself is ambiguous. As Vymazal (2024)[2] puts it: "“Urban wetlands are simply wetlands that are located within cities". This vagueness prompts every author to clearly and unambiguously state the definition they are using (Fletcher et al. 2015).

However, it seems appropriate to directly associate urban wetlands with heavy anthropogenic influence, which significantly distinguishes their ecological nature from natural wetlands. At the core of this lies urban hydrology (see Chapter X, "Urban runoff"), which is greatly modified due to human interference (Brinson 1993; Goode 2020).

In summary, like natural wetlands, urban wetlands lack a consistent and complete definition. They encompass both natural and constructed (artificial and semi-artificial) bodies of water (Alikhani et al. 2023) and the distinction between these units is unclear, since there is no consensus on the level of anthropogenic influence and the age criteria that define an urban waterbody as either natural or constructed

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[2] Jan Vymazal, Professor, Czech University of Life Sciences, email 2024-02-22.

(Frajer et al. 2021). However, a common reference to their condition is their location within city or municipal boundaries. In reality, the receipt of urban runoff can be an appropriate distinguishing factor[3] (see chapter 1.5).

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[3] Godecke-Tobias Blecken, professor, Luleå University of Technology, email 2024-02-23.

Table 3. Urban Wetland Definitions.

Author	**Definition**
Alikhani et al. 2021:4	"…urban and peri-urban wetlands are located inside and around urban areas and their suburbs"…"In priniciple, urban wetlands are classified as natural and constructed"
Australian Government 2013:1	"Urban wetlands are those which lie within the boundaries of a city or town. Peri-urban wetlands are located in areas adjacent to cities and towns"
Blacktown City Council 2019:47	"A wetland[4] is a vegetated wet basin (or series of wet basins) that filter and treat stormwater before it enters our waterways"
Blecken 2024[5]	"Urban wetlands often including stormwater ponds are constructed bodies of water that receive urban runoff"
(Dooley & Stelk 2021:2)	"Urban Wetland – Wetlands within and immediately adjacent to populated areas, including cities and towns, that provide economic, ecological, and social benefits for those communities. Urban wetlands may be naturally occurring or created"
Nebraska Government 2024	"Urban wetlands can be of a variety of types, including marshes, stream edges, wooded floodplains, or constructed ponds and reservoirs. They can be on the edge of a community or run right through the heart of town"
World Wetlands Day 2018:n.p.	"Urban and peri-urban wetlands are found in and around cities and their suburbs. They include rivers and their flood plains, lakes, swamps as well as salt marshes, mangroves and coral reefs"
Sun et al. 2004 in Wang et al. 2009:53	"…the wetlands located in the city (town) are known as the urban wetlands"
Vymazal 2024[6]	"Urban wetlands are simply wetlands that are located within cities"
Wang et al. 2008:47	"Urban wetlands, in the form of artificial and semi-artificial wetlands in urban construction…"

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[4] Mentioned in an UW-context.

[5] Godecke-Tobias Blecken, professor, Luleå University of Technology, email 2024-02-23.

[6] Jan Vymazal, Professor, Czech University of Life Sciences, email 2024-02-22.

Bevan 2020:13	"…They include urban streams and canals, ponds and lakes in urban parks, rain gardens and swales, and even ponds in private gardens"[7]

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[7] Referring to NW:s in cities.

1.7.9 What is Urban Wetland Maintenance?

To the best of my knowledge, there is currently a shortage of studies specifically examining the maintenance of urban wetlands in relation to biodiversity. Instead, most contextual studies tend to focus solely on maintenance in relation to treatment efficiency. However, the reciprocal relationship between UW-treatment efficiency and related biodiversity, as described in chapter 1.7.10, suggests that both components benefit from each other.

Therefore, this study assumes that research demonstrating examples of UW-maintenance favoring stormwater efficiency can be paralleled with positive biodiversity status. Furthermore, while most contextual studies focus on treating urban units, they specifically target the maintenance of CWs. Nonetheless, considering the considerable overlap in the nature and categorization of wetland systems, as described in chapters 1.7.6, 1.7.7, and 1.7.8, it seems legitimate to conclude that findings regarding appropriate CW-maintenance are applicable to UWs as a whole, subsequently affecting their biodiversity. This is reinforced by Alikhani et al. (2021), who emphasize that UW-/CW-maintenance routines are necessary for ensuring healthy UW-habitats that provide rich biodiversity, by Knapp et al. (2019), who state that tailored management can enhance related biodiversity and by Chen (2011 in Al-Rubaei et al. 2016), who points out that adequate vegetation maintenance correlates with productive faunal habitat development.

Albeit considered as low-maintenance by many (Beharrell 2004; Malaviya & Singh 2012; Gikas & Tsihrintzis 2014; Larm & Blecken 2019; Zhang et al. 2020; David et al. 2023; Ghosh et al. 2023), UW:s are still complex, dynamic systems that change over time (Shutes 2001), primarily due to anthropogenic flux (Grayson et al. 1999). Thus, they should by no means be considered as no-maintenance (Beharrell 2004) or build-and-forget units (Rousseau et al. 2004). Contrary to the "no/low maintenance" view, there are numerous concrete recommendations for UW-maintenance, which can be found in table 4.

Moreover, UWs do not function in isolation. Instead, they coexist with upstream and downstream hydrology and water bodies, including groundwater if they are in contact with it. These circumstances require expertise from required and experienced maintenance staff to carry out appropriate procedures (Shutes 2001; Beharrell 2004), where the nature and level of interventions are determined on a case-by-case basis, considering location, stakeholder interests (Palta & Stander 2020), trade-offs (Hanford et al. 2020) and the intended construction purpose illustrated by prioritized ecosystem services (Palta & Stander 2020).

The need for frequent and continuous monitoring of UW-functioning and health (Shutes 2001; Moore & Hunt 2012; Yang et al. 2021), with recommendations ranging from daily inspections (Rousseau et al. 2008) to weekly checks (Sundaravadivel & Vigneswaran 2001) and monitoring every one to six months (Australian Government 2006), underscores the importance of intentional UW-maintenance. However, UW-systems often suffer from maintenance neglect (Malaviya & Singh 2012; Blecken 2016; Dooley & Stelk 2021), with a lack of expertise, knowledge, and organizational coordination being contributing factors (Australian Government 2006). Starzec et al. (2015 in Blecken 2016), highlight this by finding that 50% of 26 ponds belonging to the Swedish Transport Administration did not have maintenance regimens. Consequently, omitted and/or misdirected management can lead to disrupted hydrological processes, which inhibit treatment efficiency (Reddy et al. 2014; Metcalfe et al. 2018; Wright et al. 2022). As a result, UW-biodiversity can become impaired (Gorgoglione & Torretta 2018; Wright et al. 2022).

A frequently raised concern in relation to maintenance neglect of UWs, is the overabundance of mosquitoes, which can potentially spread vector-borne diseases, thereby posing a threat to human health (Hunt et al. 2011; Hanford et al. 2020). The appropriate procedures for addressing this concern are manyfold (as presented in Table 4), with particular emphasis placed on striking the right balance of intervention (frequency, timing, disturbance) for avoiding monocultures, especially of *Typha ssp.*, and preventing an excessive accumulation of debris.

Inappropriate maintenance actions can do more harm than good, potentially reversing years of treatment processes (Wright et al. 2022). Even though table 1.4 illustrates this situation by presenting a broad array of views and recommendations for UW-maintenance, there are recurring themes. Firstly, possessing a thorough understanding of hydrological processes appears to be essential, where control of the water table level emerges as the single most important factor (Hunt et al. 2011; Bae & Lee 2018; Liao et al. 2020; Ghosh et al. 2023). This control directly affects UW-health, including their biodiversity status (Liao et al. 2020). Secondly, this is associated with negligent management practices, where debris of dead organic material is left to accumulate. This leads to raised water tables by clogging inlets and outlets (Rousseau et al. 2008; Hunt et al. 2011; Wright et al. 2022) (see figure 12 in appendix 6), reduced effective water area (White et al. 2018) as well as dead zones (Ibid.; Australian Government 2006). As a result, water velocity increases (Zeff 2011; White et al. 2018; Ghosh et al. 2023), while hydraulic conductivity and hydraulic retention time decrease (Sundaravadivel & Vigneswaran 2001; White et al. 2018), consequently resulting in decreased treatment efficiency and subsequent biodiversity loss (Wright et al. 2022), as exemplified through the formation of ecological traps (Knapp et al. 2019; Zhang et al. 2020).

Additionally, treatment efficiency and biodiversity status are interconnected with the design of the UW-system. For example, UW-systems with an appropriate land-slope ratio (generally 1:3 is recommended) (Australian Government 2006), a large surface water area, complex shoreline, diverse bottom topography (Hansson et al. 2005), and a multicellular structure (see figure 14 and 15) (Shutes 2001; Hamer & Parris 2013) contribute to positive outcomes for both ecosystem services components.

Figure 14. UW-Multi-Cellular Design, Stoby Wetland, Kristianstad Municipality (photo: Mikael Brocki).

Figure 15. CW-Multi-Cellular Design, Columbia USA (photo: City of Columbia Utilities).

Also, the layout of the system should facilitate physical access for all maintenance tasks, such as reaching macrophyte zones for weeding or providing space for heavy machinery required for dredging (see figure 16) (Australian Government 2006).

Figure 16. UW-Design allowing for Heavy Machine Access (photo: Jonas Andersson, WRS).

Considering these circumstances, maintenance becomes a tool to uphold the favorable design components, which themselves are necessary for facilitating these tasks. Therefore, maintenance strategies should be established already at the design phase (Shutes 2001).

As indicated by Blecken (2016) and suggested by Table 4, there seems to be scientific disagreement on the appropriateness of executing UW-harvesting (see figure 14).

Figure 15. UW-harvesting (photo: Öckerö Municipality).

When planning for such actions, a trade-off analysis regarding biochemical processes should precede implementation (Merriman & Hunt 2014 in Blecken 2016). This pertains to the retention or removal of post-maintenance debris, as harvesting removes phosphorus but may increase nitrogen retention due to the loss of living vegetation performing phytoremediation (Wright et al. 2022). Furthermore, if post-harvest debris is left at the site, decomposition of dead organic material can cause the resuspension of previously bound particles back into the water phase (Chimney & Pietro 2006 in Blecken, 2016).

Overlooking the above aspects may not initially manifest any obvious effects, but over time they prove to be detrimental to UW-health (Rousseau et al. 2008; Wright et al. 2022).

Table 4. Recommendations and Key Points for Urban Wetland Maintenance.

Author	Recommendations and findings
Yang et al. 2021	• Continuous monitoring (every one to six months) of treatment efficiency to ensure the health and functioning of urban wetlands
Liao et al. 2020	• Maintain/create variations in water depth to enhance food resources and improve habitats for both fauna and flora
Moore & Hunt 2012	• Maintain a shallow water table to support a healthy macrophyte population • Monitor outlet conditions to maintain the desired water table level
Rousseau et al. 2008	• Controlling water flows on a daily basis • Maintaining inlets and outlets in good condition is essential for urban wetland maintenance • Advantages of harvesting include: exporting nutrients, decreasing accumulation of dead debris inhibiting hydraulic conductivity and preventing the establishment of breeding sites for pests • Disadvantages of harvesting include: removing dead organic material necessary for the absorption of trace metals and denitrification
Malaviya & Singh 2012	• Removal of sediments • Control of water table level • Monitoring and regulation of nutrient and pollutant levels • Control of substrate and plant health • Control of weed growth • Harvesting
Birch et al. 2004	• Dredging to minimize levels of heavy metals
Larm & Blecken 2019	• Harvesting generally not recommended
Beharrell 2004; Zhang et al. 2012	• Retain finer sediments containing high levels of metals to prevent their resuspension
Hanford et al. 2020	• Misdirected and neglected maintenance can lead to unwanted mosquito infestation • Removal of invasive species should be conducted following a trade-off analysis
Bae & Lee 2018	• Maintenance of vegetation and the water table level are important parts of urban wetland upkeep

Knapp et al. 2019	• Regulation of dominant species through dredging and harvesting • Intermediate disturbance to favor biodiversity • Bad maintenance can create eco-traps
Scheffers & Paszkowski 2013	• Maintaining fringe vegetation to support frog habitat
Kadlec & Knight 1996 in Metcalfe et al. 2018	• Harvesting should not be done as it disrupts ecological cycles • Upkeeping uniform hydraulic flow • Sustaining the water table level • Controlling weeds, plant health and animal status (including pests)
Sundaravadivel & Vigneswaran 2001	• Maintaining the water table level • Maintaining inlet and outlet zones • Preserving vegetation cover • Monitoring vegetation status on a weekly basis during the first two to three seasons after construction
Gorgoglione & Torretta 2018	• Monitoring and upkeeping the hydraulic conductivity
Australian Government 2006	• Continuous inspections of inlets and oulets • Desilting inlet zone and inlet pond (every five years) • Controlling the water table level • Removing litter and debris • Removing invasive plants • Replacing missing vegetation • Monitoring and control of pests • Irrigation of littoral vegetation
Merriman & Hunt 2014	• Harvesting can have a negative effect on biology/biodiversity

Blecken 2016	• Concentrating maintenance efforts on inlet and outlet zones • Maintenance neglect of inlet- and outlet zones can raise the water table level with 0.5 with subsequent drowning of vegetation • Careful handling of sediment to prevent the resuspension of harmful substances
Reddy et al. 2014	• Clogging of media/substrate is the biggest problem, causing impaired infiltration capacity and decreased hydraulic conductivity
Wright et al. 2022	• Effective maintenance of inlets and outlets is central for UW-health • Nitrogen treatment efficiency decreases following dredging • Retained sediment equals retained phosphorus • Removed sediment equals removed phosphorus • Whether wet or dry weather conditions, have significant effects on nitrogen and phosphorus levels. Wet conditions during maintenance particularly offer advantages for P levels • Unhindered vegetation growth can lead to an increase in mosquito abundance
Hamer & Parris 2013	• Temporal draining increases biodiversity by removing fish
Revitt et al. 1999	• Resuspension, particularly during high flows, is the primary concern for UW-health • The timing of maintenance tasks is essential for success
Hunt et al. 2011	• Mosquito prevalence is one of the major drawbacks of UWs • Maintaining the water table level is the most important task for mosquito control • Clogging of inlets and outlets results in a rise in the water table, posing a risk of emergent vegetation dying out • Post-harvest debris reduce the population of mosquito predators • Post-harvest debris serves as a breeding ground for mosquitoes • Debris reduces detention time, thereby favoring monocultures of invasive plant species • Monocultures of vegetation favor mosquito prevalence
Carver et al. 2015	• Human disturbance can inhibit mosquito predators thus leading to increased numbers of mosquitos • Elevated levels of pollutants and nutrients can decrease the abundance of mosquito predators, consequently increasing mosquito populations

Ghosh et al. 2023	• Controlling the water table is the most important maintenance task for UW-health • Controlling flow rates • Removing weeds • Removing stagnant litter

1.7.10 What is Urban Wetland Biodiversity?

Until now, research has prioritized UW-treatment efficiency over biodiversity (Zhu et al. 2010). However, in the contemporary context, stormwater management is increasingly recognized as an urban resource, with biodiversity acknowledged as one of the contributing factors (Fletcher et al. 2015).

Although urban wetlands may be considered sub-optimal habitats (Zhang et al. 2020) and exhibit significantly lower biodiversity compared to natural wetland systems (Johnson et al. 2013), they remain vital components for urban biodiversity and urban ecology (Knapp et al. 2019; Zhang et al. 2020; Alikhani et al. 2021; University of Helsinki 2023). Stormwater treatment and biodiversity can function as supplementary components in the urban landscape (Hansson et al. 2005; Herrmann 2012) and there are indications that UWs exhibit ecological resilience in response to the stressors induced by urbanization (Hansson et al. 2005; Johnson et al. 2013; Blanckenberg et al. 2020).

Numerous authors emphasize the importance of inherent factors of UWs in protecting and enriching urban biodiversity such as: having the potential to become productive urban habitats (Rousseau et al. 2008; Sauer & Chang 2024) with rich biodiversity (Hsu et al. 2011) for otters, lizards, birds, insects (Public Utilities Board, Singapore 2018), amphibians (Scheffers & Paszkowski 2013), bees (Anderson et al. 2023), hedgehogs, butterflies (Bevan 2020), fish (Mackintosh et al. 2015), and native aquatic macrophytes (Kozlowski & Bondallaz 2013), exhibiting higher biodiversity compared to other green urban spaces (Thames 21 2024); housing endangered species within their ecosystems even within densely populated areas (Chovanec 1994), being important components of green corridors (Rogerson 2022), driving urban ecological sustainability, and bringing nature to city dwellers (De Martis et al. 2016; Alikhani et al. 2021). Table 5 presents key findings regarding biodiversity in UW:s.

Although ecosystems can establish relatively quickly (Worell et al. 1998 in Spieles & Mitsch 2000; Strand & Weisner 2010; Herrmann 2012; Wahlroos et al. 2015), as evidenced by practical experiences of functioning ecosystems after only a few years[8], anthropogenic stressors such as elevated nutrient and pollutant loads (Kadlec & Bevis 1990 in Spieles & Mitsch 2000) along with the presence of plastic in food webs (Ratnayaka et al. 2023), pose threats to the biodiversity of UW:s (Hou

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[8] Eleonor Häger, Landscape architect, Ekologigruppen, email 2023-03-12.

et al. 2024). However, impaired functional UWs with inadequate water cleaning treatment, leading to elevated nutrient and pollutant levels, can still serve as important habitats for aquatic organisms (Hsu et al. 2011; Sievers et al. 2019; Alikhani et al. 2021).

Deterministic factors appear to influence the species composition and abundance of individuals within species in UW-systems (Herrmann 2012). Among these factors are shoreline complexity (Ibid.; Hansson et al. 2005), nitrogen-phosphor ratio, organic carbon levels, pH levels, riparian zone length (Hou et al. 2024), access to organic material (Spieles & Mitsch 2000), benthic topography (Moore & Hunt 2012), dissolved oxygen levels (Spieles & Mitsch 2000; Korfel et al. 2010), whether the wetland is created or natural (Korfel et al. 2010; Moore & Hunt 2012; Perron & Pick 2020), water depth (Hansson et al. 2005), hydroperiod characteristics (i.e. temporal variations in inundation) (Blanckenberg et al. 2020), level of protection (Ibid.), and the nature and frequency of disturbance (i.e., maintenance) (Zhang et al. 2020).

Unfortunately, UWs can become ecological traps (Hale et al. 2019), a phenomenon supported by a substantial body of literature[9]. Misguided maintenance is one of the factors that can contribute to this (Zhang et al. 2020).

Despite the fact that fish and crayfish typically prey on mosquitoes, potentially reducing the risk of vector-spread diseases, their introduction into wetland systems is generally discouraged (Feuerbach 2014). This is because their presence as top predators can significantly decrease wetland biodiversity (Johnson et al. 2013). In conjunction with this, it is noteworthy to point out that, healthy and bio-diverse wetland systems strive for equilibrium and keep mosquitos at tolerable levels (Feuerbach 2014).

It is essential to emphasize the “proportional correlation between increased water treatment efficiency and biodiversity” (Giurgiu et al. 2023:13) in UWs, where the former benefits from the latter (Zhang et al. 2020). This highlights the importance of maintaining the ecological integrity of these systems within the urban landscape.

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[9] See for example table 2 in Zhang et al. (2020).

Table 5. Urban Wetland Biodiversity..

Author	Finding
Wahlroos et al. 2015	• Rapid colonization of amphibians and water birds following construction
Herrmann 2012	• *Gastropods* and *Isopods* establish within a few months to a few years after construction • *Trichopterans* establish later and in smaller numbers • *Cloeon dipterum* is at risk of developing too rapidly during the initial stages of ecosystem establishment
Hansson et al. 2005	• 51 invertebrate species, 51 macroinvertebrate species, 12 bird species and five fish species found in UW • Greater shoreline complexity promotes macrophyte cover • Elevated phosphorus levels pose the greatest obstacle to biodiversity
Sievers et al. 2019	• No correlation between pollutant loading and frog occupancy
Johnson et al. 2013	• The taxonomic richness of UW:s is significantly lower compared to agricultural and grassland wetlands • No effect of urbanization on habitat stability
Moore & Hunt 2012	• Less vegetation observed in UW:s (CW:s) than in “naturally occurring” wetlands • Less macroinvertebrates observed in UW:s (CW:s) than in “naturally occurring” wetlands • 50 species of vegetation were found • 31 families of macroinvertebrates were identified, representing 13 different orders • Higher levels of macrophytes corresponded to higher numbers of odonates • Odonates were more abundant in UW:s (CW:s) featuring littoral shelves
Hou et al. 2024	• Human disturbance severely disrupts UW (peri)-vegetation • Aquatic plant abundance increases with wetland area and total phosphorus in water, while it decreases with total organic carbon in water, water pH, and length of riparian zone • The abundance of native plant species decreases with increased levels of organic carbon, total soil phosphorus, and riparian zone length
Hale et al. 2019	• Many UW:s were inhabited by frogs

	• Frogs inhabited heavily polluted (heavy metals and pesticides) UW:s • Frogs thrive more in emergent and fringing vegetation zones
Stephansen et al. 2016	• UW:s (stormwater wet ponds) display comparable biodiversity in terms of invertebrate taxa richness and composition to that of natural small and shallow ponds
Semeraro et al. 2015	• 73 bird species (95% migratory), four species of amphibians, three species of reptiles and five species of mammals were found
Spieles & Mitsch 2000	• A lower occurrence of macroinvertebrates was observed near the inlet compared to those found near the middle and/or outlet • Low levels of dissolved oxygen can restrict the establishment of wetland vegetation and fauna
Korfel et al. 2010	• Dissolved oxygen levels were higher in UW-created ponds compared to UW-natural ponds • Higher amphibian taxa diversity was observed in UW-created ponds compared to UW-natural ponds • Amphibian individuals, belonging to three taxonomic families, exhibited a more even distribution in UW-created ponds compared to UW-natural ponds • Fewer *Odonata* and *Zygoptera* nymphs were observed in UW-stormwater ponds compared to UW-natural ponds • The community structure of Zygoptera in UW-stormwater ponds was similar to that observed in UW-natural ponds
Blanckenberg et al. 2020	• There was no observed difference in macroinvertebrate diversity between protected and unprotected UW:s • Predators such as *Odonata* nymphs, aquatic bugs, and *Calanoid copepods* were more abundant in protected UW:s than in unprotected ones
Rousseau et al. n.d.	• Amphibians were absent in the inlet zone but thrived in the outlet zone • 86 species of vascular plants were found • 35 avian species were found

2. Results

2.1 Descriptive Characteristics of Respondents/Questionnaires

In order to identify trends and tendencies within the relatively limited dataset presented in this thesis, the significance level has in certain cases been set at 90% confidence ($\alpha = 0.1$).

The response rate yielded 61 received questionnaires, with 80.3% ($n = 49$) deemed valid, indicating that their responses specifically pertained to UWs receiving urban runoff.

37 municipalities were represented in the valid questionnaires, with 41.0% ($n = 20$) of respondents being Bio/Eco and 59,0% ($n = 29$) being SM/UP. 22,0% ($n = 11$) of the municipalities provided responses from both professional affiliations.

As seen in figure 16, 12,3% ($n = 6$) of the questionnaires regarded big municipalities, 51% ($n = 25$) medium-sized municipalities and 36,7% ($n = 18$) small sized municipalities. Contextually, it is necessary to emphasize that there will automatically be a misrepresentation of the former category, as they are proportionally fewer in Sweden compared to medium-sized and small ones. Consequently, there are only three municipalities in Sweden categorized as large: Stockholm, Gothenburg, and Malmö.

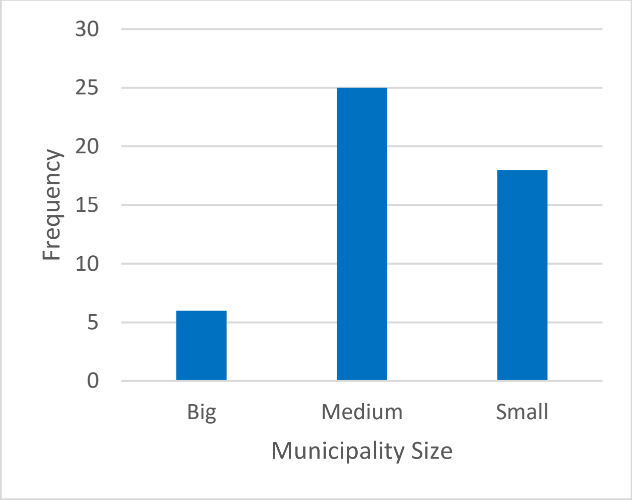

Figure 16. Number of Questionnaires by Municipality Size.

In this context, it is noteworthy that 29.5% (*n = 18*) of the respondents expressed uncertainty regarding the applied definition of UWs. The uncertainty was evenly distributed among the professional affiliations surveyed (*n = 9 and n = 9 respectively*). This observation is consistent with the information detailed in chapter 1.7.8, which sheds light on the arbitrary and vague definitions of UWs.

2.2 Inferential Analysis and Descriptive Data of Responses

2.2.1 Physical Nature of Reported UWs

Among the referred UWs, there was an overrepresentation of CWs, exemplified by *77.6%* (*n = 38*) of the questionnaires.

Professionally, SM/UP referred to CWs more frequently than Bio/Eco (*n=24, 64,9%*), a pattern supported by a statistical trend (*p = 0.094*).

2.3 Maintenance Strategies

60% (*n = 30*) of the questionnaires indicated the presence of a maintenance strategy. Across professional affiliations, municipality size does not seem to predict whether a municipality has an established and documented UW-maintenance strategy or not, as no statistical significance was found between these variables. On the contrary, SM/UP are more likely to operate according to such strategies (*n = 22, 73,3%*), underscored by a statistical test (*p = 0.005*). When big and medium-sized municipalities were combined into one group for the same analysis, this connection remained (*p = 0.005*).

Among the questionnaires that attached documents on their maintenance strategies (*n = 19*), two groups of components were identified: 1) procedures categorized as monitoring and 2) procedures categorized as actions. The monitoring routines contained four subgroups (see figure 17), aiming to control the following factors, listed in rank order: erosion (*38,5%*), vegetation (*23,1%*), water table (*19,2%*) and sediment level (*19,2%*).

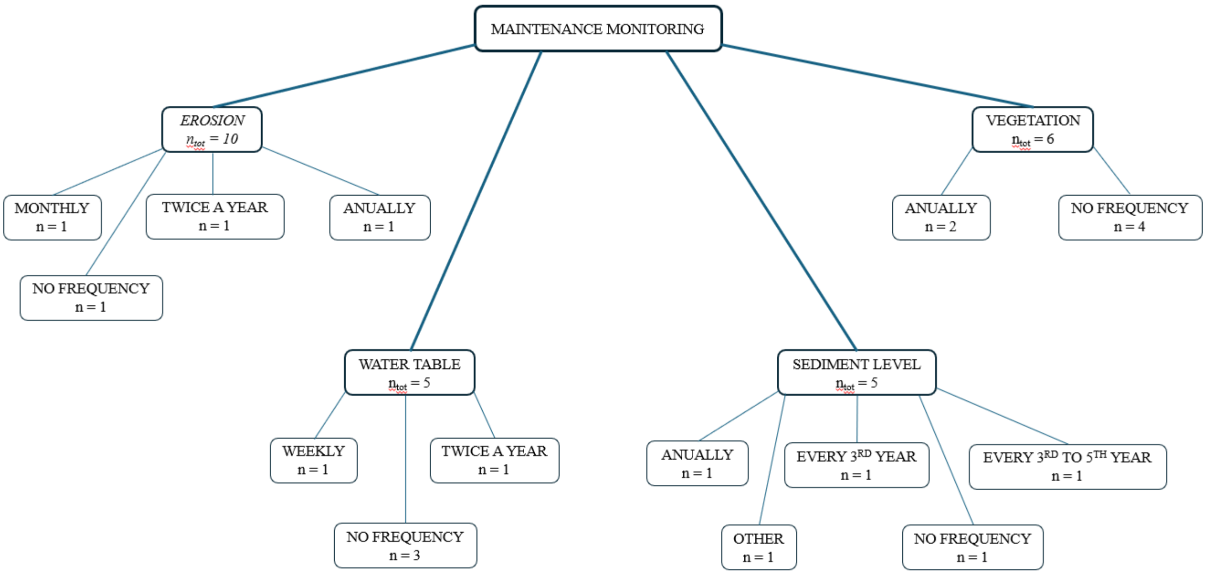

Figure 17. Frequencies of Maintenance Monitoring reported by Questionnaires.

Contextually, it is worth noting that controlling the water table, was ranked last, tied with control of sediment level, which is closely linked to the former's characteristics. For the monitoring components, it was explicitly stated in some cases, while implied in others, that control should be followed by maintenance actions such as repairing/strengthening slopes with cocoa fiber nets upon the risk of erosion being noticed. Furthermore, it was understood that weak and suffering vegetation should be accompanied by re-planting and/or re-sowing.

Regarding maintenance actions, cleaning/de-clogging of inlets and outlets (*38,5%*), was the most frequently mentioned factor. Removal of unwanted material such as waste and excess organic matter (*15,9%*) and dredging, (see figure 18) (*15,9%*) were relatively common maintenance actions, tying for second place along with trimming and cutting of vegetation in and/or around adjacent areas of the UWs (see figure 19) (*15,9%*).

Figure 18. UW-Dredging (photo: Peter Johnsson).

Figure 19. Wetland Vegetation Trimming and Cutting (photo: Emil V Nilsson).

Clearing/cutting of ligneous vegetation (see figure 20) (*11,1%*) can be regarded as an integrated part of trimming and cutting of vegetation. However, some documents emphasized that the actual maintenance action pertained to clearing of woody vegetation such as shrubs and trees. Therefore, it was documented as a separate factor.

Figure 20. UW-Clearing and Cutting of Ligneous Vegetation (photo: Thomas Johnsson).

When scything (see figure 21) (*11,1%*) was described as part of the maintenance strategy, it was often stated that the cut debris should be removed from the site.

Figure 21. UW-Scything (photo: Marilyn Cox).

Finally, weeding of water and land vegetation, including algae (*4,8%*), was the second least reported maintenance action, followed by emptying the water from the UW (*3,2%*). Additionally, as indicated by Figure 22, the option of "no frequency" was the most commonly stated temporal specification. This directive was often referred to as "when needed".

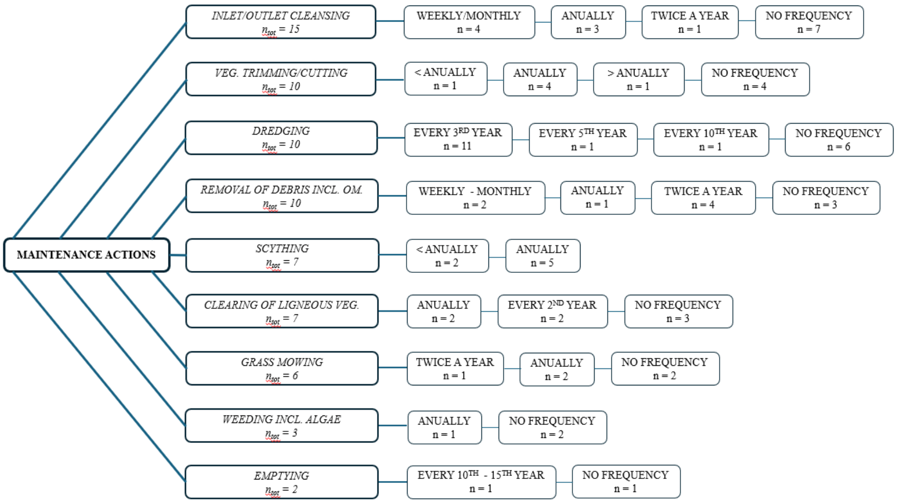

Figure 22. Frequencies of Maintenance Actions reported by Questionnaires.
Abbreviations: Veg, Vegetation; OM, Organic Material.

2.4 Maintenance Problems

65.3% (*n = 32*) of the questionnaires reported maintenance problems, however, there was no statistically significant difference between reporting among professional affiliations. Interestingly, there was a notable overrepresentation of medium-sized municipalities experiencing maintenance problems (see figure 23), a pattern observed across both professional affiliations. Importantly, this relationship displayed a statistical trend ($p = 0.087$). When considering big and medium sized municipalities as one value ("size_recoded"), this observed relationship remained ($p = 0.086$).

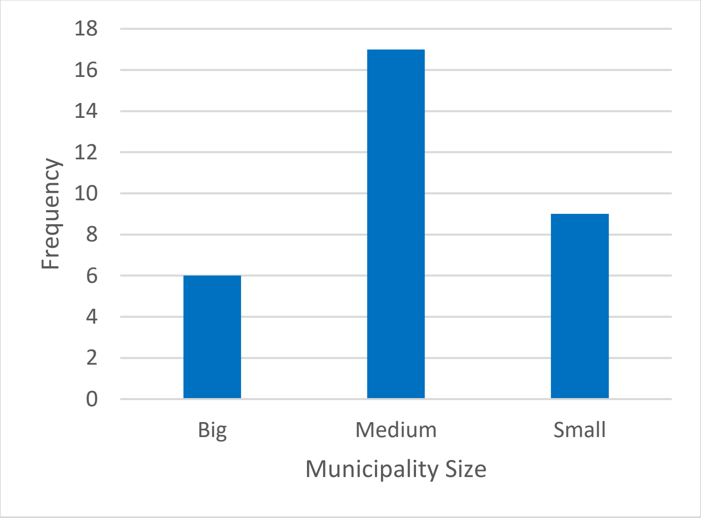

Figure 23. Number of Questionnaires reporting Problems by Municipality Size.

28.7% *(n = 14)* of the questionnaires reporting maintenance problems also described a lack of a maintenance strategy. Notably, this finding did not exhibit a statistically significant value. Moreover, neither of the professional groups were more likely to report maintenance problems and the absence of a maintenance strategy than the other.

Within the variable coded as "maintenance problem" five subcategories were identified: technical, nature-derived, design-related, organizational, and economic issues. table 6, presents the various factors connected to each subcategory.

Table 6. Subcategories of Urban Wetland Maintenance Problems.

Subcategory of problems	Type of Problem
Technology	• Lack of adequate equipment or machinery • Difficulties in waste management and sanitation • Clogging of urban wetland structures • Challenges posed by impermeable layers/sealing
Nature	• Vegetational issues such as overgrowth, invasive species, and excessive algae • Challenges with timing maintenance activities to align with natural or biological processes within the urban wetland system • Obstruction/destruction caused by beavers • Difficulties in completing maintenance tasks during and after heavy precipitation falls • Elevated post-maintenance PFAS-levels spreading to adjacent areas • Erosion
Design	• Insufficient physical access to different sections of wetland systems due to unfavourable topography, such as cumbersome slopes at inlet and outlet points
Organization	• Ambiguity regarding maintenance responsibilities and ownership • Limited time and resources • Conflicting stakeholder interests • Ineffective communication with external maintenance contractors
Economy	• Inadequate financial resources

Design-related problems were the most frequently reported (*n = 10, 29,4%*), followed by technical, nature-derived, and organizational issues, which had similar frequencies (*n = 8, 23,5%*). Economic problems were the least commonly reported (*n = 6, 17,7%*). The distribution of these sub-variables connected to professional affiliation is illustrated in figure 24. Within this category, "organizational problems" stood out as the sole variable exhibiting a statistically significant relationship with professional affiliation (*p = 0.059*), with SM/UP reporting this type of issue to a greater extent.

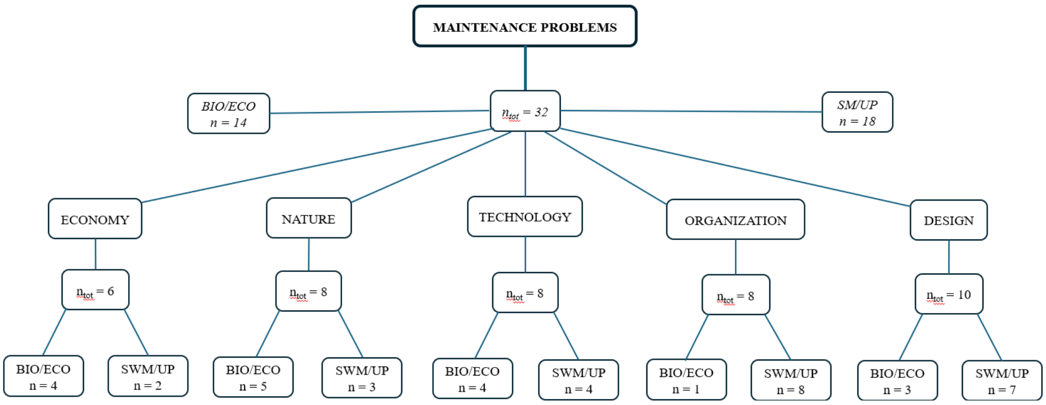

Figure 24. Frequencies of Maintenance Problems reported by Professional Affiliation.
Abbreviations: Eco/Bio, Ecologists/Biologists; SM/UP, Stormwater managers/Urban planners.

2.5 Within Organization vs Outside Organization Maintenance Execution

Looking at the distribution of maintenance execution, it was more prevalent for the investigated UWs to be maintained by within-organization maintenance actors (*n = 35, 75,4%*). However, there was no association found between this aspect and either professional affiliation.

Although respondents expressing maintenance problems while relying on external maintenance actors were more frequent (*n = 11, 78,6%*), no statistically significant relationship or trend reinforcing this pattern emerged.

Notably, there was a statistical significance at the 95% confidence level (*p = 0.037*) of having a maintenance strategy and executing the maintenance within the organization. When applying profession as a control variable, there emerged a trend (*p = 0.067*) of SM/UP demonstrating this combination to a higher extent than Bio/Eco. Additionally, municipality size showed statistical significance at the 99% confidence level (p = *0.037*) for the observed relationship. This was primarily explained by the fact that 37.9% (*n = 11*) of the municipalities having a maintenance strategy and executing their maintenance within the organization maintenance, were big and medium-sized municipalities (*p = 0.009*).

2.6 Biodiversity Follow-Ups Associated with Maintenance Strategies

Finally, *12.2%* (*n = 6*) of respondents linked to the questionnaires had conducted a biodiversity follow-up related to maintenance strategy. Among these, there were twice as many Bio/Eco (*n = 4*). However, there was no statistical significance or trend for this, nor for municipality size. Additionally, reporting maintenance problems or having a maintenance plan was not statistically connected to conducting a biodiversity follow-up related to maintenance strategy either.

Figure 25 further illustrates findings related to biodiversity follow-ups. Among the questionnaires reporting biodiversity follow-ups, two distinct groups of equal sizes (*n = 3*) were noted. One group presented information solely based on visual observations and experiences noted by maintenance staff, lacking objective administration. In contrast, the other group had objectively administered their findings. 100% (*n = 3*) of these had employed an outside organization actor.

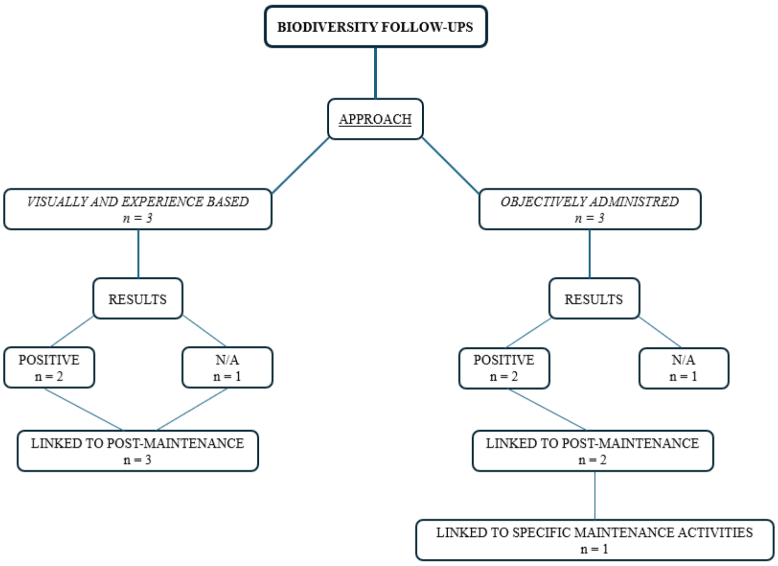

Figure 25. Biodiversity Follow-up Reports with Associated Data.

Within the former group, one questionnaire reported successful results in controlling invasive species (*Heracleum mantegazzianum* and *Lysichiton americanus*) and the establishment of native flora following maintenance actions. Another questionnaire described patterns of bird breeding associated with maintenance practices, although neither the specific pattern nor the applied maintenance strategy were provided. The remainder of this group provided no information.

In the latter group, one follow-up reported an intact or slightly increased bird fauna, a considerable increase in floral diversity, and a greater abundance of insects (including ten to twelve species of *Odonata*) following wetland restoration activities such as dredging and vegetation removal[10]. Another follow-up observed a clear increase in insect species diversity after two years of maintenance, although the specifics were not provided. The remaining follow-up included 28 urban waterbodies; however, it was unclear which ones of these received urban runoff and which ones did not. Furthermore, there was no connection to a maintenance strategy, making it impossible to gain a clear understanding of the before and after conditions.

In summary, the biodiversity follow-ups were few, characterized by a considerable degree of subjectivity coupled with sparse information, often requiring subjective interpretation. Additionally, they indicated a lack of objective administration and revealed a vague or entirely absent connection to maintenance strategy.

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[10] Thomas Johnsson, biologist, telephone 2024-04-17.

3. Discussion

3.1 Reflections on Respondents/Questionnaires and Methodology

Initially, it is appropriate to address the ambiguity and lack of clarity surrounding the definition of UWs. A large proportion of respondents were unsure of the meaning or applied definition of UWs, which could be considered a methodological flaw, challenging the validity of the results. To align with the broad scientific application of the term (see chapter 1.7.7), this study also adopted a generous and inclusive definition of UWs. One respondent explicitly emphasized that, “a wetland is not a stormwater pond”, shedding light on this conundrum. Admittedly, Blecken (2016) states that constructed wetlands (CWs) employ more biogeochemical processes in the cleansing procedure than stormwater ponds, which mainly operate through sedimentation. However, urban runoff can be treated in combined pond-wetland systems (Li et al. 2010), and stormwater ponds can separately, within themselves, include wetland areas (Blecken 2016).

Thus, the approach chosen could be regarded as a methodological advantage, in fact strengthening the validity of the findings. In other words, the methodological framework chosen correlates with the large variety of existent UWs and the various contexts in which they are utilized and maintained.

Still, divergent understandings and opinions about the true definition of UWs can potentially lead to confusions, resulting in overlooked benefits of these waterbodies. Therefore, to avoid semantic disagreement obscuring the advantages of UWs, in agreement with Everard et al. (2012) and Ribbe et al. (2024), the recommendation of this study, is to focus on their provision of ecosystem services of which biological diversity is an integral part. Accordingly, biological diversity is increasingly seen as a necessary component of contemporary stormwater management (Fletcher et al. 2015), directly supporting urban ecology (Zhang et al. 2020; Alikhani et al. 2021). In this light, using the receipt of urban runoff as a distinctive factor for inclusiveness of the study, rather than geographical location, confirms the appropriateness of this choice[11].

Several comparisons were made in this thesis between the professional affiliations of Bio/Eco and SM/UP. Investigating urban tree inventories, Östberg et al. (2013), suggest that there are discrepancies between professional groups and academical filiation in the understanding of conceptual factors and urban open space terminology. In contrast, this study provides no such evidence, as exemplified by an equal number of Bio/Eco and SM/UP, expressing uncertainty about the definition of UWs. However, it cannot be excluded that these professional groups still view UWs differently due to occupational biases and the realities of their work conditions.

Another methodological consideration is the relatively small sample size of respondents/questionnaires on which the results of this study are based. When working with small sample sizes, the power of the tests is low. Therefore, conclusions based on statistical analysis should be approached with caution. To mitigate this risk, an alternative is to employ a confidence level of 90%, indicating trends and tendencies, as done in this investigation (Baguley 2004; Columb & Atkinson 2016).

Furthermore, the method used for coding municipality size was based on corresponding population numbers. Considering the ambiguity of the term "urban" (see chapter 1.7.1), it is interesting to contemplate the Swedish context for municipality size. When using the magnitude of inhabitants as a parameter, large municipalities will inevitably be underrepresented, as only three cities - Stockholm, Gothenburg, and Malmö - are officially categorized as "big cities" (Sveriges Kommuner och Regioner 2022). The approach of recoding the "size" variable by merging large and medium-sized municipalities into one value ("size_recoded"), and in some cases applying it within statistical analysis, was done to balance this skewed representation of municipalities by population size.

3.2 Reflections on Maintenance Strategies with Associated Actions

60% of municipalities reported having a maintenance plan, which is seemingly low. However, Yang et al.'s (2021) studying stormwater maintenance regimens in

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[11] Godecke-Tobias Blecken, professor, Luleå University of Technology, email 2024-02-23.

Melbourne, found that only 21.7% of stormwater personnel integrated such procedures, which provides a different perspective. Still the fact that roughly half of Swedish municipalities have established and directed maintenance strategies is concerning, since they are necessary for the enhancement of UW-health/functioning in general (Hunt et al. 2011; Erickson et al. 2013; Blecken 2016; Gorgoglione & Torretta 2018) and the promotion of UW-biodiversity in particular (Zhang et al. 2020; Alikhani et al. 2021; Giurgiu et al. 2023).

Gray & Mabey (2005), found that formalized plans and policies occur more commonly in large organizations than in small ones. Accordingly, the results of this study indicate that UW-management is occupation- and size-related, with SM/UP in larger municipalities having maintenance strategies in a higher degree than Bio/Eco in smaller municipalities. These findings are consistent with (Östberg et al. 2018), who concluded that municipality size strongly influences maintenance practices, with larger municipalities being more likely to conduct urban tree inventories.

Within the analysis of this study, monitoring and actions are seen as integrated parts of a maintenance strategy, existing in symbiosis, by being mutually dependent on each other. This is a common approach for urban open space maintenance routines (Randrup et al. 2020). Normally, frequency indications are attached to urban open space maintenance directives. Contextually, the alternative of "no frequency" was the most reported directive, which can be interpreted as either beneficial or harmful for UW-biodiversity. On one hand, clear instructions based on expert knowledge from a top-down management perspective can be considered adequate and effective, especially for large organizations trying to achieve control in complex circumstances (Ford 2009). On the other hand, rejecting a bottom-up perspective, risks neglecting local and contextual phenomena, often noticed by maintenance staff on a daily basis. Overall, the chosen level of abstraction of maintenance directions should harmonize with staff knowledge and experience, communication possibilities, and the level of trust between managers and maintenance staff (Dempsey et al. 2014; Randrup et al. 2020). Contemporary, research on urban green space management, emphasizes the advantages of adopting holistic perspectives, integrating staff equally into maintenance plans (Jansson et al. 2019, 2020). Therefore, the "no frequency" strategy chosen by the respondents for UW-maintenance, would speculatively, given satisfactory staff knowledge, benefit UW-biodiversity. However, scientific evidence for this hypothesis was not investigated.

Respondents reported monitoring procedures in low numbers, with observation of the water table level ranked last among the monitoring factors. Since this procedure is specifically stated as the most important part of UW-maintenance (Hunt et al.

2011; Bae & Lee 2018; Liao et al. 2020; Ghosh et al. 2023), this appears to be worrisome.

On a positive note, cleaning/de-clogging of inlets and outlets was highlighted as the most frequently occurring maintenance action, followed by the removal of debris, which ranked second in frequency. These procedures directly affect the UWs water table by addressing its hydrology through water velocity (Zeff 2011; White et al. 2018; Ghosh et al. 2023), retention time and hydraulic effectivity (Sundaravadivel & Vigneswaran 2001; White et al. 2018). Ecologically, amphibians have been noticed to inhabit UWs (Wahlroos et al. 2015) despite considerable pollutant loads (Hale et al. 2019; Sievers et al. 2019). Logically as runoff in and close to the UW-inlet has not undergone purification through infiltration, sedimentation, and phytoremediation to the same extent as the water further down in the system, it will contain more pollutants. Consequently, Rousseau et al. (2008), found that amphibians were absent in the inlet zone but abundant in the outlet zone, which accentuates the importance of inlet maintenance for enhanced biodiversity.

However, this positive finding is undermined by the low rate of reported weeding, since excessive water vegetation, including algae (see figure 26 in appendix 6), can result in a considerable proportion of the effective water area being diminished (White et al. 2018). Subsequently, treatment efficiency will suffer, due to inhibition of the aforementioned hydraulic factors.

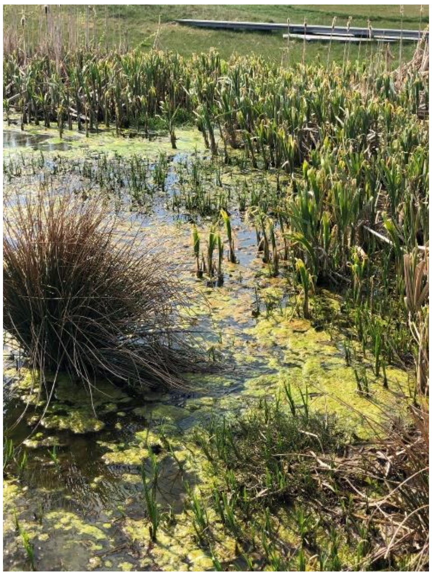

Figure 15. UW Excessive Algae (photo: Mikael Brocki).

The downsides of a low weeding rate are illustrated by the potential of invasive species spread. This is highlighted by a respondent reporting a practically complete post-maintenance extinction of *Heracleum mantegazzianum* and *Lysichiton americanus*. Applying the principles of urban ecology (Pickett et al. 2001; la Morgia 2020; Langellotto & Hall 2020) and urban aquatic ecology (Vermonden et al. 2009), neglecting such a crucial factor as weeding invasive species to promote heterogeneous habitats dominated by native species, will likely have a negative impact on UW-biodiversity.

There are divergent opinions about the benefits of UW-harvesting. Some refer to its it as a potential nutrient reducer (Blecken 2016), while others state that it plays a negligible role in nutrient reductions in regular wastewater (Okada & Vymazal 2023). Interestingly, no responses explicitly mentioned harvesting as an integrated part of maintenance strategies in the questionnaires. However, when scything was reported, it was often accompanied by instructions of post-action removal of organic material, which can be considered a form of harvesting. Additionally, "the removal of debris including OM"- factor, although less clear, can theoretically fall within this category. However, harvesting dead vegetation leads to considerably lower nutrient reductions compared to live vegetation because their decomposition has already initiated nutrient sequestration in the water and sediment[12].

Conceptually, the absence of harvesting can lead to two scenarios for UW-biodiversity: 1. It benefits UW-biodiversity (Merriman & Hunt 2014) by decreasing physical disturbance of habitats (Knapp et al. 2019), thus diminishing disruption of ecological cycles necessary for life cycle completion (Kadlec & Knight 1996). 2. It harms UW-biodiversity by worsening water quality through retained metals and nutrients in ecosystems (Rousseau et al. 2008; Blecken 2016; Wright et al. 2022), increase in breeding grounds for dominant species and carriers for vector-borne diseases such as mosquitoes (Rousseau et al. 2008; Hunt et al. 2011), facilitating monocultures of invasive vegetation (Hunt et al. 2011) (Hunt et al. 2011), and alteration of hydrology such as disrupted flow patterns generating dead zones with low levels of dissolved oxygen (Australian Government 2006).

Taken together, the appropriateness of harvesting or not for UW-biodiversity is surrounded by trade-offs, whose effects require further knowledge. Furthermore, it suggests a need for a contextual definition of harvesting, explicitly describing the process. Does it only involve cutting vegetation above root systems, or does it also include uprooting vegetation? Given that the rhizosphere zone is a vital part of wetland ecosystems, serving as a hotspot for many organisms (Neori & Agami 2017) and playing an important role in nitrogen absorption (Kirk & Kronzucker 2005) and metal binding (De Souza et al. 1999; Jacob & Otte 2003), this distinction likely has implications for UW-biodiversity. Consequently, drawing solid

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[12] Jan Vymazal, Professor, Czech University of Life Sciences, email 2024-05-04.

conclusions about the level and appropriateness of UW-harvesting for the promotion of UW-biodiversity is complicated.

Finally, considering the evidently unusual routine among Swedish municipalities to empty UWs of water within certain time intervals, it is reasonable to interpret that biodiversity is not their main contextual priority. Indeed, one respondent had noticed that amphibians had benefited from UW-emptying, as fish were removed. This finding is consistent with the recommendations of Hamer & Parris (2013); Johnson et al. (2013) and Feuerbach (2014), highlighting the alteration of food webs, favoring biodiversity achieved upon the execution of the corresponding maintenance action.

3.3 Reflections on Maintenance Problems

Seemingly contradictory to the statement that established and directed maintenance strategies are necessary for UWs to function well, there was no connection between not having a maintenance strategy and experiencing maintenance problems. SM/UP in larger municipalities experience have more documented maintenance strategies and simultaneously experience more maintenance problems than their counterparts in smaller municipalities. This could paradoxically suggest that prioritizing UWs might predispose them to health and biodiversity decline. However, the information provided did not reveal to what extent the maintenance strategies are actually executed, leaving certain grey areas in this finding. Moreover, acknowledging maintenance problems can paradoxically be seen as a positive factor for UW-biodiversity. This perspective suggests that it can indicate a prioritization UW-health by being attentive to the processes occurring within these systems. Therefore, it cannot be concluded that UW-biodiversity is necessarily poorer in larger municipalities compared to smaller ones, nor can it be confirmed that it is richer in smaller municipalities reporting fewer UW-problems than their larger counterparts.

When considering that design-related issues caused the biggest problems for municipalities, it is interesting to note that emptying the UW of water was reported as the least prioritized maintenance action. Gokalp et al. (2014), also noted that design flaws generating obstructed maintenance often leads to UW-failure. Similarly, inadequate design of the UWs included in this study, may have led stakeholders to exclude emptying them due to impracticality. This is concerning because emptying UWs during specific periods is crucial for promoting biodiversity, as mentioned in the predator-prey relationship earlier.

In natural landscapes, there are natural fluctuations in hydroperiods, with alternating shifts between inundation and drainage. Native species have adapted their life cycles to these cycles, using them for breeding, egg-laying, and instar phases. However, in urban areas, natural hydrology is often altered, disrupting these patterns. For urban wetland UW-managers, the challenge lies in understanding local natural water processes and harmonizing the disturbance of emptying. Additionally, some UWs are constructed with a bottom impermeable layer. These can cause maintenance problems as reported by one respondent, but also cut of the inundation-drying phenomenon. When planning for a new UW, this highlights the importance of choosing a location with appropriate soil porosity (Semlitsch 2000; Price et al. 2014).

A potential solution to this issue could be the design of multi-cellular structures for UWs, which is recommended for efficient maintenance (Sundaravadivel & Vigneswaran 2001). By bypassing certain cells selectively, the water table will remain consistently throughout the emptying process. Since UWs are "dynamic ecosystems" (Sundaravadivel & Vigneswaran 2001:387), this approach promotes the colonization of water-reliant rare aquatic taxa by providing them refuge. Additionally, invasive/exotic vegetation species are also disrupted by this design structure (Hanford et al. 2020).

Connectedly, pre-sedimentation cells/basins (see figure 27 in appendix 6) are recommended for improved water quality and aquatic life, as they intercept the majority of pollutants and nutrients before they reach the actual UW (McNett & Hunt 2010; Schmitt et al. 2015; Larm & Blecken 2019).

Figure 27. CW-Pre-Sedimentation Basin/Pool (photo: Godecke-Tobias Blecken).

Additionally, if these cells are utilized as part of a larger wetland system, connecting urban water bodies, they can facilitate species mobility, according to the urban ecological principal of decreasing fragmentation through connectivity (Soulé 1991; Marzluff & Ewing 2008; Haase et al. 2020). This indicates that a multicellular UW-design mitigates ecological traps, a problem in UWs (Hale et al. 2015, 2019; Knapp et al. 2019), both by improving water quality and facilitating species mobility, assisting in completing their life cycles. Taken together, this supports the notion that maintenance strategies and design features should be planned integrally (Shutes 2001). It stands to reason that this should take place early in project planning, to increase the likelihood of well-functioning UW-ecosystems and habitats.

Additional design-related features benefitting UW-biodiversity are: a varied bottom topography with different depth (Hansson et al. 2005; Zhang et al. 2020), a complex littoral zone (Moore & Hunt 2012) (figure 28 displays a uniform littoral zone) with heterogenous fringe structure (Hale et al. 2019), and surrounding buffer zones protecting organisms from anthropogenic disturbance (Semlitsch 2000).

Figure 28. UW-Uniform Littoral Vegetation (photo: Mikael Brocki).

Incorporating and maintaining these factors, such as when establishing fauna depots and maintaining vegetation in a "messy" manner, will probably generate a need for a "re-evaluation of ugliness" in the eyes of the public. These features constitute crucial habitats for urban aquatic species and should not be removed because of aesthetic reasons (Price et al. 2014). Soft infrastructure, in the form of informing local habitants about the benefits of such factors could be contextually helpful and is recommended by Yang et al. (2021) for well-functioning UWs.

Although not directly related to maintenance problems, Östberg et al. (2018) speculated that economic factors might explain why larger municipalities tend to have more active maintenance of open green spaces, due to larger budgets. Directly connected to UW maintenance, lack of resources was reported as the greatest obstacle among Melbourne stakeholders (Yang et al. 2021). However, this study does not confirm this trend, as economic issues were not found to be connected to maintenance problems in relation to municipality size. This suggests a need to refine this speculation. Presumably, budget sizes are proportionate to the size of the municipality and the scale of the areas they manage, indicating that other factors may be at play.

In contrast, if counting lack of guidance and motivation, as observed by (Ibid.), as an organizational problem, this study confirms the issue of organizational difficulties. It was the only factor that showed a statistically significant connection between UW-maintenance problems and municipality size. Organizational problems in Swedish municipalities involved unsatisfactory communication, conflicting interests, and unclear maintenance responsibilities between stakeholders. Larger organizations tend to have more control through hierarchy and a formal culture (Ford 2009; Huberts 2012), while smaller organizations typically have more favorable employee involvement (Bryson 2009). Perhaps, top-down management, may be more prevalent in the investigated larger municipalities, leading to organizational problems. Although such an analysis goes beyond the scope of this thesis, it stands to reason that organizational problems may hinder UW-biodiversity through flawed maintenance. However, this remains a hypothesis, and further research would be needed to investigate this link.

Difficulties in timing maintenance actions with ecological cycles, mentioned by respondents are worth expanding on. (Revitt et al. (1999), highlight timing as central to UW- maintenance, while Al-Rubaei et al. (2016) and (Blecken (2016) emphasize the importance of striking the right timing for maintenance, especially during the UW-maturation phase, to avoid disturbing vegetation in the establishment phase.

Johnsson[13], notes by experience, that the timing of maintenance execution directly affects UW-biodiversity. Disturbances during the winter months, when important ecological process are dormant, are necessary for positive results. Conversely, maintenance actions during the summer months will likely have a heavily negative impact on UW-biodiversity by interrupting life cycles. However, decisions for disturbance type and rate together with timing for execution will include trade-offs, since all maintenance endeavours are not applicable at all times, colliding with different species' life cycles (Semlitsch 2000; Price et al. 2014). Additionally,

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[13] Thomas Johnsson, biologist, telephone 2024-04-17.

divergent stakeholder perspectives, such as those of Bio/Eco and SM/UP, may generate conflicts of interest (Zhang et al. 2020).

Hence, striking the right temporal (Revitt et al. 1999) and disturbance balance (Knapp et al. 2019) appears to be essential yet difficult to achieve. No concrete guidelines, except for proposed executions during winter months and recommendations not to exceed moderate disturbance levels, can be extracted from the content of this study, suggesting that corresponding decisions should be made on a case-by-case basis where trade-off effects are carefully considered.

Admittedly, human disturbance will inevitably alter UW-flow regimens, thereby affecting natural habitats (Wagner 2008) and species life cycles (Semlitsch 2000). However, physical disturbance is not bad per se. Consequently, one respondent reported increased bird prevalence after milling (see figure 29) due to a favorable alteration of food flux (an increase in insects and mollusks).

Figure 19. Wetland Milling (photo: Intiativ Utö).

Because maintenance actions vary in extent, they will generate different trade-off factors such as nutrient turnover and toxic substance resuspension. For example, dredging causes a much higher degree of UW-ecosystem disturbance than weeding of algae. Therefore, appropriate level of disturbance should be analyzed in conjunction with the nature of specific maintenance tasks. These connections require deeper analysis and are legitimate areas for future investigations aimed at promoting UW-biodiversity.

3.4 Reflections on Within Organization vs. Outside Organization Maintenance Distribution

Although this study does not provide evidence that maintenance problems are more prevalent among municipalities employing outside organization sources for maintenance implementation, it does indicate a situation where having a maintenance plan is positively correlated with performing maintenance within the organization. Why SM/UP and larger municipalities report this relationship more frequently cannot be answered conclusively within this study. However, similar to the logic discussed in chapter 3.3, it could indicate that stakeholders who choose to execute maintenance within their organization, have a higher level of concern for the health of their UWs.

3.5 Reflections on Biodiversity Follow-Ups

Although, this study documents low rates of UW-biodiversity follow-ups (*12.25%*), specifically associated with maintenance strategies, among Swedish municipalities, they exceed the findings of (Yang et al. 2021) who reported a lower number (*4.3%*).

The follow-ups of this study were, at best, vaguely connected to specific maintenance strategies and, at worst, not connected to maintenance actions at all. Additionally, the presence or absence of a maintenance strategy was not associated with the degree of biodiversity follow-ups, further weakening the link between intentional UW-maintenance choices and the promotion of biodiversity in Swedish municipalities.

Given the emphasis in the literature and research on implementing directed UW-maintenance strategies to promote biodiversity (Vermonden et al. 2009; Price et al. 2014; Zhang et al. 2020; Alikhani et al. 2021), one would desire to see a higher representation of municipalities with maintenance strategies in this group. Bio/Eco, considering their expertise, were surprisingly not more likely to report biodiversity follow-ups than SM/UP.

Expanding the sample size of respondents on UW-biodiversity follow-ups would be necessary to explore any potential conceptual connections, along with corresponding explanations. Nonetheless, the situation described above suggests that, unfortunately, biodiversity is not a priority for UW-stakeholders in Swedish municipalities. Consequently, recommendations for appropriate maintenance strategies to enhance biodiversity in UWs should not primarily be based on the information reported by the respondents of this study. Rather, suggestions should be grounded in current scientific knowledge of UW-ecosystems, in relation to general principles of urban ecology, urban aquatic ecology and urban hydrology.

3.6 Additional Reflections

One respondent commented that UWs are often deprioritized in urban planning. explaining that resources for improving treatment efficiency, especially designated for stormwater function, were generously provided, while means for enhancing UW-biodiversity were often denied. Admittedly, choices based on the effects of trade-offs concerning UW-maintenance and biodiversity will always arise and must be considered. Consequently, related conflicts are not uncommon between UW-stakeholders (Zhang et al. 2020).

However, as highlighted by another respondent, contemporary and future urban planning depends on integrating multifunctional perspectives. Specifically, for UW-biodiversity, the challenge lies in a deeper understanding and conveying of the symbiotic relationship between stormwater treatment efficiency and biodiversity, with the recognition that there lies no inherent conflict between them (Hansson et al. 2005; Herrmann 2012; Giurgiu et al. 2023). This recognition is crucial for the development and implementation of more stringent and directed maintenance strategies aimed at improving UW-biodiversity. Ideally, this would diminish UWs' status as 'synthetic ecosystems' (McIntyre 2020:6) and allow them to function as 'multifunctional organs of our future cities' (Ribbe et al. 2024:104) as they have the potential to do.

4. Conclusions

60% of Swedish municipalities have established strategies for UW-maintenance. Among these larger municipalities and SM/UP are overrepresented compared to smaller municipalities and Bio/Eco. The former group also experience maintenance problems to a higher extent, with organizational and design-related obstacles being the most prevalent.

Cleaning/ de-clogging of outlets and inlets, as well as removal of excess debris, are prioritized relatively highly, likely enhancing biodiversity. Potentially decreasing biodiversity is a low emphasis on emptying UWs of water, together with infrequent monitoring routines and inadequate UW-design.

UW-biodiversity follow-ups are seldom conducted in Swedish municipalities, and there is a vague association with chosen maintenance strategies. Therefore, recommendations for enhancing UW-biodiversity should be based on contextual research rather than the routines of Swedish municipalities.

Based on the findings of this study, the overarching recommendation for promoting rich UW-biodiversity involves implementing specifically directed maintenance strategies consistently. Practical suggestions include frequent monitoring of the water table, weeding to ensure a large effective water area, removing debris (especially around inlets and outlets) to uphold sound hydrology, retaining selective dead vegetative material for habitat formation, maintaining a heterogeneous vegetation structure in the littoral zone, facilitating varied benthic topography with different depths, water drainage to establish favorable food webs/chains, minimized disturbance levels with maintenance actions limited to species dormancy, and implementing a multi-cellular design with pre-sedimentation forebays, allowing for comprehensive maintenance access and enhanced treatment efficiency. These guidelines are illustrated in figure 30.

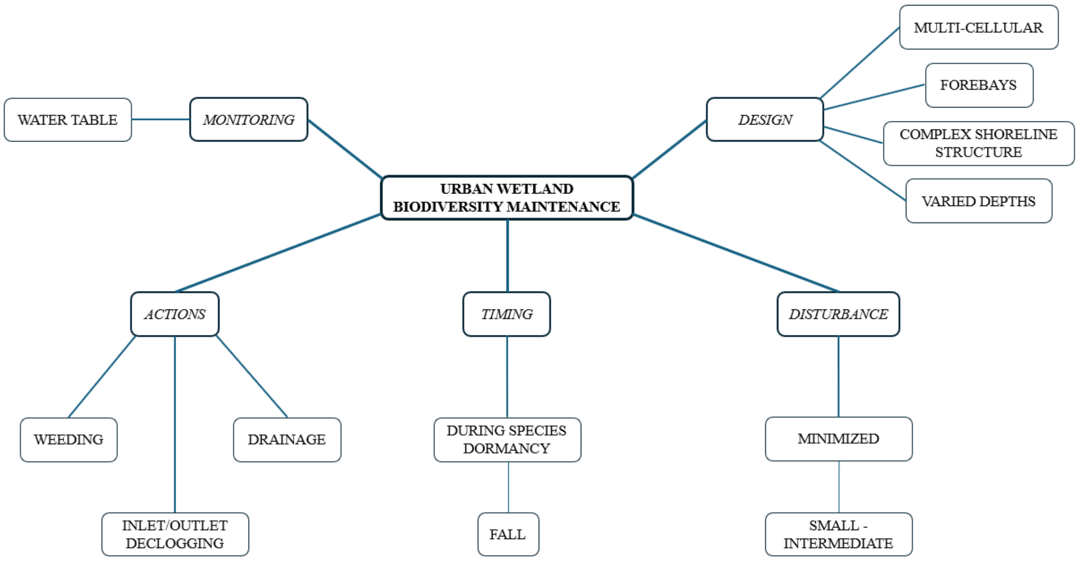

Figure 30. Recommended Urban Wetland Biodiversity Maintenance Components.

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Appendix 1 Contact Form

Hi!

I am a student at the Swedish University of Agricultural Sciences. At the moment, I am writing my master’s thesis about urban wetlands. Within this process, I am contacting Swedish municipalities to learn about their maintenance regimens for these systems. Therefore, I wonder if you could get in contact with someone who is responsible for/working with these questions in X municipality.

Best regards,
Mikael

Appendix 2 Questionnaire Template

The below questions concern **urban wetlands**

1. Does/do the wetland/wetlands receive urban run-off?

Answer:

2. Are the wetlands natural or constructed?

Answer:

3. Do you have any maintenance regimens for these systems?

Answer:

4. If yes, could you attach them in your reply?

Answer:

5. How often is the maintenance performed?

Answer:

6. Who performs the maintenance?

Answer:

7. Do you experience any problems connected to maintenance??

Answer:

8. If yes, which ones (organizational, technical, etc.)?

Answer:

9. Have you conducted any follow-ups on how maintenance has affected biodiversity in your urban wetlands?

Answer:

10. Is there any additional information that you find contextually important and that you would like to add?

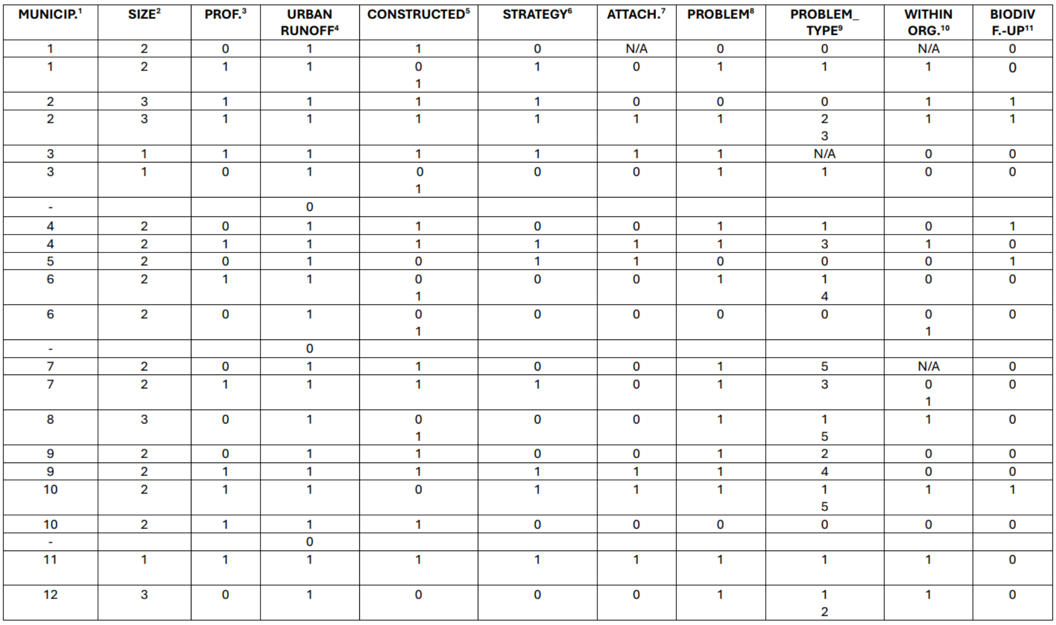
Answer:

Appendix 3 Definition Clarification of “Urban Wetland” to Respondents

“Urban wetland” is an arbitrary widely applied in science. Consequently, there is no absolute definition of its meaning. Generally, the most important characteristic appears revolve around the reception of urban runoff. Thus, stormwater ponds are usually included in this term.

The term urban is often discussed in the context of both “urban” and “peri-urban”. For the purpose of this thesis, “urban” is interpreted as referring to areas adjacent to cities. “city adjacent”. Nonetheless, the defining criterion for inclusion remains whether the waterbody receives urban runoff.

Appendix 4 Coding of Questionnaires



MUNICIP.[1]	SIZE[2]	PROF.[3]	URBAN RUNOFF[4]	CONSTRUCTED[5]	STRATEGY[6]	ATTACH.[7]	PROBLEM[8]	PROBLEM_ TYPE[9]	WITHIN ORG.[10]	BIODIV F.-UP[11]
1	2	0	1	1	0	N/A	0	0	N/A	0
1	2	1	1	0 1	1	0	1	1	1	0
2	3	1	1	1	1	0	0	0	1	1
2	3	1	1	1	1	1	1	2 3	1	1
3	1	1	1	1	1	1	1	N/A	0	0
3	1	0	1	0 1	0	0	1	1	0	0
-			0							
4	2	0	1	1	0	0	1	1	0	1
4	2	1	1	1	1	1	1	3	1	0
5	2	0	1	0	1	1	0	0	0	1
6	2	1	1	0 1	0	0	1	1 4	0	0
6	2	0	1	0 1	0	0	0	0	0 1	0
-			0							
7	2	0	1	1	0	0	1	5	N/A	0
7	2	1	1	1	1	0	1	3	0 1	0
8	3	0	1	0 1	0	0	1	1 5	1	0
9	2	0	1	1	0	0	1	2	0	0
9	2	1	1	1	1	1	1	4	0	0
10	2	1	1	0	1	1	1	1 5	1	1
10	2	1	1	1	0	0	0	0	0	0
-			0							
11	1	1	1	1	1	1	1	1	1	0
12	3	0	1	0	0	0	1	1 2	1	0

Figure 12. Extract of the Coding Process.

[1] = municipality

[2] = size of municipality 1 = big 2 = medium 3 = medium

[3] = profession of respondent 0 = Bio/Eco 1 = SM/UP

[4] = UW receiving UR 0 = no 1 = yes

[5] = constructed UW 0 = no 1 = yes 2 = both

[6] = has maintenance strategy 0 = no 1 = yes

[7] = attaching maintenance strategy 0 = no 1 = yes

[8] = has problems 0 = no 1 = yes

[9] = type of problem 1 = tech 2 = nature 3 = design 4 = org 5 = eco

[10] = maintenance execution 0 = outside org 1 = within org 2 = both

[11] = biodiversity follow-up 0 = not done 1 = done

N/A = Not Applicable

UR = Urban Runoff

Figure 13. Code Key.

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