

**This is an electronic reprint of the original article.**

**This reprint *may differ* from the original in pagination and typographic detail.**

**Author(s):** Somayeh Alikhani, Petri Nummi & Anne Ojala

**Title:** Modified, Ecologically Destroyed, and Disappeared – History of Urban Wetlands in Helsinki Metropolitan Area

**Year:** 2023

**Version:** Published version

**Copyright:** The Author(s) 2023

**Rights:** CC BY 4.0

**Rights url:** <http://creativecommons.org/licenses/by/4.0/>

**Please cite the original version:**

Alikhani, S., Nummi, P. & Ojala, A. Modified, Ecologically Destroyed, and Disappeared – History of Urban Wetlands in Helsinki Metropolitan Area. *Wetlands* 43, 33 (2023).

<https://doi.org/10.1007/s13157-023-01671-w>

All material supplied via *Jukuri* is protected by copyright and other intellectual property rights. Duplication or sale, in electronic or print form, of any part of the repository collections is prohibited. Making electronic or print copies of the material is permitted only for your own personal use or for educational purposes. For other purposes, this article may be used in accordance with the publisher's terms. There may be differences between this version and the publisher's version. You are advised to cite the publisher's version.



# Modified, Ecologically Destroyed, and Disappeared – History of Urban Wetlands in Helsinki Metropolitan Area

Somayeh Alikhani<sup>1,2,3,4</sup>  · Petri Nummi<sup>1</sup> · Anne Ojala<sup>5</sup>

Received: 9 January 2023 / Accepted: 12 February 2023  
© The Author(s) 2023

## Abstract

Urban wetlands are one of the important natural resources in cities and have an essential role in the sustainability of the urban environment. They offer various ecosystem services in cities, for example, by mitigating the risk of floods, providing water purification, groundwater regulation, and biodiversity promotion. Urban wetlands also provide recreational opportunities such as swimming and boating, that improve citizens' well-being. Unfortunately, human activities and environmental factors have been the primary reasons that have destroyed urban wetlands. To identify the main factors which threaten wetlands, as a case study, we investigated the environmental history of six urban wetlands in Helsinki starting from 19<sup>th</sup> century to the present. We collected historical information from available documents such as research articles, technical reports, maps, and photos, and then we compared the past situation of these urban wetlands with the current conditions throughout history. We also support our statements by referring to urban wetlands with similar conditions from different continents to explain the reasons for wetlands' disappearance, degradation, or survival. We show that population growth, land-use change, and climate change have been the main threats that have caused the degradation and even the loss of urban wetlands. We discuss the influencing factors which threaten urban wetlands and we highlight the role of policy and decision-makers in the rehabilitation and maintenance of urban wetlands.

**Keywords** Urban wetlands · Environmental history · Urbanization · Land-use change · Climate change

This article belongs to the Topical Collection: *Wetlands in the Developing World*

✉ Somayeh Alikhani  
somayeh.alikhani@helsinki.fi

Petri Nummi  
petri.nummi@helsinki.fi

Anne Ojala  
anne.ojala@luke.fi

- <sup>1</sup> Department of Forest Science, University of Helsinki, Latokartanonkaari 7, Helsinki, 00790, Finland
- <sup>2</sup> Helsinki Institute of Sustainability Science (HELSUS), University of Helsinki, Yliopistonkatu 3, Helsinki, 00014, Finland
- <sup>3</sup> Helsinki Institute of Urban and Regional Studies (Urbaria), University of Helsinki, Yliopistonkatu 3, Helsinki, 00100, Finland
- <sup>4</sup> Helsinki Institute of Urban and Regional Studies (Urbaria), Yliopistonkatu 3, Helsinki 00100, Finland
- <sup>5</sup> Natural Resources Institute Finland, Luke, Latokartanonkaari 9, Helsinki, 00790, Finland

## Introduction

Wetlands come in a wide array of ecosystems, from reed beds, bogs, and wet grasslands to temporal pools, ponds, lakes, rivers, and coastal marine habitats. All kinds of wetlands play vital roles in biodiversity and can provide a wide range of ecosystem services, regardless of where they are located (Mainstone et al. 2016). Although more extensive wetlands attract the most attention due to their more comprehensive ecosystem services, the role of small-scale wetlands, such as ponds, which are more abundant in urban and pre-urban areas, should also be considered.

Urban ponds are considered a type of small-scale wetlands, that commonly have an area of fewer than two hectares ( $< 2 \text{ ha}$ ) of lentic water (Hassall et al. 2016, Hill et al. 2021). Ponds are relatively shallow water bodies that are either natural or artificial (i.e., constructed), with varying level of biodiversity. These types of wetlands provide diverse ecological and cultural values in cities, such as recreation, sustainability, enrichment of biodiversity, and reduction of the urban heat island effect (Alikhani et al. 2021b, 2021a). Urban wetlands can also improve the

livability of surrounding areas by providing a convenient way for inhabitants to connect with nature and the outdoors and perceive the numerous benefits of wetlands (McInnes 2013, Odgaard et al. 2017).

Urban wetlands have undergone many changes throughout history. Unfortunately, there needed to be more knowledge about the importance of urban wetlands in the past, and they have only sometimes been considered valuable ecosystems in the urban context (Simpson and Newsome 2017). Currently, when the importance of nature-based solutions to adapt to climate change has been recognized, urban wetlands are seen as an essential part of the urban landscape, playing an important role in the development of the urban environment (Thorslund et al. 2017).

Urban wetlands, due to the constant change of land use, commonly become a combination of natural and constructed wetlands and exist in the forms of artificial and semi-artificial wetlands or remnant natural wetlands in urban construction (Frajer et al. 2021). However, these different types of wetlands differ in hosting biodiversity (Hill et al. 2018). In urban environments, constructed wetlands are accepted as a practical and effective approach to improving the cities' environmental quality and having a pivotal role in strengthening urban ecosystems (Hassall and Anderson 2015, Kačergytė et al. 2021, Čehovská et al. 2022).

The changes in land use often lead to changes in the hydrology, water chemistry, the structure of wetlands, changes in the plant community, and changes in the hard structure, e.g., the construction of a concrete bottom (Wang et al. 2008, Zorrilla-Miras et al. 2014). As a result, the land use change may destroy the wetlands' ecological function. In addition, it can lead to the predominance of non-native or invasive plant species in wetland environments. Thus, this reduces the biodiversity in wetlands, impairs their functional value for humans and other species, and even leads to the complete extinction of the wetland (Houlahan et al. 2006, Durigan et al. 2022).

The environmental history of urban wetlands can be used as a basis for evaluating how humans have interacted with wetlands and affected them (Swetnam et al. 1999, Kim and Kim 2010). The environmental history of wetlands can also help in effectively managing these environments (Robertson and McGee 2003, Simpson and Newsome 2017), as wetlands' history can provide essential information on hydrology, ecology, and structure of wetlands (Szabó et al. 2017). This information can therefore enhance our perception of the importance of wetlands and their functional roles in urban areas. The information can also be used to rehabilitate wetlands and help obtain models for future management decisions (Swetnam et al. 1999, Robertson and McGee 2003).

In principle, we can extract historical information on wetlands from various sources, including environmental records e.g., sedimentology, microfossils records (Kim and Kim 2010, Szabó et al. 2017), instrument records such as river flow measurements (Stein et al. 2010, Owen 1998), oral records (Robertson and McGee 2003), and documentation e.g., investigation of old reports, books, photos and maps (Simpson and Newsome 2017, Cao X 2008). However, in some cases where the data recorded for a particular environment is scarce, long-term environmental history documentation would be one of the few valuable available information sources. In addition, where recorded data are available, environmental history documentation can be used to validate the available information (Robertson and McGee 2003). Hence, by studying the history of urban wetlands using the available documentation, we can show the factors threatening wetlands or improving their ecosystem in the urban context.

The state-of-the-art research in the literature applies different approaches to studying urban wetlands. For example, the study in (Szabó et al. 2017) uses data from four disciplines, including palaeoecology, ecology, landscape archaeology, and archival data, to study wetlands. The research in Simpson and Newsome (2017) investigates wetland water quality, native flora, and fauna using historical photos, documents, and reports from the wetland. Other studies in Cao X (2008), Hu et al. (2020), and Wang et al. (2008) use remote sensing to analyze historical land use change and predict the dynamic development of wetland landscapes. In addition, the research in (Stein et al. 2010) uses ArcGIS to stack historical maps to create a geographic database for river watersheds. The rest of the studies (Owen 1998, Szabó et al. 2017) consider water chemistry, and palaeoecological analysis e.g., macrofossil, and vegetation changes in wetlands. In literature, the studies that carry out the environmental history evaluation consider natural resources and green spaces other than wetlands (Clark 2006, Schönach 2016, Luckin et al. 2017).

Unlike the earlier research, we study the long-term environmental history of six urban wetlands in the city of Helsinki using old maps, photos, and other historical documents. To the best of our knowledge, our paper is the first research that evaluates the environmental history of wetlands in the northernmost cities. The existing studies that consider water areas in Helsinki mainly investigate the major epidemics and pollution in urban waters (regardless of the type of the water area) (Laakkonen and Laurila 2007, Juuti et al. 2005).

In our study, to obtain information about the history of wetlands in Helsinki (as a case study), we explore

the environmental history of urban wetlands through the collection and integration of historical documents such as textual data sources, photographs, and historical maps from the year 1800 until the present. Then, we (i) provide information about the study area on land-use change, population growth, and climate change during the study years, (ii) document the impact of urbanization processes on the environmental history of these wetlands, (iii) discuss the importance of urban land-use change, population growth, and climate change on wetlands, (iv) summarize the key factors threatening urban wetlands, (v) and emphasize the role of policymakers and urban planners in realizing the importance and preserving urban wetlands.

## Study Area and Methodology

### Land-use change in Helsinki

Helsinki is located on the eastern end of the Baltic sea on the coast of Finland's Gulf (60°08'N, 25°00'E). Structurally, Helsinki is partly surrounded by the sea and the archipelago and contains many inland wetlands. Approximately, four-fifths of the city is the sea area, which includes many islands. The city's landscape is relatively flat, whereas the highest natural point is only 60 meters above sea level (Vähäaho 2014).

The area was formed 7,500 years ago, during and after the recent glaciation. When the land appeared for the first time, Helsinki was only two small islands named Tähtitornivuori and Linnanmäki, which were formed on the surface of the sea. These islands gradually became an archipelago that formed the current city of Helsinki (Laakkonen et al. 2001).

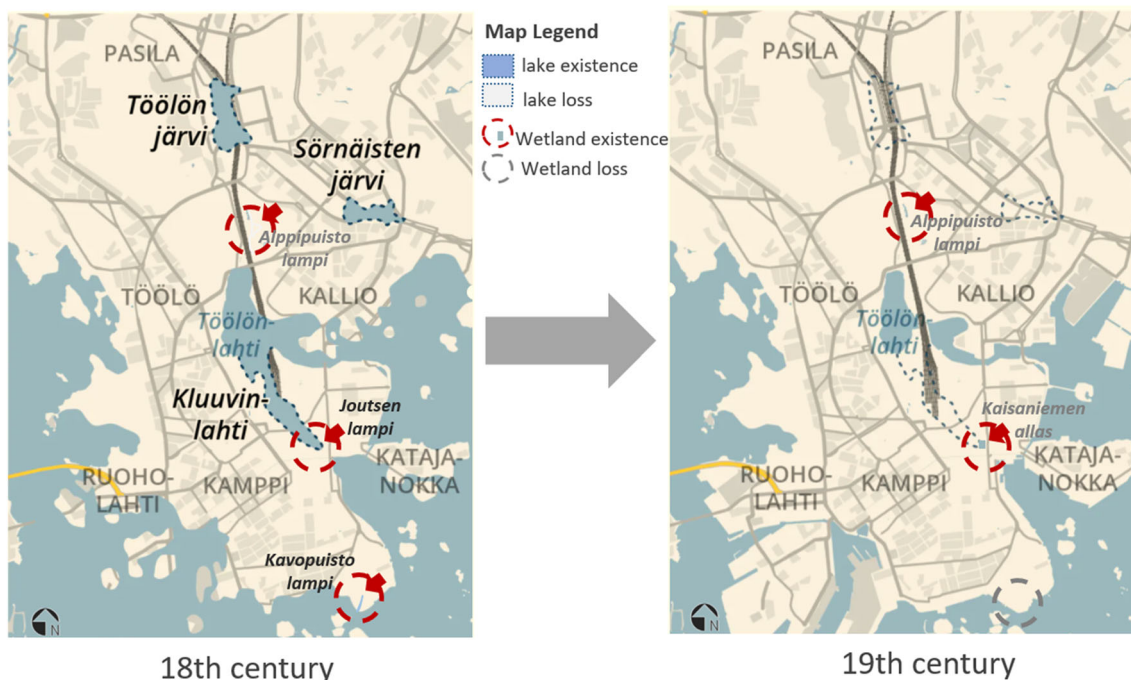
Over the centuries, due to rising landscape as well as rapid growth and industrialization, some lakes and bays have gradually disappeared in the city. Wetlands were no exception to this disappearance, as several wetlands were used for urban construction due to land-use change and were lost by human intervention (Schulman 2001). For example, until 200 years ago, in the area of Helsinki's current city center, there were two large lakes, two bays, and several ponds such as the Kaivopuisto pond, and the Kaisaniemi pond as a remnant of the Kluuvi bay. In 19<sup>th</sup> century, Kluuvi bay was drained to construct the Helsinki railway, and as a result, a large part of the water resources in the city disappeared (Helsingin Kaupunki 2020). In such a way that today there is no trace of these waters that can be seen in the city (Laakkonen 2001). In addition, some lakes and wetlands were also drained and filled in the city to create agricultural fields and construct buildings (Helsingin Kaupunki 2020).

Moreover, during the 19<sup>th</sup> century, another reason that destroyed large water bodies, e.g., Kluuvi bay was the water pollution in the city. Due to rapid urbanization and industrialization, the pollution originated from common sources including untreated sewage in water bodies, air pollution from industries, combustion engines, and infrastructure related to energy production and waste management (Schönach 2016, 2008). Figure 1 demonstrates the disappearance and water drainage and subsequently land-use change in Helsinki. The left sub-figure shows the status of the water bodies in the 18<sup>th</sup> century and the right sub-figure illustrates the status of the water bodies in the 19<sup>th</sup> century. As demonstrated in both sub-figures the water bodies Töölö Lake, Sörnäisten Lake, and Kluuvi bay (all shown with black dotted lines) have disappeared in the 19<sup>th</sup> century. The red dotted circles also demonstrate the locations of three ponds. While the Kaivopuisto pond has been drained, the shapes of the Kaisaniemi and Alppipuisto ponds have been transformed. Detailed information about these wetlands including the geographic coordinates, structure, age, and current and past areas sizes of wetlands are presented in Table 1; comparing the present area sizes of wetlands with their area sizes in the past explains the effect of land use change on wetlands. The example of the Kaivopuisto pond proves this statement, as 0.40 ha of wetland area has been totally drained and disappeared 100 years ago. As presented in Table 1, Kaisaniemi and Alppipuisto ponds also show a significant shrank, i.e., from 0.39 ha to 0.24, and from 0.55 ha to 0.25 ha, respectively.

### Population in Helsinki

The population in Helsinki had rapid growth since the 1810s when it became the capital of Finland. Industrialization and further strengthening of the city's position as the capital provided a strong motivation for population growth in Helsinki. This city changed from a small city of about 20,000 residents in 1860 to a city of more than 130,000 in 1910 (Finni et al. 2001). Finland was involved in the international industrial development process in the late 19<sup>th</sup> century, and therefore large-scale urbanization began. The city's population doubled every 20 years between 1860 and 1940. Growth began in the 1870s, peaked after the recession of the early 1890s, and continued almost constantly until the late 1960s. This growth continued except for World War II, and it also declined in the following decade (Häyrynen 1994).

By the 1970s, extensive migration to urban areas, especially to Helsinki, took place, and the population almost doubled between 1944 and 1969, from 275,000 to 525,600. Industrialization led to an unusually rapid increase



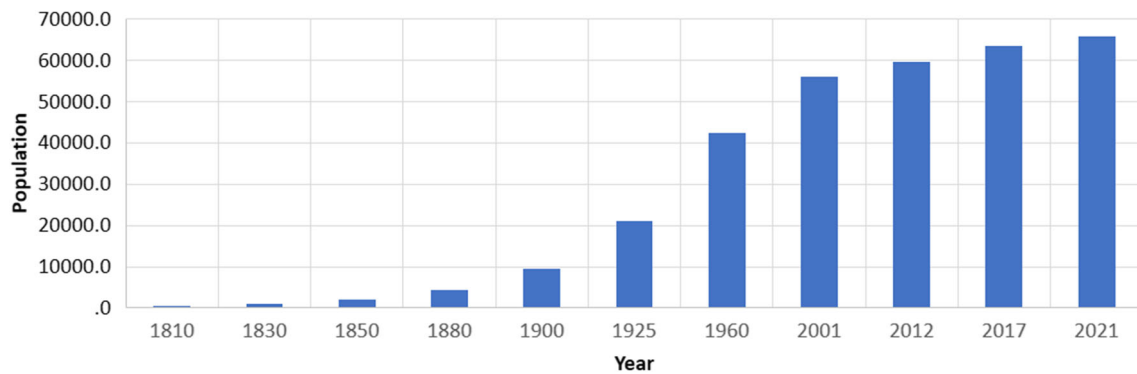
**Fig. 1** Land-use change and water drainage in Helsinki from 18<sup>th</sup> to 19<sup>th</sup> centuries (Jaarni C 2021, Helsingin Kaupungin Museo 2022)

in uncontrolled population, and as a result, the growing city needed land for residential use (Schulman 2001). With the rapid growth of Helsinki and due to housing shortages in the city, some residents began moving to neighboring cities of Espoo and Vantaa, which increased population growth in those cities too (Butzin 1978). Indeed, the growth of the

Helsinki region accelerated, the population increased, and new town plans were drawn up to expand the zoned areas. While many industrial establishments were located on the city’s outskirts, they gradually appeared close to the city center, impacting the population growth in Helsinki. The population growth in the city as shown in Fig. 2 explains

**Table 1** Selected wetlands and their characteristics

Wetland profile	Kaivopuisto pond	Kaisaniemi pond	Appippiusto pond	Konelampi pond	Kangaslampi pond	Vaarala ponds
Latitude	60°09'21.7" N	60°10'24.3" N	60°11'23.2" N	60°11'54.5" N	60°13'17.5" N	60°15'34.8" N
Longitude	24°57'15.8" E	24°56'37.6" E	24°56'10.1" E	24°52'22.1" E	25°08'07.2" E	25°05'15.2" E
Altitude	3 m	2 m	6 m	1.5 m	14.6 m	6 m
Max depth	2 m	0.6 m	0.5 m	1 m	1.3 m	0.5 m
Area (past)	0.40 ha	0.39 ha	0.55 ha	0.0 ha	0.5 ha	0.0 ha
Area (present)	0.0 ha	0.24 ha	0.25 ha	1.2 ha	1.1 ha	1.67 ha
Catchment area	—	—	1.3 ha	1.3 ha	4.9 ha	5.9 ha
Original age	ca 200 yrs	ca 200 yrs	ca 200 yrs	ca 100 yrs	3500 yrs	—
Urban pond age	1830	1827	1873	1964	1960s	1958
Pond shape and structure	Coastal wetlands like waterways led to the sea	Rectangular shape with a concrete bottom with no connection to substrate	Infinite shape with asphalt bottom with no connection to substrate	Asymmetric oval shape of substrate connected to stormwater network	Kettle pond substrate connected to drainage network	Four ponds in different shapes connected to stormwater network



**Fig. 2** Helsinki Population growth from year 1800 to 2021 (Statistics Finland 2021)

the rapid urbanization in Helsinki. As depicted in the figure, the population growth shows an increasing trend in the city, mainly starting from the 1990s. Whereas, just in the last century, the population has increased from 100,000 to 600,000 people.

The rapidly growing city attracted workers from the suburbs looking for work in the various industrial establishments. Although small workshops were scattered throughout the city, the industrial sectors were concentrated north and northeast of the city center (Schönach 2016). Industrialization and population growth changed hydrology in many ways since buildings, traffic lanes, and urban facilities took over the space of natural water bodies. In addition, the influx of municipal sewage polluted the water; for example, despite the city bans, Kluuvi bay, which no longer exists today, was used as a landfill. As a result, the bay became smelly and unhealthy, and city planners decided to fill the bay (Schulman 2001).

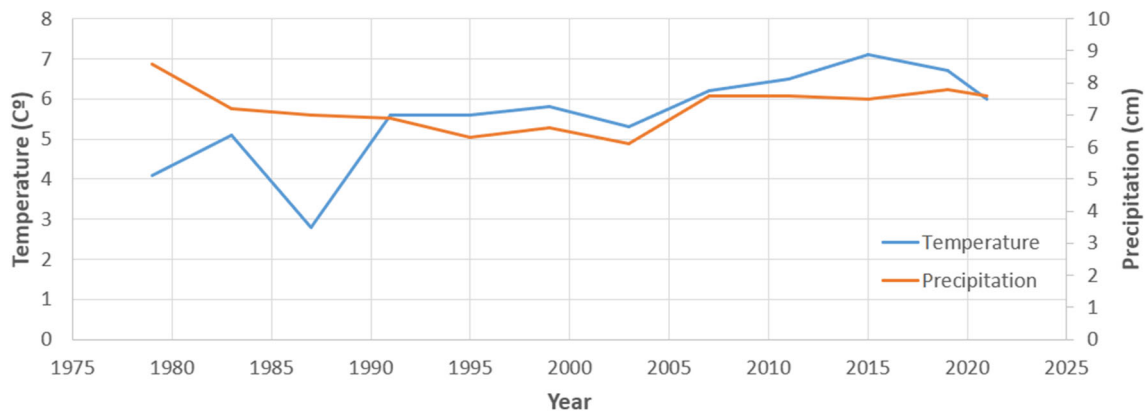
### Climate change in Helsinki

The global temperature has risen by about 1°C since the mid-1800s. The temperature increase has also been evident in Finland over the past 100 years. Since Finland is located in the northern latitudes, it is exposed to the polar intensification of warming affected by climate change, primarily due to the enhanced melting of snow and ice in polar areas (Mikkonen et al. 2015).

Different water bodies, such as rivers, lakes, and ponds, are affected by climate change on a global scale (Heino et al. 2009). However, the responses of large water bodies, such as lakes, differ from those of forest rivers or ponds in urban areas. The effect of climate change on small water bodies such as streams and ponds has been strong. This is due to the fact that there is a tight connection between air temperature and water temperature in these small water bodies, they are more sensitive to thermal stress than larger water bodies (Corcoran et al. 2009).

Small water bodies are susceptible to the effects of summer droughts and may be exposed to intermittent long-term drought. In addition, these small water bodies (i.e., streams and ponds) are sensitive to surface runoff changes, such as low flows and flash floods caused by changes in rainfall (Heino et al. 2009). Indeed, rainfall affects the volume and quality of water in water bodies, the flow rates, the likelihood of flooding, the leaching of nutrients and solids into water bodies, and thus oxygen levels in the water. Moreover, rainfall determines the hydrological status of water bodies, changes their temporal distribution; and has significant impacts on the ecological status (including biological communities) of water bodies (Suomalainen et al. 2006).

According to a report on the hazards caused by climate change in Helsinki, the most important hazards threatening Helsinki include floods, increasing winter rainfall, rising summer temperatures due to the heat island effect, and threats to natural biodiversity (Pilli-Sihvola et al. 2019). Based on this report, due to climate change winter rainfall has increased in Helsinki over the past 100 years. This increase results in several challenges. For example, in winter when rainfall occurs in the form of water instead of snow, it increases the probability of stormwater in the central regions of Helsinki. The central regions of the city have dense urban structures with impermeable surfaces. These regions in the city also had severe land-use changes over the past 100 years. Figure 3 depicts the temperature and precipitation changes in Helsinki from 1975 until the present. The figure shows an increasing trend in the variations in temperature throughout the years. The variations of precipitation also follow the temperature increase mainly from 1990, indicating the massive pressure of industrialization and urbanization starting from the 1990s. Moreover, the winter rainfall increases the nutrient loading into water bodies. This occurs because during the winter there is no layer of vegetation to absorb nutrients and thus it causes the accumulation of nutrients in water



**Fig. 3** Yearly temperature and precipitation variations in Helsinki (Meteoblue 2022)

bodies. As a result, high levels of nutrients accelerate plant growth and increase eutrophication in water bodies (Pilli-Sihvola et al. 2019). Indeed, during the past 100 years, eutrophication has been the most common problem in Helsinki's urban wetlands. Furthermore, eutrophication triggers the growth of aquatic species, such as blooming algae and cyanobacteria. The blooms reduce oxygen and block sunlight in the water. As a result, this leads to an excess of nutrients and biodiversity loss, especially the disappearance of many fish species and the growing abundance of some cyprinid fish (Bergström et al. 2016, Szabó et al. 2017).

## Methodology

In this paper, we studied the effects of land-use change on urban wetlands by selecting six ponds from the Helsinki metropolitan area. Note that in this paper we interchangeably use the terms “urban wetland” and “pond”. According to the report on environmental services of the city of Helsinki which was published in 2006, there are more than 40 urban ponds in Helsinki metropolitan areas (Marttila 2007). However, based on our search from the online map of Helsinki,<sup>1</sup> there are more than 50 urban ponds numbered on the map. Then, after careful exploration and investigation, from these 50 urban ponds, we selected six ponds with similar environmental conditions, all being in green spaces of the city. These wetlands were chosen based on their well-known environmental history as well as their historical changes which have been documented over time. These wetlands have appropriate documents, photos, and historical maps which provide helpful information including the following criteria:

- **Distribution:** selected ponds are distributed from the center (e.g., Kaisaniemi: 443 m) to the outer edges of the city (e.g., Vaarala ponds: 13,9 km).

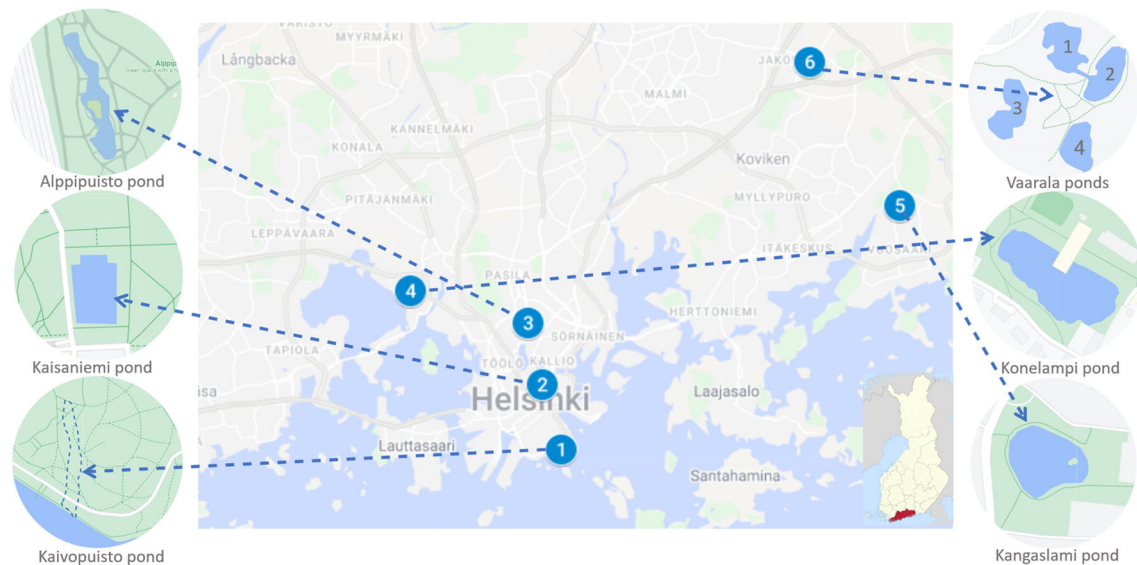
<sup>1</sup><https://kartta.hel.fi>

- **Shoreline structure:** vary from well-vegetated pond shoreline (e.g., Konelampi pond) to the concrete shoreline (e.g., Alppipuisto pond).
- **Substrate structure:** vary from the natural substrate (e.g., Kangaslampi) to the concrete-based substrate (e.g., Kaisaniemi pond).
- **Age:** vary from an ancient pond (e.g., Kangaslampi pond 3500 years ago) to a young pond (Konelampi pond 58 years ago).

The names of these green spaces where the ponds are located are Kaisaniemenpuisto, Alppipuisto, Kaivopuisto, Munkinpuisto, Ilveskorvenpuisto and Vaaralan riviera. Figure 4 shows the locations of these urban wetlands on the map of Helsinki. Table 1 also provides detailed information about the profiles of these urban wetlands, which have different characteristics such as structure, age, type, shape, and area sizes. In our evaluation, we use these characteristics as indicators to study the environmental changes in these wetlands during their life cycle in history.

As shown in Fig. 4, wetlands numbered with 1, 2, and 3 are located in the central part of the city. In these locations, there have been many changes in terms of urban planning during the last 100 years. Urbanization has transformed these three wetlands in such a way that urban expansion has even led to their loss. An outstanding example is the Kaivopuisto wetland (No. 3) which has completely disappeared. As illustrated in the figure, wetlands numbered with 4, 5, and 6 are in those parts of the city which were pre-urban areas in the past while today they are urban areas.

In this article, first, we collect and document the old photos, historical (cartographic or aerial) maps, and historical textual documents (reports, books) of these wetlands. We collect these documents from different resources such as the Helsinki Region Infoshare (Helsinki Region Infoshare 2013), Helsinki city Museum (Helsingin Kaupungin Museo 2022), old maps of Finland services (Kutilainen 2020), the publicly available information and



**Fig. 4** Map of the studied urban ponds in the Helsinki area list by number: 1. Kaivopuisto pond, 2. Kaisaniemi pond, 3. Alppipuisto pond, 4. Konelampi pond, 5. Kangaslampi pond, 6. Vaarala ponds

reports from the Helsinki Municipality website (Donner et al. 2017, Hengard et al. 2007, Olsson et al. 1925, Harju et al. 2007, Karisalo et al. 2020, Sitowise 2018, Marttila 2007, Holstein et al. 2011, Maisema Arkkitehtitoimisto Näkymä 2013, Hirvonen and Sjöholm 2007, Helsingin Kaupunki 2020) articles (scientific or public) (Jaarni C 2021, Pajari 2007, Mikkonen et al. 2015, Heino et al. 2009, Suomalainen et al. 2006, Pilli-Sihvola et al. 2019, Vuorela et al. 1990, Veijalainen et al. 2019, Finni et al. 2001, Laakkonen and Laurila 2007, Vähäaho 2014) and books (Laakkonen et al. 2001, Schulman 2001, Laakkonen 2001, Hackzell 2001, Seppälä 2008, Häyrynen 2001, 1994). Next, we analyze changes in urban wetlands over time using *i*) the collected documents, *ii*) the characteristics presented in Table 1, and *iii*) other information including land-use changes, population and climate changes in areas where wetlands are located.

## Selected Wetlands

In this section, we provide a detailed description of the historical documentation of the ponds in Helsinki, which we explained in Section “Methodology”. To this end, we use textual documents such as books, reports, and existing surveys in the literature to investigate how urbanization through land-use change, climate change, and population growth has transformed the shape and affected the functionality of these urban wetland ecosystems over time. In addition, to support our statements, we use available maps and photos from our selected ponds to demonstrate the changes in different years. For each selected pond,

we choose four important images and maps to show an important event that has caused a fundamental change in the wetland - positive or negative. The red dotted lines in the maps show the location of the ponds.

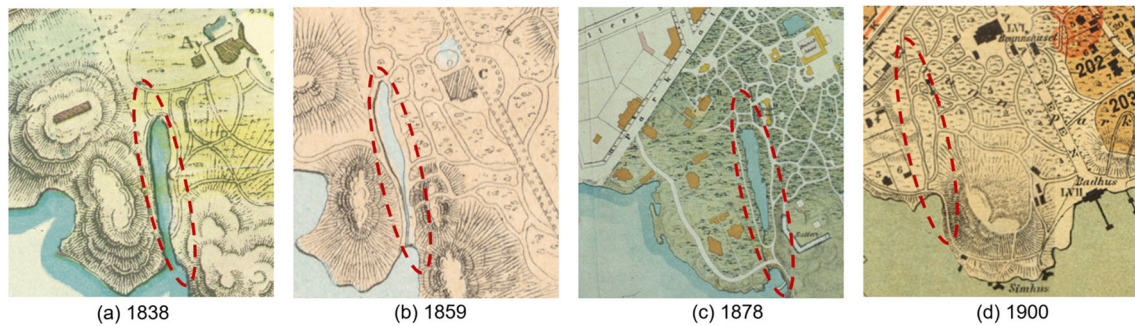
### Kaivopuisto Pond

Due to the urbanization in Helsinki, the Kaivopuisto pond does not exist anymore. Previously, the Kaivopuisto pond was a coastal wetland connected to the sea (i.e., the Gulf of Finland) at the southwestern end of Kaivopuisto park. The location and partial magnification of the former Kaivopuisto pond are shown on the map of Helsinki with No. 1 in Fig. 4. Fortunately, there are few maps and photos available from this wetland since the 19<sup>th</sup> century. The existing maps and photos are shown in Figs. 5 and 6, respectively.

According to (Donner 2009), before the rapid urbanization in Helsinki (i.e., before 1810), the area where the Kaivopuisto pond existed was underdeveloped. The area was covered with cliffs, forests, and marshlands. Based on the available documents, in the 1830s the pond was connected to the sea by a channel with a wide neck (as shown in Fig. 5(a)). The pond and its surrounding area were used for recreation by locals, for example, boating, walking, picnics, and leisure time (as portrayed in Fig. 6(a)).

Due to an increase in recreational activities, the authorities designed a private spa park for the elite in the area with the name Kaivopuisto park (Seppälä 2008). However, the spa ceased operations in the late 19<sup>th</sup> century, and in the 1830s the private park was redesigned to be a public park. For the new design, the marshes and lowlands





**Fig. 5** The maps of Kaivopuisto pond shown with the dotted red circles in years 1838, 1859, 1878 and 1900 (Helsinki Region Infoshare 2013)

areas were converted into a coastal wetland and a habitat for swans and fish.

Gradually, in the 1860s the width of the pond's neck was significantly reduced in only two decades (depicted in Fig. 5 (b)). As shown in this map, the decrease in the width of the pond's neck is associated with the new design and changes on the pond. However, the rapid reduction in the width of the pond's channel drastically continued such that in the next decade the wetland lost its connection with the sea (as shown in the map (c)). Due to urbanization, the pond was drained and filled some years later, and its land was changed into a playground (This is illustrated in the map (d)).

As demonstrated in the available photos from this pond (i.e., Fig. 6(a)), the structure of this coastal wetland was a water channel connected to the sea, with both sides of the wetland covered with leafy trees. Photos (b) and (c), taken in the years 1872 and 1890, present a tranquil wetland with trees around it. These photos addressed the period when the wetland was losing or had lost its connection with the sea. These photos display the water in the pond as an attractive element that has an aesthetic function by representing the Kaivopuisto pond surrounded by trees and dense grass as well as habitats for fish and waterfowl (Seppälä 2008). According to (Seppälä 2008), industrialization and the increase in the population of Helsinki necessitated enhancing the recreational areas and facilities for the people living in the rapidly expanding city. To this end, based on a new design (Harju et al. 2007) the Kaivopuisto pond was dried up, and instead, a playground was built in its place (as depicted in Fig. 6(d)). This land-

use change in Helsinki was a unique project with great importance in its own time.

Studying the life of the Kaivopuisto pond throughout history shows the impact of urbanization and population growth on valuable ecosystems such as wetlands which can offer various ecological and recreational services in cities. But, more importantly, the example of the Kaivopuisto pond alone addresses the significance of policymakers' decisions on the wetlands that can improve their functions or can destroy them. The case is evident in the Kaivopuisto pond as the policymakers changed a marshland to a coastal wetland in 1830 to create a recreational place. Conversely, they destroyed the same wetland in 1900 and left dried land for the public.

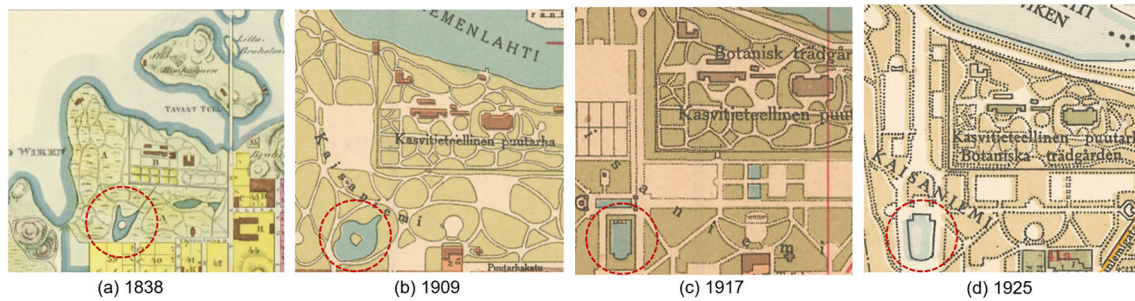
### Kaisaniemi Pond

Currently, Kaisaniemi pond is a rectangular system with a concrete bottom, that is located on the south side of Kaisaniemi park in the center of Helsinki. The pond is a large water pool which is the dominant element in the park. Formerly, this pond was a natural wetland called Swan pond. The location and partial magnification of Kaisaniemi pond are shown on the map of Helsinki with No. 2 in Fig. 4. In addition, Figs. 7 and 8 demonstrate the maps and photos of the Kaisaniemi pond in different years, respectively.

Based on Hautamäki et al. (2020), in the early 19<sup>th</sup> century, due to urbanization and urban sprawl in Helsinki, the city needed more open space to provide adequate recreational facilities for its growing population. Therefore,



**Fig. 6** Kaivopuisto pond old photos in years 1870, 1872, 1890 and 1930 (Helsingin Kaupungin Museo 2022)



**Fig. 7** The maps of Kaisaniemi pond shown with the dotted red circles in years 1838, 1909, 1917 and 1925 (Helsinki Region Infoshare 2013)

the Kaisaniemi park along with ponds was designed and constructed in 1827. As demonstrated in Fig. 7 (a), the pond has an organic shape, and there is an island in the middle of the pond. According to Härkönen (2021), Kaisaniemi park was designed as a landscape park by following natural changes in the terrain's topography. Whereas, a large part of the area was preserved in its natural form, containing the pond which was the remnants of Kluuvi bay in its fairly natural shape.

In 1894, the Kaisaniemi pond had a natural structure where its surrounding areas were covered with brooks and lush trees (as shown in Fig. 8(a)) forming the Kaisaniemi park. Due to its attraction, the park was an essential part of the city center by being an urban promenade and a popular and attractive walking destination that has left pleasant memories for the residents of Helsinki (Donner et al. 2017).

Then in 1909, the pond was widened in a new renovation plan, using the remnant of Kluuvi bay to create an organic pond (Häyrynen 1994). With this change, as shown in the map (b) the shape of the pond had become almost an irregular circle, and its island had become prominent. Nevertheless, the pond had maintained its natural shape and conformed to the topography of the landscape (Härkönen 2021).

Therefore, a fountain and an island were built in the middle of the pond, and deciduous trees were planted inside it, providing space for swans' nesting. The presence of children around the pond, and several swans swimming in the pond indicate the existence of a safe and dynamic ecosystem in the park (Hemgard et al. 2007, Helsingin Kaupungin Museo 2022). The livability and refreshing

atmosphere created by the pond are depicted in Photo (b) which is taken in 1912.

Later in the 1900s, to improve the functionality of the space in the city, some new designs were proposed to renovate the Kaisaniemi park including the pond (Häyrynen 1994). Hence, in 1911 the first phase of the renovation of Kaisaniemi park was planned (Hautamäki et al. 2019, 2020) and the Helsinki City Council decided to approve the plan in 1912. According to the new plan, reflecting the geometric gardening ideals of the era (Hautamäki et al. 2020), it was agreed to transform the natural shape of the swan pond into a rectangular pool (Olsson et al. 1925, Häyrynen 1994).

Between 1912 and 1920, the pond caused floods (as illustrated in Fig. 8(c)) in the area every year in spring and autumn (Aartelo 1968), which in turn incurred additional costs for renovation and maintenance (Olsson et al. 1925). This natural hazard was due to several factors such as the change in the pond's design, climate change, rapid urban construction expansion in Helsinki, and subsequent land-use changes. For example, filling the Kluuvi bay in order to build the Helsinki railway station put additional pressure on urban nature (Schönach 2008, Helsingin Kaupunki 2020). Therefore, the pond was isolated by buildings; in practice, there was no space for floodplains to store excess water. As a result, the area was prone to intermittent floods. In 1917, a new design for this pond was suggested to overcome this natural hazard, which significantly changed it into a rectangular shape, representing an artificial concrete pool rather than a natural wetland (this is shown in Fig. 7(c)).



**Fig. 8** Kaisaniemi old photos in years 1894, 1912, 1920 and 1929 Kaisaniemi (Helsingin Kaupungin Museo 2022)

Consequently, in 1925 the Helsinki City Council declared the final decision to permanently fill the Kaisaniemi pond because the pond had lost its former function as a natural wetland (Härkönen 2021). In addition, due to the rising water and the low altitude of the site above sea level, it was impossible to plant trees in the park. Therefore, the pond functioned only as a decorative element in the new park design (Olsson et al. 1925) and was restructured, becoming a rectangular concrete pool as it is seen today (this is shown in Figs. 7(d) and 8(d)).

Recently, two studies about Kaisaniemi park have been carried out to investigate how to improve the functionality of the pond. In 2007 one study proposed a new renovation plan for the park that emphasized the historical importance of the pond as a vital element. The renovation plan proposed exploring options for a new shape for the pond and constructing a new cafe building and an ice rink in the park (Hemgard et al. 2007). In the same year, another study aimed to improve Kaisaniemi park's condition and make the park a cosy city oasis for citizens. Therefore, the study conducted a survey of the citizens and as a result, many participants demanded the return of the Swan pond (Pajari 2007). However, based on Hautamäki et al. (2020), the complete renovation plan of the park was considered not to be financially feasible. Thus, despite the emphasis on the historical importance of the pond and the citizens' positive opinion on the pond's rehabilitation, in the end, the pond remained as a concrete pool without vegetation and biodiversity.

### Alppipuisto Pond

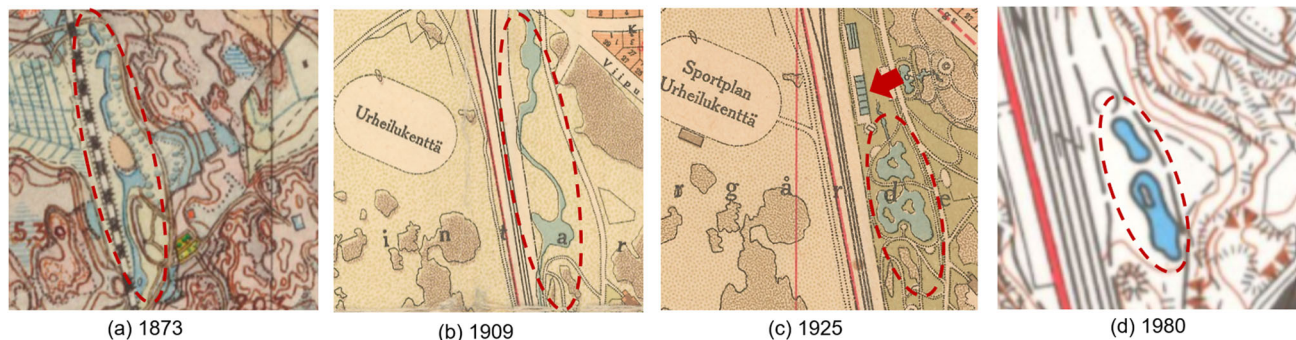
The Alppipuisto pond is located in the central valley of Alppipuisto park, which is in the central region of Helsinki. Currently, the Alppipuisto pond is divided into three parts with two wooden bridges. The pond has an asphalt bottom and consists of a small island and fountains. The location and partial magnification of the Alppipuisto pond are shown on the map of Helsinki (Fig. 4 No. 3). Figures 9 and 10

demonstrate the maps and photos of the Alppipuisto pond in different years, respectively.

According to a study in Lindholm (1986), the Alppipuisto park (known earlier as Eläintarhapiisto park) was a rocky forest with springs and ponds in the valley. As demonstrated in Fig. 9(a), the springs and ponds in the park were connected to Töölö bay through a creek. Töölö bay is one of the largest Baltic Sea bays in the center of Helsinki. Due to the natural structure of the Eläintarhapiisto park, in the 1850s this park was considered a place for recreation as it included a spa, ponds, and a restaurant (as shown in Fig. 10(a)). Later in the 1860s during the construction of the Helsinki railway, the park was divided into two parks (Helsingin Kaupunki 2020). While the park on the west side of the railway remained with the name Eläintarhapiisto park, the east side of the railway was named Alppipuisto park (Hirvonen and Sjöholm 2007).

This land-use change, i.e., division, drained most of the ponds and springs in the Eläintarhapiisto park and only left one pond on the east side of the railway in Alppipuisto park, which is known as Alppipuisto pond (Tyrväinen et al. 2014). The Alppipuisto pond is shown in Fig. 9(b) with an elongated and organic shape. In addition, Fig. 10(b) portrays the state of the pond in the year 1899. The photo shows the east side of the railway after dividing Eläintarhapiisto park into two separate parks. Trees and shrubs have surrounded the pond, and the back and right sides of the photo present the embankment of the railway. This photo demonstrates how the expansion of the city and the construction of the Helsinki railway threatened the Alppipuisto pond.

To improve the usability and strengthen the park's landscape (for example, by creating a connection between the ponds and the central valley), the Alppipuisto park and the pond were renovated in 1913. Unfortunately, in this renovation, the bottom of the pond was asphalted, and the connection between the pond with the substrate was lost (Maisema Arkkitehtitoimisto Näkymä 2013). This is also depicted in the photo in Fig. 10(d)). Consequently, this



**Fig. 9** The maps of Alppipuisto pond shown with the dotted red circles in years 1873, 1909, 1925 and 1980 (Helsinki Region Infoshare 2013)



**Fig. 10** Alppipuisto pond old photos in years 1890, 1899, 1910 and 1913 (Helsingin Kaupungin Museo 2022)

natural wetland ecosystem was destroyed and turned into an artificial pond (Marttila 2007). Such that the shape of the pond changed into two separate ponds hosting three islands, as depicted in Fig. 9(c).

Furthermore, since 1910 the Alppipuisto pond was used as Helsinki's first municipal wastewater treatment plant. Whereas, the wastewater was filtered in the Alppipuisto pond and eventually discharged to Töölön bay (Helsingin Kaupunki 2011). Later, in 1924 because of the expansion of the railway embankment, the treatment plant was damaged and demolished in 1959 (Helsingin Kaupunki 2020, Juuti et al. 2010). The wastewater treatment plant buildings, located northwest of the Alppipuisto pond (shown by red arrow) next to the railway line, can be seen in Fig. 9(c). The renovation of the railway embankment and the construction of the wastewater treatment plant affected the pond's structure. The effect is evident in Fig. 10(c) in which the construction work has destroyed the vegetation, including trees and shrubs around the pond. The reasons for using Alppipuisto pond as a wastewater filtration treatment system were as follows (Laakkonen 2001):

- (i) The rapid urbanization and the increase in population in the 19<sup>th</sup> century put extreme pressure on the area where the pond was located.
- (ii) In the early 1880s, due to increased transport and industrialization, Helsinki encountered widespread and increased air pollution emissions, e.g., CO<sub>2</sub> for the first time, especially in the Töölö bay region. As a result, the air pollution emissions tripled in the next three decades in the area (i.e., until 1910) (Laakkonen 1999, Schönach 2008).
- (iii) Another problem was the increased sewage pollution and the increase of seabed waste in Töölö bay.

As a matter of fact, this bay is trapped in the center of Helsinki which makes its water circulation remain poor. As a result, the pollution of the bay posed health risks to people and reduced the aesthetic values and well-being of the bay. Therefore, the only solution was to reduce the spread of pollution to the bay through wastewater treatment (Juuti et al. 2010). After half a century, in the 1980s the two ponds

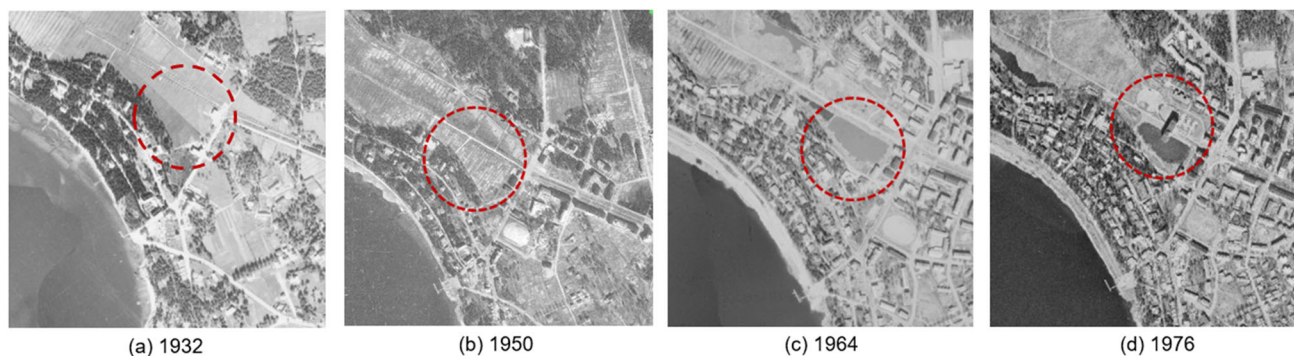
were connected by a bridge and only one island was left in the pond (Lindholm 1986). The new shape and plan of the pond are demonstrated in Fig. 9(d). The shape of the pond has remained the same until today.

The case of the Alppipuisto pond shows how the city expansion and subsequent increase in urban construction have threatened the survival of urban wetlands. The land use change, for example, the construction of the Helsinki railway led to the destruction of a part of the Alppipuisto pond. In addition, the increase in population and transportation has enhanced air and water pollution in the area where the pond is located. These facts have put pressure on the pond and caused the loss of connection between the pond and its natural substrate. As a result, a major part of the pond's natural vegetation and biodiversity has been lost. Currently, similar to the Kaisaniemi pond, the Alppipuisto pond is empty of water (based on the authors' site observation). Eventually, urbanization and industrialization have changed a wetland that was capable of offering diverse recreational opportunities in the past (Fig. 10(a)) to a drained and spiritless pond as it is today.

### Konelampi pond

The Konelampi pond is located in Munkinpuisto park in the west of Helsinki city. While there are several ponds in Munkinpuisto park, the main shallow pond is the Konelampi pond which is at the eastern end of the park. The location and partial magnification of Konelampi pond are shown on the map of Helsinki (Fig. 4 No. 4). Figures 11 and 12 also illustrate the maps and photos of the Konelampi pond in different years, respectively.

According to the documents (Hackzell 2001), in the 1930s, there was no pond in the Munkinpuisto park area. The area was initially a combination of moist wasteland and meadow areas and as Figs. 11(a) and 12(a) explain there is no influence of urban development and construction in the 1930s. Later, between the 1940s and 1950s, the area turned into farmland, where the agriculture plant was collecting its wastewater (Hackzell 2001). This land-use change is shown in Fig. 11(b).



**Fig. 11** The aerial maps of Konelampi pond shown with the dotted red circles in years 1932, 1950, 1964 and 1976 (Helsinki Region Infoshare 2013)

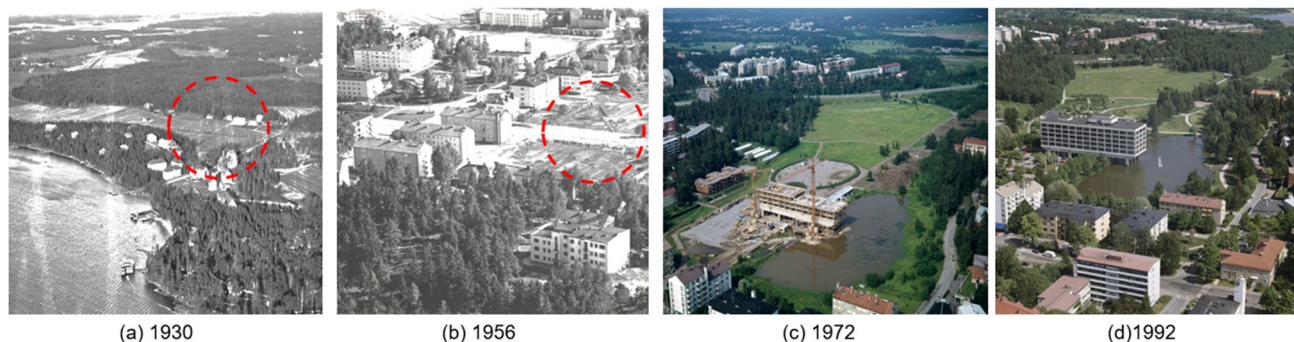
However, the agricultural wastewater treatment plant was damaged and blocked after a few years. So instead, in the 1960s, the wastewater stems were used to collect water at the park's eastern end, which gradually formed an asymmetric oval pond. This natural pond that is connected to the stormwater network from the substrate is currently known as Konelampi pond (Hackzell 2001). Figure 11(c) shows the agricultural farmland around the pond in 1964 when urban construction in the area had not yet been intensified. The situation is also shown in Fig. 12(b) which shows that the area transformed into farmland in 1956 and that building construction has gradually started in the area.

However, a decade later urban development has affected the surrounding area of the pond (Hackzell 2001). For example, the Kone company (a Finnish international engineering and service company founded in 1910) built its headquarters office building on the pond (Figs. 11(d) and 12(c)). Even the Konelampi pond has taken its name from the company name Kone. Figure 12(c) also depicts that the pond has improved the area's vitality by increasing the biodiversity through the vegetation and trees around the pond. Figure 12(d) taken in 1992, portrays that despite extensive construction around the pond, the pond has been preserved and has kept the quality of the biodiversity in the

area. These conditions and the state of the pond have been kept until the present.

Since 2016, the Kone office building has been converted into a residential building, which has increased the area's population. This conversion has put much pressure on the Konelampi pond (Vehkaoja 2016). Indeed, one-third of the building is extended above the Konelampi pond, whereas the building's pillars are placed in the pond. Thus, any change in the building would have a direct effect on the pond. Then, when planning and implementing the building renovations, efforts have always been made to preserve the natural values of the pond. To this end, in 2017, a plan for the renovation of the park was presented by the city of Helsinki to:

- (i) Rehabilitate the natural values of all of the ponds in the area, mainly the Konelampi pond. This is performed for example by dredging the pond substrate and improving the aquatic vegetation condition according to the landscape pattern of the pond. Furthermore, the ponds in the area provide diverse habitats for bats, birds, amphibians, and invertebrates. These varied and rich habitats are considered natural values of the region, which are mainly concentrated around the littoral areas of the wetlands (Holstein et al. 2011).



**Fig. 12** Konelampi pond old photos in years 1930, 1956, 1972 and 1992 (Helsinki Region Infoshare 2013)

- (ii) Renovate the stormwater treatment system in the area. The area is located on low-lying terrain and suffers from drainage problems. Thus, the plan aimed to drain the mixed water in the area and direct the stormwater to the sea using the main stormwater network. This way, the ponds are connected to each other through a creek and to the stormwater network and establish a wetlandscape. Therefore, the wetlandscape can increase biodiversity in this urban area by acting as a network of fragmented habitats to facilitate species movement in the environment (Hassall et al. 2016, Hassall and Anderson 2015).

Studying the case of Konelampi pond explains that preserving the wetlands in urban areas improves vitality and increases biodiversity. The improvement is performed by creating a blue and green space by establishing the connection between all the ponds (to manage the stormwater) and the green vegetation in the area. As a result, we are improving habitats for animals and plants and a better living environment for people.

### Kangaslampi pond

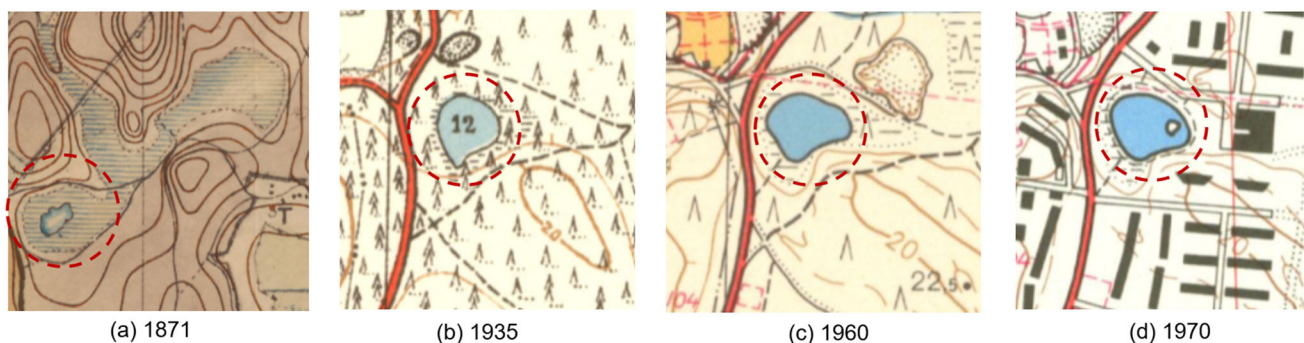
The Kangaslampi pond is located in the middle of Ilveskorvenpuisto park on the east side of Helsinki. The location and partial magnification of the Kangaslampi pond are depicted with No.5 in Figs. 4. Figures 13 and 14 demonstrate the maps and photos of the Kangaslampi pond in different years, respectively.

Presently, the Kangaslampi pond is almost circular, with an island on its eastern side. This pond was initially detached from the sea about 3,500 years ago (Hietanen and Vaalgamaa 2021, Marttila 2007). The pond is a water-filled cavity created by the melting of ice blocks leftover from glaciers in the ground (Vasić et al. 2020). In the 1870s, the pond was separated from the surrounding waters and has become a kettle pond (Vuorela et al. 1990) and later in the 1930s, the pond was shaped and its surroundings

were covered with forest areas. These occurrences can be observed in Figs. 13(a) and (b), respectively. Until the early 1960s, the pond was also marshy, and people were warned and they were asked to avoid walking in the marshy area (Vuorela et al. 1990). Figures 14(a) and (b) portray the inappropriate conditions of the pond in the 1960s. These photos show the pond with its marshy structure and the surrounding area where yet the urban context is not entirely formed around it.

In the late 1960s, the marshy area was dredged to create a park around the pond (Hietanen and Vaalgamaa 2021). Hence, Ilveskorvenpuisto park was created on the dredged site hosting the Kangaslampi pond. The pond's location in the middle of the dredged area is depicted in Fig. 13(c). Between the 1960s and 1970s, the area experienced rapid population growth that increased the construction of residential complexes in the areas around the pond (this is obvious in Fig. 13(d)), causing the pond and the park to become popular recreational places. With improvements that took place later, a small island was constructed on the eastern side of the pond using the mud and sedimentary soil collected from dredging in the mid-1960s. The small island hosts a few birch trees that act as a nesting habitat for many water birds.

Figure 14(c) taken in 1975, illustrates the urban context entirely developed around the pond. The photo shows that the area around the pond is planted with trees and grass. Improving the vegetation around the pond has enhanced biodiversity and has created a special identity for the landscape in the area. Later, in 1990 a plan for the renovation of the pond was presented and implemented by the city of Helsinki. The plan was based on a paleoecological study conducted on the pond before the renovation implementation. After careful research, the renovation plan was implemented, and the pond was dredged. The shoreline around the pond also was partly restored to its natural condition (Hietanen and Vaalgamaa 2021). The result of the renovation is portrayed in Fig 14(d) taken in 1990. This image demonstrates dense vegetation



**Fig. 13** The maps of Kangaslampi shown with the dotted red circles in years 1871, 1935, 1960 and 1970 (Kutilainen 2020, Helsinki Region Infoshare 2013)



**Fig. 14** Kangaslampi old photos in years 1960, 1966, 1975 and 1990 (Helsingin Kaupungin Museo 2022)

around the pond that resembles a cosy and peaceful forest pond in the center of the city.

Moreover, during the course of the years, the Kangaslampi pond has been highly eutrophicated. Indeed, water eutrophication occurs when nutrients in the water increase and threaten the pond's existence (Szabó et al. 2017). In 2019, a study was carried out by the city of Helsinki that revealed:

- (i) In the Kangaslampi pond dense masses of plankton algae exists that reduce the recreational value of the pond.
- (ii) The eutrophication of the pond has reduced the amount of water and the water circulation in the pond.
- (iii) Due to eutrophication, the pond occasionally suffers from a lack of oxygen in the water in winter. Therefore, a suction dredging operation, the most suitable method for revitalizing the pond, is needed (Hietanen and Vaalgamaa 2021).

In conclusion, evaluating the example of the Kangaslampi pond shows that it is essential to conduct detailed studies on pond conditions before renovating the pond. Furthermore, studying the status of wetlands before any renovation helps identify the challenges that we may face during the implementations.

### Vaarala cluster ponds

Vaarala cluster ponds are located on the northeast side of Helsinki. These cluster ponds have shaped a wetlandscape consisting of four small-scale wetlands that are hydrologically connected and gradually have been created in a swampy forest area. In the past, the formation of the wetlandscape started with the creation of a hole in the area due to sand extraction. Later, this hole was turned into ponds and the surrounding areas were afforested (Karisalo et al. 2020, Helsingin Kaupunki 2015). The location and partial magnification of the Vaarala cluster ponds are depicted with No.6 in Fig. 4. These cluster ponds are numbered from 1 to 4 based on their times of formation on the map of Helsinki. Figure 15 demonstrates the maps of the cluster ponds in different years. Unfortunately, there are no old

photos available from the Vaarala cluster ponds. Instead, there are aerial photos (as depicted in Fig. 16) available that could be used to further evaluate the Vaarala cluster ponds' development. Both figures (the maps and aerial photos) illustrate the changes in the wetlandscape in different years.

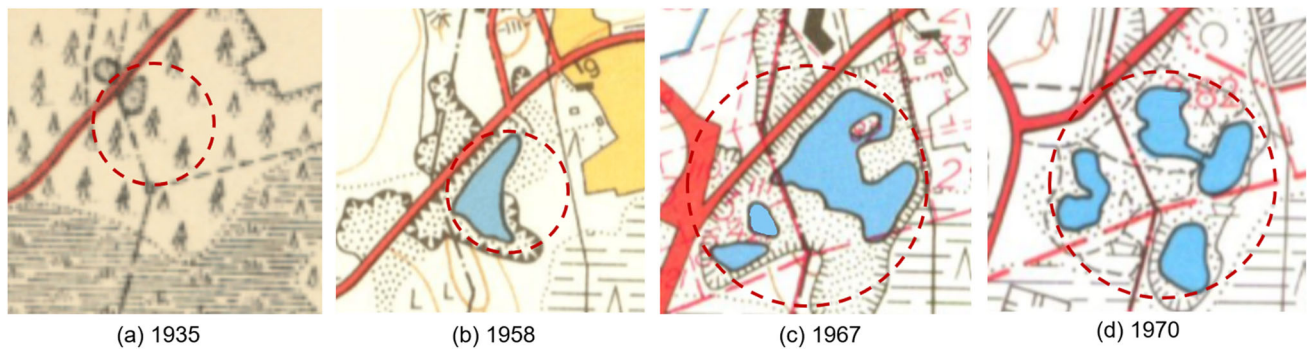
Initially, there was no pond in the area where the cluster ponds are now located, and the place was mainly a swampy and forested area (Karisalo et al. 2020). The initial state of the place is shown in Fig. 15(a) and its respective aerial photo in Fig. 16 (a).

During the 1940s and 1960s, a hole was created as a result of soil (i.e., sand) extraction and exposure of groundwater (Helsingin Kaupunki 2014), thus this hole gradually turned into a wetland (Karisalo et al. 2020). This change is shown in Fig. 15(b) and its respective aerial photo in Fig. 16(b). As the figures depict the created wetland initially was a large single shallow wetland.

Later in 1967, two separate small wetlands were shaped next to the first wetland. At the same time, the first wetland was expanded further and two small islands were created on the north side of the pond, which disappeared over time (as illustrated in Fig. 15(c)). These wetlands, their locations, and sizes are also shown in the aerial photo in Fig. 16(c), taken in 1964. In the aerial photo, while the initial wetland is shown with a lighter colour, the small wetlands are shown with a darker colour.

After a decade, in 1980 the first initial wetland was gradually divided into two ponds which are still hydrologically connected. While the newly created ponds are depicted in Fig. 15(d), they are also demonstrated with numbers 1 and 2 in the aerial photo in Fig. 16(d). The area of these two ponds (i.e., 1 and 2) together is approximately equal to 0.88 ha (Karisalo et al. 2020). A tiny island on the south side of pond 1 has created a good place for waterbirds to rest.

In the same decade, the city constructed a bridge above the connection of these ponds. The connection locations are shown with an arrow in Fig. 16(d). During the 1980s, the former small wetlands that were shown in Fig. 15(c) were gradually merged and formed a new single pond which has an area of about 0.43 ha (Karisalo et al. 2020).



**Fig. 15** The maps of Vaarala cluster ponds shown with the dotted red circles in years 1935, 1958, 1967 and 1970 (Kutilainen 2020, Helsinki Region Infoshare 2013)

This pond is shown in Fig. 15(d) and Fig. 16(d) with the number 3. Besides, in the wetlandscape another pond was interestingly created (a result of sand mining and exposure of groundwater) which has a depth of 4 meters which makes it the deepest pond among the four ponds (Helsingin Kaupunki 2014). The area of this pond reaches about 0.36 ha (Sitowise 2018). The location of the pond is shown with the number 4 in Fig. 16(d).

To compare the biodiversity and vegetation in these four ponds, the conditions in ponds with numbers 1 and 2 are better than the other two ponds (i.e., 3 and 4) (Helsingin Kaupunki 2015, Liao 2017). However, the lower biodiversity levels in the latter ponds have made them suitable water bodies for water-based recreational activities (Karisalo et al. 2020, Helsingin Kaupunki 2014).

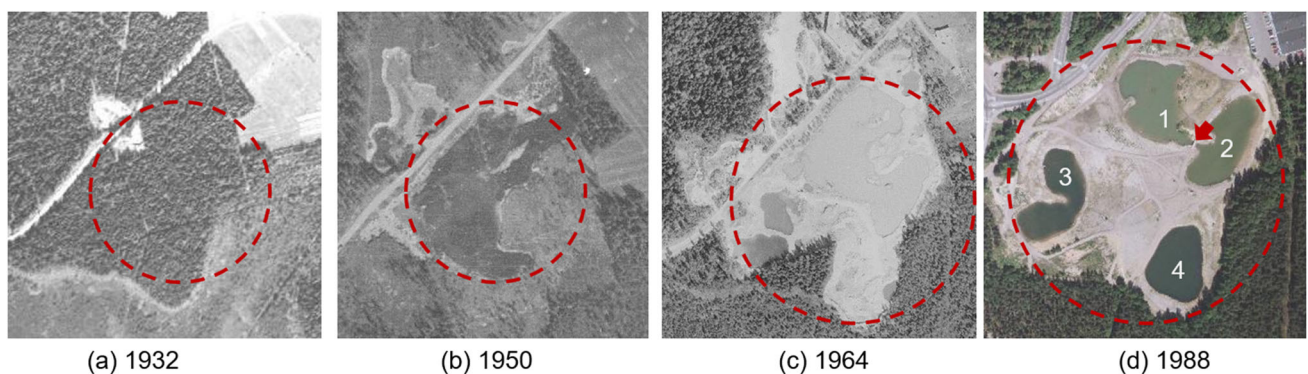
There have been no further changes or transformations on the ponds after the 1980s (Fig. 16(d)). However, currently, a plan by the city has been defined for the development of recreational use in the Vaarala cluster ponds area. Therefore, two studies were carried out in 2018 and both suggested emphasizing the suitability of the ponds for water-based recreational use (Karisalo et al. 2020, Sitowise 2018). Moreover, due to the existence of proper hydrological connectivity and rich biodiversity in ponds 1 and 2,

these ponds will be preserved in their natural conditions (Helsingin Kaupunki 2015). Based on the plan, there will be modifications to ponds 3 and 4 in order to create supervised swimming areas (that aim to avoid the destruction of the water environment).

Studying the case of Vaarala cluster ponds enlightens creating and maintaining connectivity between ponds as a network of fragmented habitats that facilitate the movement of species and strengthen vegetation in the environment. This practice improves biodiversity and brings urban vitality to the citizens, and increases recreational opportunities, e.g. swimming in cities which results in the well-being of citizens.

## Summary and Factors

Based on their conditions and transformations, the ponds that we presented in Section “Selected Wetlands” can be grouped into three categories, including the ponds that 1) have totally disappeared during history, 2) have ecologically destroyed, and 3) still ecologically functioning. For each category, we further summarize and present the transformations of the ponds in Tables 2, 3 and 4.



**Fig. 16** The aerial photos of Vaarala cluster ponds in years 1932, 1950, 1964 and 1988 (Kutilainen 2020, Helsinki Region Infoshare 2013)



**Table 2** Summary of land-use change for totally disappeared wetlands

	Year	Transformation	Impact
Kaivopuisto	1800–1838	An organic and natural wetland that was connected to the sea	The wetland is covered with green and leafy trees that made possible recreational activities such as walking and boating
	1838–1859	The connection between the wetland and the sea was reduced	The wetland was the habitat of swans and fish, and also provided recreational services
	1859–1878	The wetland was isolated and lost connection to the sea	The wetland was considered an attractive element that had an aesthetic function
	1878–1900	The wetland was dried up and replaced with a playground	Due to urbanization, the wetland disappeared forever from Kaivopuisto park

### Totally Disappeared

Wetlands are vulnerable natural elements in the environment. Moreover, wetlands are affected by different environmental and urbanization factors such as climate change and industrialization. Unfortunately, their vulnerability may even threaten the life of wetlands and may cause their loss and disappearance.

In the following, we present the Kaivopuisto pond's transformation, an example of such wetlands. We further summarize the impacts and benefits of the pond on the environment from the year 1800 to 1900 in Table 2.

**Kaivopuisto pond** This pond is an outstanding example of such loss. Sadly, this pond which is located in Helsinki has totally disappeared throughout history and does not exist anymore. Based on the available historical documents, as depicted in Section “[Selected Wetlands](#)”, we observed that this pond had a good ecological and recreational function in the region. Between the years 1838 and 1900, the urbanization and industrialization of Helsinki led to an increase in population in the area where the pond was located. Hence, in the vicinity of the area where people were living, there was a need for a park area rather than a wetland. Therefore, with a land-use change plan, the Kaivopuisto pond was filled and instead, the pond area turned into a playground. Based on this land-use change plan, the pond completely disappeared (Harju et al. 2007).

However, we argue that re-designing the area and the rehabilitation of Kaivopuisto pond even in the form of a constructed wetland would bring many benefits including flood control, stormwater management, and providing additional recreational opportunities such as a place for spending leisure time. An outstanding example of wetland rehabilitation is the Letenských pond in the city of Prague in the Czech Republic (City of Prague 2022). The Letenských

pond is reconstructed and formed in a slight depression hole in Prague. Among the effective proceedings to combat drought challenges in Prague includes the creation and revitalization of new ponds and green spaces. Thus, after geological and archaeological investigations, the City of Prague decides to redesign a pond in the place where the pond is located in order to provide recreational services such as swimming and boating in the future. Moreover, the City's decision to start construction of Letenských pond is influenced by the dry seasons of recent years and the attention that Prague pays to climate change.

Another example is the Chatra Wetland located in eastern India, due to the increase in urbanization and land use conversion rate, it is forecasted to disappear by 2040 (Das and Basu 2020). Hence, the research urges for the restoration of wetland ecological conditions and environmental management change by decision-makers that would prevent the destruction and loss of the wetland.

### Ecologically Destroyed

In the past, the ecological values of urban wetlands were not widely realized, leading to many urban wetlands' ecological destruction. Indeed, several reasons such as urban construction, land-use change, hydrological structure change, and urban water pollution were destroying urban wetlands or making them fragmented ecosystems (Kingsford et al. 2016). In the following, we explain the examples of Kaisaniemi and Alppuisto ponds as two instances of ecologically destroyed wetlands. In Table 3, we also summarize the transformation and the impacts of these two ponds on their environments in the 19<sup>th</sup> century.

**Kaisaniemi pond** The Kaisaniemi pond is an example of an ecologically destructed urban wetland. At the end of the 18<sup>th</sup> century, Kluuvi bay was a spectacular recreation area for city dwellers (Helsingin Kaupunki 2020). However,

**Table 3** Summary of land-use change for ecologically destroyed wetlands

	Year	Transformation	Impact
Kaisaniemi	1800–1838	Use the remnant of Kluuvi bay to create a natural pond	The pond became a small habitat for birds and a place for recreation for Helsinki residents
	1838–1909	The park was designed as a landscape park under influence of natural shape of pond and its land topography	The pond established itself as a popular destination for recreation in the memories of the city's residents
	1909–1925	Transform the natural shape of the pond into a rectangular pool	The reason for the pond's changing shape is the flooding of the pond every year in spring and autumn
	1925–1930	The pond shape was completely changed, and the connection with the natural substrate was lost due to the concrete bottom	Occurrence of physical and technical problems of the pool
Alppipuisto	1800–1873	A forested area that became a recreational area while preserving the natural shape of the ponds that flowed throughout the park	An organic pond that was almost like a stream and some parts of it widened sometimes
	1873–1909	During the construction of the railway, the eastern part of the pond was turned into another park, and some parts of the ponds were destroyed	The rest of the pond still existed in its natural shape in the park
	1909–1925	The pond was renovated, and the bottom of pond was asphalted and turned into two separate ponds with three islands	The connection with the natural substrate was lost due to the pond's asphalted bottom
	1925–1985	The ponds were restored, the shape of the pond was changed and two ponds were connected and turned into one pond	The three islands in the ponds were reduced to one in the southern pond which further reduced biodiversity in the pond

in the same century, the rapidly increasing population and industrialization were calling for more land for construction. Due to urbanization part of the bay area and its shoreline were used as landfills, causing environmental problems e.g., water pollution in Helsinki. Thus, based on a plan, the City filled Kluuvi bay in the 19<sup>th</sup> century to overcome this challenge (Laakkonen et al. 2001, Finni et al. 2001).

Furthermore, during the construction of the Helsinki railway in the 1850s and 1860s, more parts of the bay were drained to build the railway station and the railroad. The only part left of the former Kluuvi bay was a pond which, later in 1927, due to frequent floods turned into a concrete pool that currently exists in Kaisaniemi park (Laakkonen et al. 2001, Finni et al. 2001). The destiny of Kluuvi bay's remnants can be considered the cornerstone of Helsinki's environmental history which highlights the destruction of an ecological wetland within the last 100 years. That is due to the city's drastic urbanization and industrialization, and new gardening ideals (Hautamäki et al. 2020).

Currently, due to the concrete bottom of the pool and the lack of contact with the substrate, practically no vegetation grows in the pool, so in terms of higher plants, there is no biodiversity in the pool. Thus, removing the concrete pool and instead creating a natural pond would lead to revitalizing this concrete pool as a natural pond that can connect the water with the substrate of the pond, hence increasing the biodiversity in the environment and attracting different species to the center of Helsinki. The studies in the literature suggest ecological restoration and conservation by elucidating areas most appropriate for the restoration of wetlands and habitats. For example, assessing 105 years of the historical status of the San Gabriel River watershed in the USA shows that more than 86% of the wetland has been destroyed since around 1870 (Stein et al. 2010).

**Alppipuisto Pond** The transformation of the Alppipuisto pond is another piece of evidence of the ecological destruction of an urban wetland. As the Alppipuisto pond is

**Table 4** Summary of land-use change for ecologically functioning urban wetlands

	Year	Transformation	Impact
Munkkiniemi	1932–1964	There was no pond in the park area and then the area became farmland	Agricultural sewage was drained in the area
	1964–1976	Gradually a natural pond was formed	The agricultural sewage was blocked, and sewage stems were placed in the pond
	1976–1988	The Kone company office was built while part of the office was located at the top of the wetland	A sidewalk was built near the pond. The pond was rich in natural values such as green vegetation and diverse habitat for different species
Kangaslampi	1871–1935	This pond was basically a kettle pond separated from the sea 3500 years ago	Until the 1960s, people were warned to stay away from the pond as it was a marshy area
	1935–1960	The pond was dredged in the 1960s and became a park containing the pond	After dredging the pond, the space around the pond created a suitable place for spending leisure time
	1960–1970	The pond has a small island with several birch trees, born after dredging in mid-1960s	The pond had good biodiversity and was a place for recreation
Vaarala cluster ponds	1932–1958	The first pond to appear in a swampy forest area	The pond was a large shallow wetland suitable for diverse species
	1958–1967	The first pond was still integrated. Gradually two small islands appeared in the north of the pond, and two small ponds were being formed next to the first pond	The ponds were used as swimming places over the years
	1967–1970	The two separate ponds became as a single pond and the first pond was separated with a hydrological connection. The last pond was shaped in the 1970s	While biodiversity and vegetation in the two connected ponds were in better condition than the other two ponds, the latter ponds were used for swimming

located in the center of Helsinki, throughout its history the pond has been intensively affected by the consequences of urbanization such as population growth and water pollution (Tyrväinen et al. 2014, Laakkonen 2001). The population growth and industrialization gradually increased the amount of wastewater and waste dumped into the water, i.e., into Töölö bay which increased the amount of water pollution in the area. Hence, in 1910 to reduce the spread of water pollution, a wastewater treatment plant was built in Alppipuisto park. Whereas, the wastewater was filtered in the Alppipuisto pond and discharged to Töölö bay.

Similar to the Kaisaniemi pond during the construction of the Helsinki railway in the 1860s and when renovating the Alppipuisto pond in 1913, unfortunately, the natural structure of the pond was destroyed. The destruction was due to covering the bottom of the pond with asphalt, leading to losing the connection between the pond and its substrate.

Currently, this pond needs a higher level of biodiversity. Therefore, similar to the Kaisaniemi pond, redesigning the pond by removing the asphalted bottom and returning it to its previous state as a natural pond, would create a connection between the pond and the substrate, and thus would lead to an increase in the biodiversity of the pond. Existing studies suggest the ecological restoration of wetlands as an effective approach for revitalizing wetlands. For instance, the restoration of the native plants in an urban wetland in southern Wisconsin, USA, has revealed that the approach overcomes water surface runoffs, increases biodiversity, and supports native species in the urban area (Owen 1998).

### Ecologically Functioning

In the urban environment, small-scale wetlands, i.e., ponds, can increase the local biodiversity. Thus, preserving and

increasing the connection between these wetlands will increase their ecological functionality (Hassall et al. 2016, Hassall and Anderson 2015). Connectivity will help protect biodiversity and conserve wildlife species and habitats in urban environments (Krivtsov et al. 2020). In the following, we further evaluate the three examples of ecologically functioning ponds which were explained in Section “Selected Wetlands”. We also present a summary of the transformation and the impacts of these three ponds on their environments in Table 4.

**Konelampi Pond** The Konelampi pond, created in the 1960s, is an urban wetland that, despite urbanization has kept its proper ecological function. Along with urbanization, this pond and the surrounding area gradually established themselves as a recreational place among the residents. Due to the inclusion of the pond conservation program in the area’s development plans, this pond has been maintained in good condition to date, improving the quality of biodiversity in the area.

In addition, the current renovation plan, presented in 2017 by the City of Helsinki, considers the revitalization of the pond while preserving its natural values. The revitalization includes dredging the pond substrate and improving the aquatic vegetation (Vehkaoja 2016). The renovation plan suggests establishing a connection between the Konelampi pond as the main pond with other ponds in the Konelampi park area. This suggestion aims at establishing a wetlandscape in the area and also managing stormwater in the area to ensure adaptation to the climate change policies (Holstein et al. 2011).

Currently, this pond is facing an increasing number of cyprinid fish which, as a result, endangers other species, especially the large invertebrates and amphibians (Vehkaoja 2016). Thus, controlling the number of fish in the Konelampi pond would result in increased biodiversity of the pond. For example, investigating 160 years of the environmental history of a coastal wetland in Australia explains that weed control and the planting of native species improve the remnant of wetlands and also increase the number of birds in wetlands (Simpson and Newsome 2017).

**Kangaslampi Pond** The Kangaslampi pond is a rare kettle pond in Helsinki that dates back to 3,500 years. Before the 1960s, this pond was a marshy area known as an unsafe place for people. However, with rapid population growth and increased construction in the areas around the pond, the pond was dredged, and a park was created around it. Later, the park and the pond became popular places for locals. In principle, the Kangaslampi pond is a unique natural pond with suitable biodiversity that represents a proper ecological function and is an oasis for those living in the area.

However, the pond has become very eutrophic due to various factors such as climate change and shoreline configuration. As a result, the amount of water and water circulation in the pond has reduced, as well as the vegetation of the pond’s shoreline has also decreased. Investigating 700 years of history of a lowland wetland landscape Dúbrava Wood in the southeastern part of the Czech Republic explains that improper management and eutrophication of wetlands lead to changes in nutrient cycling and cause nutrient accumulation which results in oxygen depletion and loss of biodiversity in wetland (Szabó et al. 2017).

To overcome the challenges with the eutrophication of the Kangaslampi pond, in 2019, a pond rehabilitation plan by the City of Helsinki suggested dredging operations, which are known as an appropriate method for rehabilitating the pond. Indeed, investigating the Kangaslampi pond as a properly ecologically functioning pond shows that carrying out rehabilitation plans can help maintain and preserve them at different stages of their lives. Rehabilitation can be achieved by pond dredging and vegetation improvement in the pond. For example, by increasing the vegetation in the shoreline areas of the Kangaslampi pond as well as removing the trees from the island of the pond (that are not in good condition) and instead planting vegetation which has lower heights such as shrubs and bushes.

**Vaarala Cluster Ponds** These cluster ponds which consist of four ponds are an example of a wetlandscape that gradually has been created in a swampy forest area in the 1960s. According to the recreational development plan for the Vaarala cluster ponds, while two of the ponds are planned to be maintained in their natural conditions; the other two ponds are planned to be improved. By maintaining the current conditions of the former ponds, the aim is to preserve biodiversity and the hydrological connection between them that provides a gateway for species in these two ponds. The improvement plan also aims to facilitate supervised swimming areas within a land-use change. This is feasible as the ponds have low levels of biodiversity which makes them suitable for recreational use.

Indeed, these cluster ponds can have multiple functions in the environment. These cluster ponds as small habitats can play an important role in creating a wetland network by connecting with each other and as a result, the wetland network can support higher biodiversity at the landscape level (Hassall et al. 2016, Hassall and Anderson 2015). For example, the research in Oertli et al. (2002) evaluates the relationship between the sizes and diversity of eighty ponds in Switzerland. This research concludes that a network of ponds of small sizes can host and enhance more faunal and floral diversities than a single large pond of the same total area. Similarly, another study in Deacon et al. (2018) that investigates pondscales consisting of natural and artificial

ponds in the KwaZulu-Natal Midlands in South Africa shows that the ecological networks created by these ponds can expand conservation corridors across the landscape which can protect the different species and vegetation in the area.

As a result, to enable various functions of ponds through improvements and land-use change plans, the natural values of ponds must be properly considered. To this end, the implementation plans for the ponds require careful evaluation by studying the possible impacts of the plans on the natural environment. The plans should prevent the ecological degradation of the ponds and preserve the ecosystem where the ponds are located.

## Discussion

### Factors Threatening Wetlands

According to our historical evaluation of the selected wetlands and the summaries that we presented in Section “[Summary and Factors](#)”, we conclude that the most influential factors which threaten the wetland ecosystems over time include population growth, urbanization, industrialization, land-use change, and climate change. Furthermore, based on our study, these factors have interrelations with each other. The interrelation and the interactions between these factors are depicted in Fig. 17.

The population growth in cities puts much pressure on aquatic ecosystems including urban wetlands. Population growth, urbanization and industrialization indeed have a direct interrelation. This means that the increase in population in cities enhances urbanization as well as industrialization. Conversely, the latter factors directly impact the population in cities (Veijalainen et al. 2019). These factors also cause further urban development, the main reason that transforms natural urban wetlands into other types of landscapes. Whereas, in built- environments this transformation is known as land-use change. In this case, urban wetlands can be for example drained, shrunk, or transformed into other types of urban built environments such as parks, buildings or even industrial sites. As a result, the land-use change completely destructs the wetland and its biodiversity (Laakkonen 2001, Laakkonen and Laurila 2007).

As shown in Fig. 17, the land-use change also may directly reduce and change the vegetation in and around the wetland. As a result, reducing vegetation in wetlands may cause eutrophication in the water. It also may influence the wetlands’ hydrology by degrading the water quality which leads to weakening the biodiversity in wetlands (Szabó et al. 2017, Khan and Ansari 2005). Moreover, land-use change directly affects the pollution of urban wetlands. Pollution is

due to anthropogenic activities such as industry, agriculture through excess fertilizers, and debris and animal droppings such as dog faeces. In addition, the land-use change may affect the soil in and around wetlands. For example, the connection between water and wetlands substrate may be lost due to asphaltting and the use of concrete. As a result, artificial substrates threaten the biodiversity around the wetland (Houlahan et al. 2006).

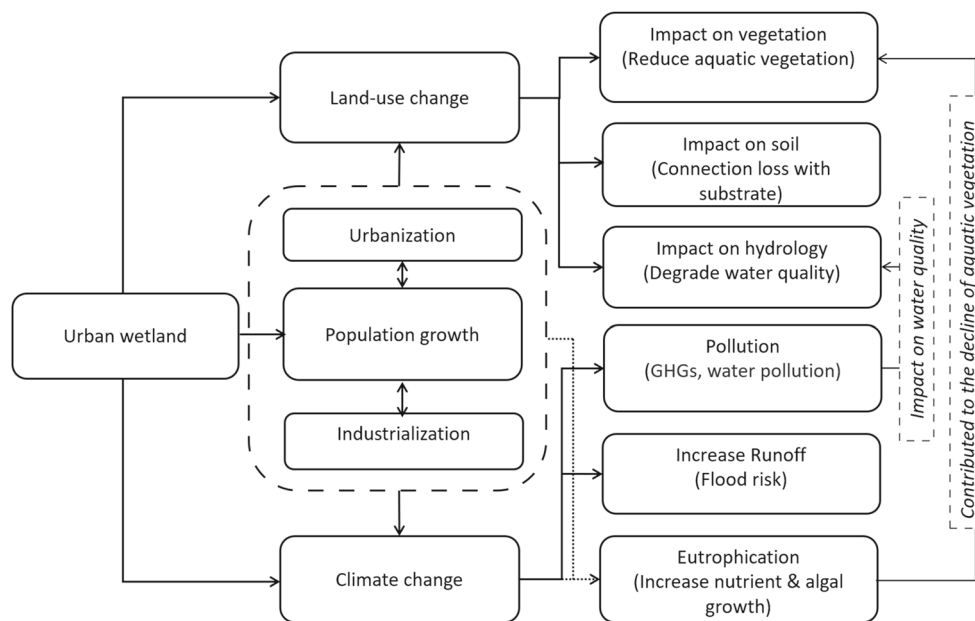
Climate change is another critical factor that affects urban wetlands. Due to urbanization and industrialization, climate change has severely affected and changed the nature of urban wetlands over the past 100 years. Climate change can increase eutrophication as a result of the interaction between meteorological factors e.g., high temperatures and precipitation and the availability of nutrients in wetlands (Nazari-Sharabian et al. 2018). As a result, this would for example increase algal growth in wetlands’ water, leading to the reduction of oxygen in the water and thus, biodiversity loss. Indeed, water eutrophication, one of the potential impacts of climate change, is the main problem of Helsinki’s wetlands (Marttila 2007). Climate change also affects the quality of urban wetlands by reducing or increasing precipitation, the size, and quality of the catchment areas, and the ratio of size and depth of the wetlands, which all increase runoffs and flood risks in cities.

Furthermore, these runoffs increase the pollution in wetlands by bringing various environmental and industrial compounds, which all affect the hygienic quality of the wetlands. All of these pollutants together pollute the water in wetlands and as a result, increase the water pollution levels in cities (Kim and Kim 2010). Moreover, one primary function of wetlands is carbon sequestration; thus, with the increase of pollution in wetlands, their carbon sequestration capabilities can change. Therefore, the pollutant after oxidization is released in the form CO<sub>2</sub> and hence enhances the air pollution (Salimi et al. 2021, Brinson 1993).

### Wetlands’ Management Policies

Wetlands management policies refer to the need for a better understanding of the values of wetlands maintenance in both peri-urban and urban areas. Understanding urban wetlands’ values help policymakers plan nature-based solutions in urban areas (Thorslund et al. 2017). Fortunately, in recent decades scientific understanding and public awareness have improved. Better understanding has helped the policymakers to protect and create wetlands rather than draining them (Li et al. 2010).

The decisions of policymakers, however, would be different in various countries, that would be due to the location of the country on the planet. For example, in Helsinki metropolitan area, the policymakers and urban



**Fig. 17** The conceptual framework that presents factors affecting the transformation and loss of urban wetlands

designers aim to design wetlands in order to manage stormwater, enrich the diversity and create recreational spaces for the residents in the city (Wahlroos et al. 2015). While, in Prague in the Czech Republic, the decisions are influenced by the dry seasons of recent years and in principle due to the consideration that Prague has for climate change (City of Prague 2022).

Our study showed that the disappearance of urban wetlands is closely related to the expansion of built environments in urban areas (Wang et al. 2008). Furthermore, the key to protecting wetlands lies in urban planning policies. To this end, policymakers should prevent the destruction of the wetlands by adopting appropriate policies such as implementing pollution management policies and restoration of the wetlands' ecosystem.

One way to gain knowledge about wetlands is to study the environmental history of wetlands. The environmental history analysis (i) helps to realize the legacy of activities and land-use changes in urban areas (Foster et al. 2003, Li et al. 2010), (ii) can increase our understanding of the current conditions of urban wetlands and reduce the number of mistakes of policymakers, and (iii) enables understanding of whether the current condition of a wetland is sustainable, or whether it requires prioritizing better management decisions, actions, and maintenance (Swetnam et al. 1999, Frajer et al. 2021). In the following, we present findings from our historical evaluation of urban wetlands that would benefit policymakers.

- The environmental history study of wetlands shows that urban wetlands are rarely included in local wetland

rehabilitation policies. Unfortunately, urban wetlands have been severely affected by urbanization and have fragmented or completely disappeared. Instead, rehabilitation policies often were concentrated on other types of wetlands, such as large-scale wetlands, intermittent streams, and lakeside wetlands. Thus, it is necessary to plan appropriate policies for urban wetlands that offer diverse ecological and cultural values (Alikhani et al. 2021b).

- The historical evaluations show that the process of urban wetland degradation is strongly linked with population growth, human activities, and the expansion of urban construction (Hu et al. 2020, Wang et al. 2008). Hence, it is necessary to consider these factors while planning wetland rehabilitation and maintenance policies.
- The historical investigations of wetlands can lead to a better understanding of cultural and natural processes that have led to the current situation of wetlands. Actually, by comparing the current and previous conditions, policymakers can provide decisions that are appropriate to the current conditions and better management of urban wetlands (Stein et al. 2010).
- The historical analysis of wetlands helps identify the areas where the most wetland losses have occurred as well as the areas with significant potential for renovation and improvement. The analysis assists policymakers to perform suitable decisions and actions (Stein et al. 2010).
- The historical evaluations of wetlands help learn the factors affecting the destruction of the wetland. This

enables developing models for the restoration and protection of urban wetlands in the areas which were threatened by the land use change (Stein et al. 2010).

## Conclusion

Urban wetlands are valuable environments that offer diverse ecosystem services in cities. Urbanization and human activities have always affected these natural solution providers throughout history. The historical evaluation of wetlands would be an appropriate approach to understanding the reasons for their disappearance or survival in urban areas. Environmental history evaluation also enables making correct and scientific management decisions. In this research, we use the historical environmental data of six urban wetlands in Helsinki from the existing research in literature, and available documents such as technical reports, old maps, and photos to investigate the states of these wetlands throughout history.

In a nutshell, we show that the degradation and disappearance of urban wetlands are linked to urbanization, i.e., the population growth and expansion of built environments in urban areas, and even climate change. We show that these factors have caused a land-use change, shrinkage, destruction of some urban wetlands, and even the disappearance of another wetland in Helsinki. We also call for special attention to urban wetlands that still have stable conditions to continue their normal function. Our study addresses the need for appropriate policy and decision-making in order to stop the destruction of urban wetlands and instead revitalize and improve wetlands in cities.

**Acknowledgements** The grant from the City of Helsinki Research is highly acknowledged. The authors thank Ms. Markéta Čehovská for sharing the information about the ponds in Prague in the Czech Republic.

**Author Contributions** Somayah Alikhani (S. A.) was involved in the conceptualization, planning, and writing of the manuscript, designing the layout and structure, and editing and revising the manuscript. Petri Nummi (P. N.) helped in the conceptualization, supervised, edited, and revised the manuscript. Anne Ojala (A. O.) co-supervised, reviewed, and revised the manuscript. All authors have read and approved the current version of the manuscript.

**Funding** Open Access funding provided by University of Helsinki including Helsinki University Central Hospital. This work was supported by the City of Helsinki Research grant.

**Data Availability** The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

## Declarations

**Competing interests** The authors have no relevant financial or non-financial interests to disclose.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

## References

- Aartelo S (1968) Kaisaniemen puiston kehittäminen vapaa-ajankäyttötarkoituksiin ja liittäminen ympäröiviin jalankulku-ja viheralueisiin. Master's thesis, Aalto University
- Alikhani S, Nummi P, Ojala A (2021) Urban water bodies and recreational opportunities in Finland. In: Proceedings of the 17th international conference on environmental science and technology (CEST2021), Athens, Greece. pp 1–4. <https://doi.org/10.30955/gnc2021.00094>
- Alikhani S, Nummi P, Ojala A (2021) Urban wetlands: a review on ecological and cultural values. *Water* 13(22):3301. <https://doi.org/10.3390/w13223301>
- Bergström L, Bergström U, Olsson J et al (2016) Coastal fish indicators response to natural and anthropogenic drivers—variability at temporal and different spatial scales. *Estuar Coast Shelf Sci* 183:62–72. <https://doi.org/10.1016/j.ecss.2016.10.027>
- Brinson MM (1993) Changes in the functioning of wetlands along environmental gradients. *Wetlands* 13(2):65–74
- Butzin B (1978) Helsinki—aspects of urban development and planning. *GeoJournal* 2(1):11–26
- Cao X (2008) Dynamics of wetland landscape pattern in Kaifeng city from 1987 to 2002. *Chin Geogr Sci* 18(2):146–154. <https://doi.org/10.1007/s11769-008-0146-x>
- Čehovská M, Kattainen S, Väänänen VM et al (2022) Compensating freshwater habitat loss—duck productivity and food resources in man-made wetlands. *Eur J Wildl Res* 68(3):1–14. <https://doi.org/10.1007/s10344-022-01577-8>
- City of Prague (2022) Letenskesady pond. Available at, <http://www.praha7.cz/rybnik-v-letenskych-sadech/>
- Clark P (2006) The European city and green space: London, Stockholm, Helsinki and St. Petersburg 1850–2000. Ashgate Publishing, Ltd.
- Corcoran RM, Lovvorn JR, Heglund PJ (2009) Long-term change in limnology and invertebrates in Alaskan boreal wetlands. *Hydrobiologia* 620(1):77–89. <https://doi.org/10.1007/s10750-008-9616-5>
- Das A, Basu T (2020) Assessment of peri-urban wetland ecological degradation through importance-performance analysis (IPA): a study on Chatra Wetland, India. *Ecol Indic* 114:106,274. <https://doi.org/10.1016/j.ecolind.2020.106274>
- Deacon C, Samways MJ, Pryke JS (2018) Artificial reservoirs complement natural ponds to improve pondscape resilience in conservation corridors in a biodiversity hotspot. *Plos One* 13(9):e0204,148. <https://doi.org/10.1371/journal.pone.0204148>
- Donner J (2009) Kaivopuisto-kokemuksen paikka. *Kulttuurintutkimus* 26(4 Kaupunki):55–58
- Donner J, Silfverberg S, Ryymin A (2017) Kaisaniemenpuiston ja Kaisaniemenrannan ympäristöhistoriallinen selvitys ja kehittämissperiaatteet Helsingin kaupungin. Tech Rep rakennusviraston julkaisut, Helsingin kaupungin rakennusvirasto Arkkitehtuuri- ja ympäristövirasto

- Durigan G, Munhoz CB, Zakia MJB et al (2022) Cerrado wetlands: multiple ecosystems deserving legal protection as a unique and irreplaceable treasure. *Perspect Ecol Conserv*. <https://doi.org/10.1016/j.jpecon.2022.06.002>
- Finni T, Laurila S, Laakkonen S (2001) The history of eutrophication in the sea area of Helsinki in the 20th century. *AMBIO: a J Human Environ* 30(4):264–271. <https://doi.org/10.1579/0044-7447-304264>
- Foster D, Swanson F, Aber J et al (2003) The importance of land-use legacies to ecology and conservation. *Bioscience* 53(1):77–88. [https://doi.org/10.1641/0006-3568\(2003\)053\[0077:TIOLUL\]20CO;2](https://doi.org/10.1641/0006-3568(2003)053[0077:TIOLUL]20CO;2)
- Frajer J, Kremlová J, Fiedor D et al (2021) The importance of historical maps for man-made pond research: from the past extent of ponds to issues of the present landscape. a case study from the Czech republic. *Morav Geogr Rep* 29(3):184–201. <https://doi.org/10.2478/mgr-2021-0014>
- Hackzell K (2001) Rakas vanha munkkiniemi. Helsingin vanhoja kortteleita, Helsingin Sanomat, Helsinki
- Harju K, Peurasuo P, Karttunen J, Raisio J, Koto R (2007) Kaivopuiston ison puistotien puukujanteen uusiminen peruskorjaussuunnitelma. Tech Rep, rakennusviraston julkaisut, Helsingin kaupungin rakennusvirasto Arkkitehtuuriosasto
- Härkönen S (2021) Helsingin kantakaupungin puistojen ekologinen ja sosiaalinen merkitys. B.S. thesis, University of Helsinki
- Hassall C, Anderson S (2015) Stormwater ponds can contain comparable biodiversity to unmanaged wetlands in urban areas. *Hydrobiologia* 745(1):137–149. <https://doi.org/10.1007/s10750-014-2100-5>
- Hassall C, Hill M, Gledhill D (2016) The ecology and management of urban ponds. In: *Urban landscape ecology*. Routledge, London, United Kingdom, pp 147–165
- Hautamäki R, Donner J et al (2019) Historiallinen kerroksellisuus kaisaniemen puiston suojelun ja vaalimisen avaimena. Suomen historiallinen seura Ry
- Hautamäki R, Donner J et al (2020) Park in flux: Change and continuity in the planning discourse of kaisaniemi park. In: *NAF/NAAR symposium, nordic academic press of architectural research*, pp 153–180
- Häyrynen M (1994) Maisemapuistosta reformipuistoon: helsingin kaupunkipuistot ja puistopolitiikka 1880-luvulta 1930-luvulle Helsinki club, Helsinki, Finland
- Häyrynen M (2001) Helsingin kaupunkipuistot. In: *Hortus fennicus-suomen puutarhataide. Viherympäristöliiton julkaisu; 17, puutarhataiteen seuran julkaisu; 1. Viherympäristöliitto ry, Puutarhataiteen seura ry, Helsinki, Finland*, pp 176–189
- Heino J, Virkkala R, Toivonen H (2009) Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions. *Biol Rev* 84(1):39–54. <https://doi.org/10.1111/j.1469-185X.2008.00060x>
- Helsingin Kaupungin Museo (2022) kaisaniemi swan pond. Available at, <https://hkm.finna.fi/Search/Results?lookfor=kaisaniemi+lammikko&type=AllFields&dfApplied=1&limit=20>
- Helsingin Kaupunki (2011) Ympäristövaikutusten arviointiselostus. Tech Rep, Liikennevirasto Helsingin kaupunki
- Helsingin Kaupunki (2014) Huleveden varassa olevien luonto ja virkistysarvojen kartoitus. Tech Rep, Helsingin kaupungin rakennusvirasto
- Helsingin Kaupunki (2015) Jakomäkitattariharjun aluesuunnitelman luonnonhoidon osio. Tech Rep, Helsingin kaupungin ympäristökeskuksen
- Helsingin Kaupunki (2020) Rautatien ja asema aukio. Tech Rep, Kaupunkirakenne ja ympäristöhistoriaselvitys
- Helsinki Region Infoshare (2013) Helsinki old map. Available at <https://hri.fi/data/fi/group/kartat>
- Hemgard G, Järvinen K, Nieminen M (2007) Kaisaniemen puiston asemakaavatasoinen yleissuunnitelma. Tech Rep, Helsingin kaupungin kaupunkisuunnitteluvirasto
- Hietanen S, Vaalgamaa S (2021) Vuosaaren kangaslammen ruoppaus. Tech Rep, Sitowise
- Hill MJ, Hassall C, Oertli B et al (2018) New policy directions for global pond conservation. *Conserv Lett* 11(5):e12,447. <https://doi.org/10.1111/cons.12447>
- Hill MJ, Greaves HM, Sayer CD et al (2021) Pond ecology and conservation: research priorities and knowledge gaps. *Ecosphere* 12(12):e03,853. <https://doi.org/10.1002/ecs23853>
- Hirvonen L, Sjöholm K (2007) Alppipuiston ja leninipuiston hoito- ja kehittämissuunnitelma 2007–2016. Tech Rep, Helsingin kaupungin rakennusvirasto
- Holstein M, Elohaka E, Sihvola E, Ulvila J, Ekholm A (2011) Munkkiniemen aluesuunnitelma. Tech Rep, Helsingin kaupungin rakennusvirasto
- Houlahan JE, Keddy PA, Makkay K et al (2006) The effects of adjacent land use on wetland species richness and community composition. *Wetlands* 26(1):79–96
- Hu T, Liu J, Zheng G et al (2020) Evaluation of historical and future wetland degradation using remote sensing imagery and land use modeling. *Land Degrad Dev* 31(1):65–80. <https://doi.org/10.1002/ldr3429>
- Jaarni C (2021) Harva tietää, että helsingissä oli ennen useita järviä, jotka ovat nyt kadonneet – katso, miten ne vaikuttavat edelleen elämään kaupungissa. Available at <https://yle.fi/uutiset/3-11772437>
- Juuti P, Katko T et al (2005) *Water, time and European cities: history matters for the futures* Tampere University Press, Tampere, Finland
- Juuti P, Tapio K, Rajala R (2010) *Metropoli ja meri-100 vuotta jätevedenpuhdistusta helsingissä*
- Kačergytė I, Arlt D et al (2021) Berg {AA Evaluating created wetlands for bird diversity and reproductive success. *Biol Conserv* 257:109,084. <https://doi.org/10.1016/j.biocon.2021.109084>
- Karisalo V, Äärelä R, Talusen M, Löytönen L, Kangas K, Kinnunen P (2020) Vaaralan lammet. Tech Rep, Maankäytön, rakentamisen ja ympäristön toimiala, kaupunkisuunnittelu
- Khan FA, Ansari AA (2005) Eutrophication: an ecological vision. *Bot Rev* 71(4):449–482
- Kim H, Kim JG (2010) A 2000-year environmental history of the upo wetland on the Korean peninsula. *J Paleolimnol* 44(1):189–202. <https://doi.org/10.1007/s10933-009-9396-6>
- Kingsford RT, Basset A, Jackson L (2016) Wetlands: conservation's poor cousins. *Aquat Conserv: Mar Freshwat Ecosyst* 26(5):892–916. <https://doi.org/10.1002/aqc2709>
- Krivtsov V, Birkinshaw S, Arthur S et al (2020) Flood resilience, amenity and biodiversity benefits of an historic urban pond. *Philos Trans Royal Soc A* 378(2168):20190,389. <https://doi.org/10.1098/rsta20190389>
- Kutilainen M (2020) Helsinki old map. Available at <https://vanhatkartat.fi/#12.6/65.0088/25.46912>
- Laakkonen S (1999) Nokea ja pilvenhattaroita: helsinkiläisten ympäristö 1900-luvun vaihteessa. Helsingin kaupungin museo
- Laakkonen S (2001) Vesiensuojelun synty: Helsingin ja sen merialueen ympäristöhistoriaa 1878–1928. *Gaudeamus*
- Laakkonen S, Laurila S (2007) Changing environments or shifting paradigms? strategic decision making toward water protection in Helsinki, 1850–2000. *AMBIO: a J Human Environ* 36(2):212–219. [https://doi.org/10.1579/0044-7447\(2007\)36\[212:CEOSPS\]20CO;2](https://doi.org/10.1579/0044-7447(2007)36[212:CEOSPS]20CO;2)
- Laakkonen S, Laurila S, Kansanen P, Schulman H (2001) Nakokulmia Helsingin ympäristöhistoriaan: kaupungin ja ympäristön muutos 1800- ja 1900-luvuilla Helsinki, Helsinki, Finland



- Li Y, Zhu X, Sun X et al (2010) Landscape effects of environmental impact on bay-area wetlands under rapid urban expansion and development policy: a case study of lianyungang, china. *Landsc Urban Plan* 94(3-4):218–227. <https://doi.org/10.1016/j.landurbplan.2009.10.006>
- Liao W (2017) Jakomäki-vaarala and fazerila wetlands. Tech Rep, University of Helsinki, Ecosystems and Environment Research Programme
- Lindholm T (1986) Alppipuisto. Tech rep, Dendrologian seura
- Luckin B, Massard-Guilbaud G, Schott D (2017) Resources of the city: contributions to an environmental history of modern Europe. Routledge
- Mainstone C, Hall R, Diack I (2016) A narrative for conserving freshwater and wetland habitats in england. *Natural England Res Rep*, vol 64
- Maisema Arkkitehtitoimisto Näkymä (2013) Eläintarhan alueen ympäristöhistoriallinen selvitys. Tech Rep, Helsingin kaupunkisuunnitteluvirasto
- Marttila H (2007) Helsingin lammet. Tech Rep, Helsingin kaupungin ympäristökeskuksen julkaisuja
- McInnes RJ (2013) Recognising wetland ecosystem services within urban case studies. *Mar Freshw Res* 65(7):575–588. <https://doi.org/10.1071/MF13006>
- Meteoblue (2022) Climate change helsinki. Available at, [https://www.meteoblue.com/en/climate-change/helsinki\\_finland.658225](https://www.meteoblue.com/en/climate-change/helsinki_finland.658225)
- Mikkonen S, Laine M, Mäkelä H et al (2015) Trends in the average temperature in finland, 1847–2013. *Stoch Environ Res Risk Assess* 29(6):1521–1529. <https://doi.org/10.1007/s00477-014-0992-2>
- Nazari-Sharabian M, Ahmad S, Karakouzian M (2018) Climate change and eutrophication: a short review. *Eng, Technol Appl Sci Res* 8(6):3668
- Odgaard MV, Turner KG, PK Bøcher et al (2017) A multi-criteria, ecosystem-service value method used to assess catchment suitability for potential wetland reconstruction in denmark. *Ecol Indic* 77:151–165. <https://doi.org/10.1016/j.ecolind.2016.12.001>
- Oertli B, Joye DA, Castella E et al (2002) Does size matter? the relationship between pond area and biodiversity. *Biol Conserv* 104(1):59–70. [https://doi.org/10.1016/S0006-3207\(01\)00154-9](https://doi.org/10.1016/S0006-3207(01)00154-9)
- Olsson S, Brunila B, Taucher G, Castren A (1925) Rahatoimikamarin esitys kaisaniemen puiston uudestaan järjestelemisestä. Tech Rep, Helsingin Kaupunginvaltuustolle
- Owen C (1998) Hydrology and history: land use changes and ecological responses in an urban wetland. *Wetl Ecol Manag* 6(4):209–219
- Pajari K (2007) Lampi, lamppuja ja luistinrata. Available at, <https://www.hs.fi/kotimaa/art-2000004510167.html>
- Pilli-Sihvola K, Haavisto R, Leijala U et al (2019) Weather and climate change risks in helsinki. City of helsinki. *Publ Urban Environ Div* 32:112
- Robertson HA, McGee TK (2003) Applying local knowledge: the contribution of oral history to wetland rehabilitation at kanyapella basin, australia. *J Environ Manag* 69(3):275–287. [https://doi.org/10.1016/S0301-4797\(03\)00155-5](https://doi.org/10.1016/S0301-4797(03)00155-5)
- Salimi S, Almutkar SA, Scholz M (2021) Impact of climate change on wetland ecosystems: a critical review of experimental wetlands. *J Environ Manag* 286:112,160. <https://doi.org/10.1016/j.jenvman.2021.112160>
- Schönach P (2008) Kaupungin savut ja käryt: Helsingin ilmansuojelu 1945–1982. PhD thesis, University of Helsinki
- Schönach P (2016) Historical paths of environmental injustice: a century of placing industrial facilities in helsinki, finland. *Local Environ* 21(4):397–413. <https://doi.org/10.1080/135498392014985641>
- Schulman H (2001) Helsingin kasvu suurkaupungiksi. In: näkökulmia helsingin ympäristöhistoriaan: kaupungin ja ympäristön muutos 1800- ja 1900-luvuilla. Edita, Helsinki, Finland, pp 14–31
- Seppälä MO (2008) Kaivopuisto Helsinki-seura, Helsinki, Finland
- Simpson G, Newsome D (2017) Environmental history of an urban wetland: from degraded colonial resource to nature conservation area. *Geo: Geogr Environ* 4(1):e00,030. <https://doi.org/10.1002/geo.230>
- Sitowise (2018) Vaarala-jakomäen lammet tekninen selvitys. Tech Rep, Vantaan kaupunki ja Helsingin kaupunki
- Statistics Finland (2021) Available at, [https://www.stat.fi/index\\_en.html](https://www.stat.fi/index_en.html)
- Stein ED, Dark S, Longcore T et al (2010) Historical ecology as a tool for assessing landscape change and informing wetland restoration priorities. *Wetlands* 30(3):589–601. <https://doi.org/10.1007/s13157-010-0050-x>
- Suomalainen M, Vehviläinen B, Veijalainen N et al (2006) Effects on the hydrological cycle—inland waters. *Clim Change Adapt Hydrol Water Resour*. vol 6
- Swetnam TW, Allen CD, Betancourt JL (1999) Applied historical ecology: using the past to manage for the future. *Ecol Appl* 9(4):1189–1206. [https://doi.org/10.1890/1051-0761\(1999\)009\[1189:AHEUTP\]20CO;2](https://doi.org/10.1890/1051-0761(1999)009[1189:AHEUTP]20CO;2)
- Szabó P, Gálová A, Jamrichová E et al (2017) Trends and events through seven centuries: the history of a wetland landscape in the czech republic. *Reg Environ Change* 17(2):501–514. <https://doi.org/10.1007/s10113-016-1033-0>
- Thorslund J, Jarsjo J, Jaramillo F et al (2017) Wetlands as large-scale nature-based solutions: Status and challenges for research, engineering and management. *Ecol Eng* 108:489–497. <https://doi.org/10.1016/j.ecoleng.2017.07.012>
- Tyrväinen L, Ojala A, Korpela K et al (2014) The influence of urban green environments on stress relief measures: a field experiment. *J Environ Psychol* 38:1–9. <https://doi.org/10.1016/j.jenvp.2013.12.005>
- Vähäaho I (2014) Underground space planning in helsinki. *J Rock Mech Geotech Eng* 6(5):387–398. <https://doi.org/10.1016/j.jrmge.2014.05.005>
- Vasić F, Paul C, Strauss V et al (2020) Ecosystem services of kettle holes in agricultural landscapes. *Agronomy* 10(9):1326. <https://doi.org/10.3390/agronomy10091326>
- Vehkaoja M (2016) Munkkiniemen puiston kosteikot. Tech Rep, Helsingin kaupungin rakennusvirasto
- Veijalainen N, Ahopelto L, Marttunen M et al (2019) Severe drought in finland: modeling effects on water resources and assessing climate change impacts. *Sustainability* 11(8):2450. <https://doi.org/10.3390/su11082450>
- Vuorela I, Grönlund T, Kankainen T (1990) Helsingin vuosaaren luonnon- ja asutushistorian paleoekologinen tutkimus. Geologian tutkimuskeskus Raportti KA
- Wahlroos O, Valkama P, Mäkinen E et al (2015) Urban wetland parks in finland: improving water quality and creating endangered habitats. *Int J Biodivers Sci, Ecosyst Serv Manag* 11(1):46–60. <https://doi.org/10.1080/2151373220151006681>
- Wang X, Ning L, Yu J et al (2008) Changes of urban wetland landscape pattern and impacts of urbanization on wetland in wuhan city. *Chin Geogr Sci* 18(1):47–53. <https://doi.org/10.1007/s11769-008-0047-z>
- Zorrilla-Miras P, Palomo I, Gómez-Baggethun E et al (2014) Effects of land-use change on wetland ecosystem services: a case study in the doñana marshes (sw spain). *Landsc Urban Plan* 122:160–174. <https://doi.org/10.1016/j.landurbplan.2013.09.013>

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.