The role of citizen science in urban biodiversity governance

A comparative study of German and Swedish cities

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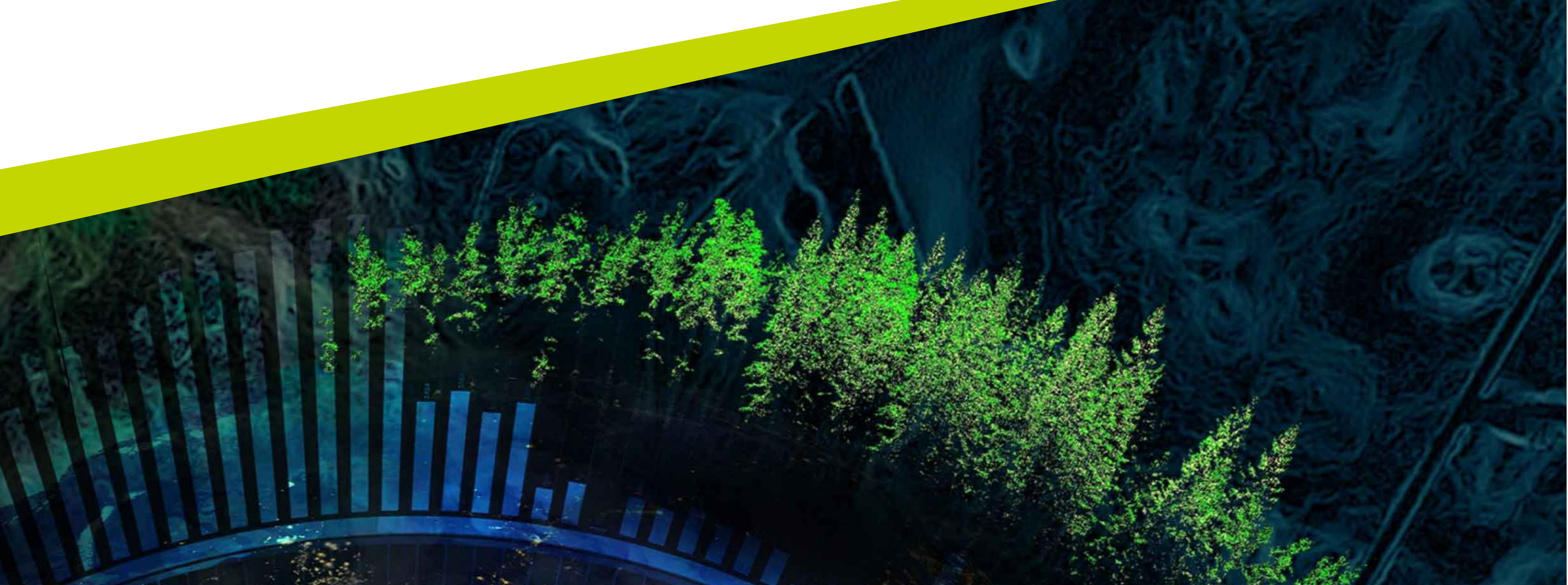

The role of citizen science in urban biodiversity governance. A comparative study of German and Swedish cities

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Abstract

Biodiversity forms the foundation of resilient ecosystems, a stable climate and human well-being. With ongoing urbanization, protecting biodiversity in cities has become increasingly important. Effective monitoring is essential to understand dynamics and the condition of the environment, and to enable informed conservation measures. In this context, citizen science (CS) can provide valuable additional data through observations collected by the public. However, despite its growing popularity and the increasing availability of data, it remains unclear to what extent CS data is actually used by city authorities. This study explores whether and how CS data is used in municipal biodiversity management and how it is translated into practical measures. It compares approaches in Sweden and Germany following a comparative qualitative research design. The four selected cities Stockholm, Uppsala, Cologne and Bielefeld were analysed using a document research and semi-structured interviews with city representatives. CS is used in all cities for conservation measures, planning decisions and raising environmental awareness. In Sweden, CS is strongly institutionalized and integrated into everyday practice through the centralized platform Artportalen. By contrast, the CS platform landscape in Germany is more fragmented and used in project-based, species-specific contexts often with a stronger emphasis on awareness-raising. Overall, the study suggests, that CS is becoming an increasingly important resource for biodiversity governance. At the same time, it remains a complementary data source alongside professional monitoring and always requires careful interpretation.

Keywords: citizen science, biodiversity monitoring, urban biodiversity, municipal biodiversity management, comparison, Sweden, Germany, interviews, document analysis

Table of contents

List of tables

List of figures

Abbreviations

Abbreviation	**Description**
AI	Artificial Intelligence
CBD	Convention on Biological Diversity
CS	Citizen Science
ECSA	European Citizen Science Association
ecs	European Citizen Science Platform
ES	Ecosystem services
GBIF	Global Biodiversity Information Facility
GBF	Kunming-Montreal Global Biodiversity Framework
IAS	Invasive Alien Species
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
NABU	Nature and Biodiversity Conservation Union
SLU	Swedish University of Agricultural Sciences
SDG	Sustainability Development Goals
SBDI	Swedish Biodiversity Data Infrastructure
UN	United Nations
UU	Uppsala University

1. Introduction

Biodiversity is of fundamental importance for human health and well-being, as it is essential for functioning ecosystems (Dasgupta 2021). These provide a wide range of essential ecosystem services (ES), meaning the "benefits people obtain from ecosystems" (Millennium Ecosystem Assessment 2005, p. 1) and can be classified as provisioning, regulating, supporting and cultural services (Millennium Ecosystem Assessment 2005; Mu et al. 2025). They include food production, clean air and water, carbon storage, protection against natural hazards, climate regulation, soil formation and nutrient cycling, as well as recreational values.

The capacity of ecosystems to deliver ES depends strongly on biological diversity (IPBES 2024; Dasgupta 2021; Hussein 2021). Biodiversity refers to the variability within species, between species and of ecosystems (Secretariat for the Convention on Biological Diversity 2011). It supports ecosystem functioning, both directly through pollination or carbon sequestration, and indirectly by supporting ecological interactions that enhance system stability. Diverse ecosystems are generally more resilient to changing environmental conditions and disturbances, allowing them to maintain ES over time (Hussein 2021).

However, biodiversity is increasingly under pressure from multiple anthropogenic drivers. Land-use change, pollution, climate change and the spread of invasive species are among others the main factors driving biodiversity loss (Christian 2023). Recent global assessments indicate a decline by approximately 2 – 6 % per decade over the past 30 to 50 years (IPBES 2024). Although biodiversity loss is a global problem, it becomes particularly pressing in urban areas. With 68% of the growing global population expected to live in cities by 2050, urban expansion intensifies the environmental pressure through land sealing, habitat fragmentation, increased emissions and pollution (Keinath et al. 2025; Soni et al. 2025). At the same time, biodiversity and well-functioning green and blue infrastructure are essential components in urban areas to mitigate impacts of heat waves and flooding as well as to improve air and water quality (Uppsala kommun 2021; Kowarik et al. 2025).

To understand current environmental conditions, track species trends and evaluate the conservation efforts, systematic biodiversity monitoring is essential (Johnston et al. 2023; Della Rocca et al. 2024). However, research conducted by Affinito et al. (2024) indicates that the implementation of comprehensive monitoring remains challenging. Key constraints include limited funding as well as the labour intensive and time consuming methodology, resulting in data gaps. As a result, complementary approaches are needed to support traditional monitoring. Against that background, increasingly popular citizen science (CS) can be a promising tool (Habel et al. 2025).

CS refers to the voluntary participation of non-professional citizens in scientific research and knowledge production, particularly through data collection to support professional scientific research in fields such as environmental and biodiversity monitoring (Somerwill & Wehn, 2022). While structured surveys of plants, butterflies, birds and many other taxa have existed for decades, less structured projects without fixed protocols or long-term commitment have recently expanded rapidly. This expansion of CS data has the potential to strengthen biodiversity monitoring by filling temporal and spatial data gaps, thereby providing essential evidence for decision making (Johnston et al. 2023). Beyond its scientific contribution, CS offers a range of social and educational benefits. It supports a greater environmental awareness, empowers participants and cultivates a sense of community (Fraisl et al. 2022).

The United Nations (UN) have increasingly recognized this potential and encourage the use of CS and other emerging technologies, such as remote sensing, alongside traditional monitoring methods (UNEP 2021). Despite some constraints, such as variable data quality, biases in participant distribution, uneven coverage of geographic areas or species, CS already contributes to a significant share of biodiversity data. Fraisl et al. (2022) found that CS projects, focusing on species monitoring, contribute at least 50% of the observations in global databases. Additionally, CS has proven its potential in providing reliable data for scientific research (Mason et al. 2025). However, little research has been done about how cities use CS to support urban biodiversity and adjust their municipal biodiversity planning.

The goal of this study is to examine the role of CS in urban biodiversity management, focusing on how citizen-generated data are integrated into municipal planning and decision-making processes. Specifically, the study investigates the extent to which CS data is used in urban biodiversity planning, how they contribute to the implementation of concrete conservation measures and how they are incorporated into policy frameworks. To explore the use of CS across different national contexts, the study compares cities in Sweden and Germany. The comparison aims to identify differences, challenges and opportunities, allowing to learn from each other´s experience, exchange ideas and discover possible improvements (OECD 2020).

To achieve these objectives, three central research questions are addressed:

1) To what extent is citizen science used in the urban context to support biodiversity management?
2) In what ways is citizen science embedded in municipal biodiversity governance structures and policy documents?
3) What differences can be observed between Swedish and German cities?

The thesis first provides a conceptional background on CS and biodiversity governance, before outlining the methodological approach, including the case selection, data collection and analysis. It then presents and discusses the findings from document analysis and interviews, focusing on the institutionalization of CS, the selective nature, biases and limitations, as well as its potential for supporting biodiversity conservation. Finally, it reflects on constraints, offers suggestions for future research and concludes the key findings.

2. Conceptual Background

2.1 Citizen Science

CS refers to the involvement of non-professional participants in scientific research (Feldman et al. 2021). Although it has a long history, its popularity significantly increased since the 1990s (Vohland et al. 2021). This growth has been especially facilitated by technological advancements such as the internet and smartphones, that make participation easier and more accessible (Roy et al. 2018; Lotfian et al. 2022; Meeus et al. 2023). CS is used in a wide range of disciplines, including astronomy, meteorology, history, medicine, but predominantly in biology, especially for biodiversity monitoring (Strasser et al. 2018; Finger et al. 2023). Within the latter field participants contribute in various ways, including classifying images, recording environmental data and especially collecting biodiversity observations (Strasser et al. 2018; 2023a). However, CS initiatives vary in their design and level of engagement. They range from open projects, recording opportunistic observations, to structured monitoring programs, where volunteers follow standardized protocols (Kelling et al. 2019; Binley et al. 2023). By involving a large number of volunteers, CS generates a large-scale dataset across space and time in a very cost-effective way, making it a valuable complement to traditional monitoring (Rega-Brodsky et al. 2022a; Binley et al. 2023; Backstrom et al. 2024). Well-designed CS projects can be very accurate and even comparable with professional surveys (Bonney 2021). Beyond data collection, CS also plays an important role in education and public engagement and strengthens people´s connection with their environment (McKinley et al. 2017; Anhalt-Depies et al. 2019; Kelling et al. 2019; Lopez et al. 2020; Cappa et al. 2022). However, the reliability of CS is limited due to uneven spatial and temporal coverage, observer biases and misidentifications. So, careful filtering and verification is required (Johnston et al. 2023). Artificial intelligence (AI) tools can further improve data quality by supporting species identification and validating observation (Lotfian et al. 2022). Despite its limitations, CS data improves knowledge of species abundance and distributions, especially in areas and for taxa that are otherwise undersampled (Callaghan et al. 2020b). Therefore, CS can support biodiversity monitoring and research, conservation planning, habitat protection and restoration, detect invasive species, inform decision-makers and raise awareness (Chandler et al. 2017; Bonney 2021; Quinn 2021; Fontaine et al. 2022; Fraisl et al. 2022; Kc & Sapkota 2024).

2.2 Biodiversity governance

Currently, biodiversity is declining at unprecedented rates and is further reinforced by urban expansion, which is projected to cause habitat loss of 26–39% and significant species richness and abundance reduction by the end of the century (Li et al. 2022; Simkin et al. 2022). To address this crisis, strong international cooperation, long-term commitment and shared governance are needed (Jóhannsdóttir et al. 2010, Secretariat of the Convention on Biological Diversity 2020). Biodiversity governance refers to the system of rules, institutions and decision-making processes that shape how biodiversity is managed (Sampford 2002; UNDP 2011). Many international laws and policy frameworks have been developed in recent decades to coordinate action and strengthen global efforts to protect biodiversity (BISE n.d. a).

The Convention on Biological Diversity (CBD), established in 1993, is the most important global framework and has been ratified by 196 nations. It focuses on conserving biodiversity, using natural resources sustainably and requires countries to develop a national biodiversity strategy. Under the CBD, parties meet regularly to review progress and set new goals. Examples include the Aichi Targets (Visseren-Hamakers & Kok 2022, European Commission 2025) and more recently, the Kunming-Montreal Global Biodiversity Framework (GBF). This sets long term targets for 2050 and includes the 30*30 target, which aims to protect 30 % of land and oceans and restore 30 % of degraded ecosystems by 2030 (CBD 2022, European Commission 2025). Beyond that, biodiversity is also integrated within the UNs Sustainable Development Goals (SDG), especially SDG 11 (Sustainable Cities and Communities), 14 (Life Below Water) and 15 (Life On Land) support biodiversity protection (Somerwill & Wehn 2022; Keinath et al. 2025; UN 2015).

In the European Union (EU) the European Green Deal serves as an overarching framework for all environmental actions. It aims to make the EU climate neutral and resource efficient, while protecting biodiversity and ecosystems (European Commission n.d.). It is supported by the EU Biodiversity Strategy for 2030. Its key objectives include expanding protected areas, restoring degraded ecosystems and integrating biodiversity considerations into agriculture, forestry, fisheries and urban planning. The EU Nature Restoration Law focuses on restoring degraded ecosystems. It aims to restore 20 % of land and sea in Europe by 2030, and all areas by 2050. In cities, preserving green spaces and tree cover (European Commission 2020a). Furthermore, endangered animals, plants and habitats are protected through the Birds and Habitats Directive. To track dynamics and ensure compliance, member states are obligated to report on species and habitats status every six years (European Environment Agency 2024). The EU also addresses the threat of invasive alien species (IAS) for local ecosystems with the IAS Regulation. It provides instructions for prevention, early detection, rapid eradication, and management of

IAS. Member states have to report on the status of species every six years (BISE n.d. b). Countries adopt national biodiversity strategies to implement international and EU goals, which are then carried out at regional, state and local levels.

Despite these frameworks, many targets are not being met and biodiversity continues to decline (European Commission 2020b, IPBES 2019; Rega-Brodsky et al. 2022b). Because of this, Hermoso et al. (2022) argues that biodiversity needs a stronger integration into other sectors, especially agriculture and economy, to strengthen its implementation and enforcement. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) helps linking science and policy by providing information on biodiversity through reports and communication (Díaz et al. 2015). At the same time, biodiversity monitoring faces major challenges, including insufficient and fragmented data, limited spatial and temporal coverage, lack of long-term monitoring and shortages of financial, technical and human resources. These weaknesses make it difficult for countries to meet reporting obligations (Moersberger et al. 2024). To address this, stronger coordination and collaboration are needed, along with standardized data collection and sharing. In that regard, CS can play an important role by making data collection and analysis more cost-efficient and enabling coverage on a larger scale (Santana et al. 2025).

3. Methods

3.1 Study design

This study follows a comparative qualitative research design to explore how CS supports urban biodiversity management in two Swedish and two German cities. Comparing municipalities from two different countries made it possible to identify both similarities and differences in the way CS is applied (Lim 2006; Rihoux 2006). In a document analysis official strategies, policies and existing CS projects were reviewed, before semi-structured interviews with city representatives were conducted to gain more detailed insights into municipal practices, specific measures and challenges (Young et al. 2018). The collected data was analyzed using reflexive thematic analysis to find patterns and themes across the cities (Braun & Clarke 2006; Bowen 2009). Based on these findings, the role of CS in supporting urban biodiversity governance across different cities were compared.

3.2 Case selection

Sweden and Germany are both members of the European Union and follow EU policy frameworks, including the biodiversity strategy (European Commission. 2020a), making them suitable for comparison. At the same time, the two countries differ in their governance structures. Sweden has a unitary system, where regional authorities mainly have administrative responsibilities, while Germany has a more decentralized federal system (Government Offices of Sweden n.d.; The federal Government n.d.). Also they were chosen because the author has done her university education in both these countries.
As case studies, the cities of Stockholm, Uppsala, Cologne and Bielefeld were selected (overview see Appendix Table 4). This was mainly based on population size and includes both metropolitan areas and medium sized cities. Stockholm and Cologne represent large urban centres with around one million inhabitants and greater administrative capacities than the medium sized cities of Uppsala and Bielefeld (Statistisches Bundesamt 2026, Statistika centralbyrån 2026, OECD & European Commission 2020). All four cities have a strong commitment to environmental protection and biodiversity conservation. This can be seen in measures such as green space preservation, species protection and sustainable city planning (see 3.3).
Another similarity is that all four are university cities. Therefore, they have relatively young populations and share a comparable demographic profile (Revington et al. 2023; OECD 2025). Universities also play an important role in CS, for example by initiating projects and connecting researchers, local authorities and the public (Rossoni et al. 2024). A further reason for selecting these cities is their participation

in the annual City Nature Challenge (CNC), also known as BioBlitz. During this global event, residents document local biodiversity over a four-day period. Cities compete to record as many species as possible, which raises awareness of urban biodiversity and simultaneously contributes to scientific data collection (Callaghan et al. 2020a; Meeus et al. 2023).

3.3 City profiles

3.3.1 Stockholm

Sweden's capital city Stockholm, home to almost one million inhabitants, is located in the southeast of the country (Statistika centralbyrån 2026). The city is strongly defined by its green and blue infrastructure, as it is built on an archipelago of 14 islands (Euro Cities n.d. b). Of its total area, around 13% is water and 59% are green spaces (Stockholms stad 2019), including ecologically valuable habitats such as coniferous forests, wetlands, meadows and century old oaks (Stockholms stad n.d. a, 2024). Approximately one fifth of the area is protected nature, containing eleven nature reserves, one cultural reserve and a national city park (Stockholms stad 2025). The urban area is expanding continuously due to population growth and increasing housing demand, resulting in land-use change, making preserving biodiversity increasingly challenging (Adem Esmail et al. 2022, Statistika centralbyrån 2026). Drawing on their strong ecological foundation, Stockholm has high ambitions to maintain viable ecosystems and a large diversity of species (Stockholms stad 2024b). Additionally, the city is working towards becoming climate positive by 2030 and fossil-free by 2040 (Stockholms stad 2025). These goals are supported by investments in sustainable waste and water management, wastewater treatment and low emission transportation. Stockholm´s role as a leading example is widely recognized and the city was the first to be named a European Union Green Capital, highlighting its commitment to environmental protection and sustainability (Bibri & Krogstie 2020). Additionally, the city is a leading academic centre, with five universities and a wide range of research institutes, shaping Stockholm's profile in science, innovation and sustainability (Stockholm university n.d., Adem Esmail et al. 2022).

3.3.2 Uppsala

Uppsala as one of Sweden's oldest cities is located around 60 km north of the capital. With 230,000 residents Uppsala is the fourth largest and one of the fastest growing cities in Sweden (Statistika centralbyrån 2026). By 2050, a population increase of approximately 100,000 inhabitants is expected. Despite the high rate of construction to accommodate its growing population, the city places strong

emphasis on sustainable development and preservation of the natural environment (Uppsala kommun 2021). The municipality is characterized by a mixture of parks, forests, meadows, watercourses and agriculture, accounting for approximately 56 % (Husqvarna n.d.; Uppsala kommun 2026a). Biodiversity protection is promoted by measures such as the selection of pollinator friendly plants, the creation of diverse microhabitats in green spaces and extensive management practices (Uppsala kommun n.d. a, b). Additionally, the municipality is working to strengthen wildlife corridors, increase the tree cover and expand nature protection. Currently, about 21% of the city's area is covered by nature reserves, with more than 50 areas in total (Uppsala kommun 2021, 2026a).
Uppsala was repeatedly awarded as Sweden's Climate City and acknowledged as World Climate City by the World Wide Fund for Nature in 2018 (Uppsala kommun 2021). Uppsala is influenced by its two universities, Uppsala University (UU), Sweden´s oldest university, and the Swedish University of Agricultural Sciences (SLU), which are both known for their focus on life and environmental sciences (SLU n.d., UU n.d.) and for their links to knowledge-intensive industries (Uppsala kommun 2021, Euro Cities n.d. c).

3.3.3 Cologne

With around one million residents, Cologne is the fourth-largest city in Germany and is located in the federal state of North Rhine-Westfalia (Statistisches Bundesamt 2026). The city has a highly diverse urban landscape. Roughly half of the municipal area is built-up, while forests cover around 18 % and agricultural land accounts for 16 %. Parks and other green spaces make up about 10 % and lakes together with the Rhine River represent approximately 5 % (Statista 2026). In addition, Cologne contains 22 designated nature reserves, which account for 8.4 % of the city's territory (LANUK 2025). At the same time, Cologne faces challenges that are typical for many growing cities. The increasing demand for housing has intensified land-use competition, making it more challenging to balance urban development with environmental protection (City of Cologne 2023). In response, the city increasingly focuses on sustainability and climate adaptation, particularly in areas such as urban planning, mobility and energy. Goals include climate neutrality by 2035 and strengthening urban biodiversity through measures such as creating wildflower meadows, expanding green spaces, planting additional city trees and improving ecological connectivity across the city (City of Cologne 2020, 2023).
Cologne also has been awarded the gold status of the "StadtGrün naturnah[1]" label, which recognizes municipalities for environmentally friendly green space management (Kommunen für biologische Vielfalt n.d. a). Beyond its environmental

[1] eng.: nature-oriented urban green spaces

initiatives, Cologne is also one of Germany´s major university cities. Around 100.000 students are enrolled across 31 universities and research institutions, contributing to a strong academic and innovation landscape (City of Cologne n.d.). As a result, Cologne has become an important centre for research and international exchange (Köln Business n.d., Euro Cities n.d. a).

3.3.4 Bielefeld

Bielefeld is a medium-sized city in North Rhine-Westfalia with around 330.000 inhabitants (Statistisches Bundesamt 2026). The city is characterized by a relatively high share of green spaces. Around 45 % of city's area consists of urban infrastructure, while more than half is vegetated area (Stadt Bielefeld 2022). The Teutoburg Forest, which accounts for approximately 20 %, stretches through the city and plays a central role in both recreation and biodiversity conservation (Stadt Bielefeld n.d. a). The city contains 39 nature reserves, covering around 8 % of its territory (Stadt Bielefeld n.d. b). Even though Bielefeld is facing ongoing population growth and housing demand (IT.NRW 2024), the city aims to become climate neutral by 2030. Current measures focus on green mobility, renewable energy, heating and the protection and restoration of local ecosystems and biodiversity (Stadt Bielefeld 2021, 2024). For measures like using native plants, adjusting mowing cycles or reduced herbicide use, Bielefeld is also awarded the golden status of the "StadtGrün naturnah" label (Kommunen für biologische Vielfalt n.d. b).
Beyond its environmental profile, Bielefeld is also an important university city. Several higher education institutions with strong interdisciplinary research are strengthening Bielefeld´s role as a regional academic centre (Bielefeld University n.d., Stadt Bielefeld c n.d.).

3.4 Document analysis

To gain a comprehensive overview of how the selected cities use CS data and to provide a foundation for further evaluation, a document analysis was performed (Bowen 2009). Therefore, an online research to identify local CS projects related to urban biodiversity monitoring and conservation was conducted. This was based on city websites, policy documents, institutional reports, university websites and other associated media sources (Chand 2025). An overview of the policy documents is provided (see Appendix Table 5). The search was conducted from January to April 2026 using Google Scholar and the Google search engine, complemented by targeted searches on municipal and institutional websites (Stansfield et al. 2016). Keywords such as *citizen science, public engagement, biodiversity, biological diversity, sustainability* and *participation* were used in English, as well as retrospectively in Swedish and German to discover further relevant information (MacDonald et al. 2024). On city websites all search results per keyword were screened and additional relevant references were identified through snowballing (Wohlin 2014). In this study, CS projects are understood as initiatives that involve active participation by the public in the collection of biodiversity data. Projects were considered relevant if they provide accessible data and are potentially useful for municipalities. Whereas purely educational initiatives without a data collection component, as well as phenological and other ecological projects not directly related to biodiversity were excluded to maintain a clear focus on biodiversity monitoring.

To complement the analysis of local projects, additional online research was carried out to identify relevant CS platforms and initiatives at the international and national scale. Using the keywords *CS landscape, infrastructure, database*, *projects, initiatives, platforms, portals* connected to *biodiversity monitoring* and *global*, *Sweden* or *Germany*. The search process was iterative, moving from one website to another, where relevant platforms and references were followed. Only those initiatives were considered, that collect or aggregate species observations with the help of citizens and are currently operating. Considering these levels is particularly important, as municipalities often rely not only on data generated through local projects, but also on observations that are provided by more established national and international open access biodiversity platforms (Liu et al. 2021). This broader perspective helps to capture the full range of CS data available beyond the local level, as well as to better understand how CS is organised within the two countries (Haklay 2015).
This approach provides only limited insights in how CS data is actually applied by municipalities in practice. To address these constraints and gain a deeper understanding, interviews were conducted (Tisdell et al. 2025). Using multiple methods to examine the same phenomenon from different perspectives, a so-called triangulation approach, helps to provide a more comprehensive overview of how CS is used (Bans-Akutey & Tiimub 2021; Morgan 2022).

3.5 Interviews

To complement the findings of the document analysis and to increase validity (Noble & Heale 2019), interviews were conducted. They are an effective tool for accessing information that would otherwise been hidden (Belina 2023). For this study, semi-structured interviews were chosen, as they combine structure and flexibility (Young et al. 2018). An interview guide with open-ended questions was developed to structure the conversation and ensure comparability across all conversations. It was based on the research questions, conceptual background and insights from the document analysis, including city-specific projects and strategies. Priority questions were identified in case of time constraints. The guide was developed in an iterative way and revised throughout the research process and particularly after the first interview (Kallio et al. 2016; Abraham & Padmakumari 2026). The final version included sections on (1) background of the interviewee, followed by (2) broader questions on the use of CS in the city, including purpose, prioritization, challenges and potential, before going further into detail on (3) city-specific approaches (see Appendix 9.1). The semi-structured format allows follow up questions to clarify responses and to discuss emerging topics, supporting a natural conversation flow (Mueller & Segal 2015; Ruslin et al. 2022). Given the diverse approaches, practices and projects related to the use of CS for biodiversity conservation across the cities, this flexibility was essential for capturing differences.

The interview partners were municipal representatives with expertise in biodiversity strategies and experience in the implementation and coordination of CS. Potential participants were identified through city websites and contacted via email. In most cases, the head of the environmental department was approached and asked to nominate the most suitable person for the interview. In other cases, individuals who were publicly listed as person in charge of specific CS projects were contacted directly. This approach ensured that interviewees had relevant knowledge and practical experience in that field. All interviews were conducted with consent and personal data was anonymized throughout interview notes, transcripts and the final work. In the Swedish cities, the interviews were conducted in English, while those in Cologne and Bielefeld were carried out in German.
The interviews were conducted in late March and early April of 2026 either via video conference or by telephone and had a duration ranging from 35 to 70 minutes (see Table 1). To ensure a comprehensive and accurate analysis all interviews were recorded with the participants´ consent and transcribed into written text manually.

Table 1. Summary of conducted interviews by city, including the interviewees role, date, communication channel and duration.

City	Interviewee roles	Date	Communication channel	Duration [min]
Stockholm	Environmental and health administration, ecologist	27.03.2026	Zoom	50
Uppsala	Forest and nature conservation	26.03.2026	MS Teams	35
Cologne	Species conservation, biologist	08.04.2026	Telephone	70
Bielefeld	Species conservation	02.04.2026	Telephone	40

3.6 Reflexive Thematic Analysis

Building on the gathered interview data, the material was systematically analysed using reflexive thematic analysis developed by Braun and Clark (2006). It is a widespread qualitative research method to identify, analyse and report patterns within data. This approach is particularly suitable given the explanatory nature of the research study, offering a high degree of flexibility and adaption (Braun & Clarke 2023). The analysis follows six phases in an iterative process (see Table 2). First, the researcher familiarised themselves with the data by repeated listening to the recordings and active reading of the transcripts. Second, initial codes are generated, before they are summarized in themes related to the research question, which are "patterned response[s] or meaning within a dataset" (Braun & Clarke 2006). In the fourth step these themes are reviewed, afterwards defined and named. The last step is the production of the report, in this case the thesis. This process is iterative, involving continuous changes between codes and themes (Braun & Clarke 2006). An example of the coding process is provided (see Appendix Table 6).

Table 2. Procedure for reflexive thematic analysis according to Braun and Clark (2006).

Step 1	Familiarization
Step 2	Coding
Step 3	Generation of themes
Step 4	Reviewing themes
Step 5	Defining and naming themes
Step 6	Report writing

For this study, a primarily deductive approach with inductive, data-driven elements was applied. The analysis was guided by the main topics of the questionnaire, which directed attention to certain areas of interest. Additionally, the coding process remained flexible, allowing for the identification of unexpected patterns and insights, emerging from the data. This hybrid approach made it possible to capture context specific municipal perspectives while keeping the analysis focused on the predetermined topics of the questionnaire and aligned with the research questions (Fereday & Muir-Cochrane 2006; Proudfoot 2023). At the same time, this approach acknowledges that the researcher plays a crucial role in the analysis by actively creating themes based on their personal assumptions and perspectives. As preconceptions can never be avoided completely, strong emphasis is placed on personal reflection. Because of this subjectivity, Braun and Clark (2019) emphasize the researchers reflexivity and critical engagement throughout the analysis process.

4. Results

A selection of global, European and country-level CS initiatives are presented to provide a context of the CS landscape. Additionally, the analysis of the documents and semi-structured interviews has revealed a number of themes, including institutionalization, selective nature, biases and potential of CS.

4.1 Global, European and country-level citizen science projects

This overview contains a selection of examples and does not claim to be exhaustive. The CS landscape is illustrated below (see Figure 1).

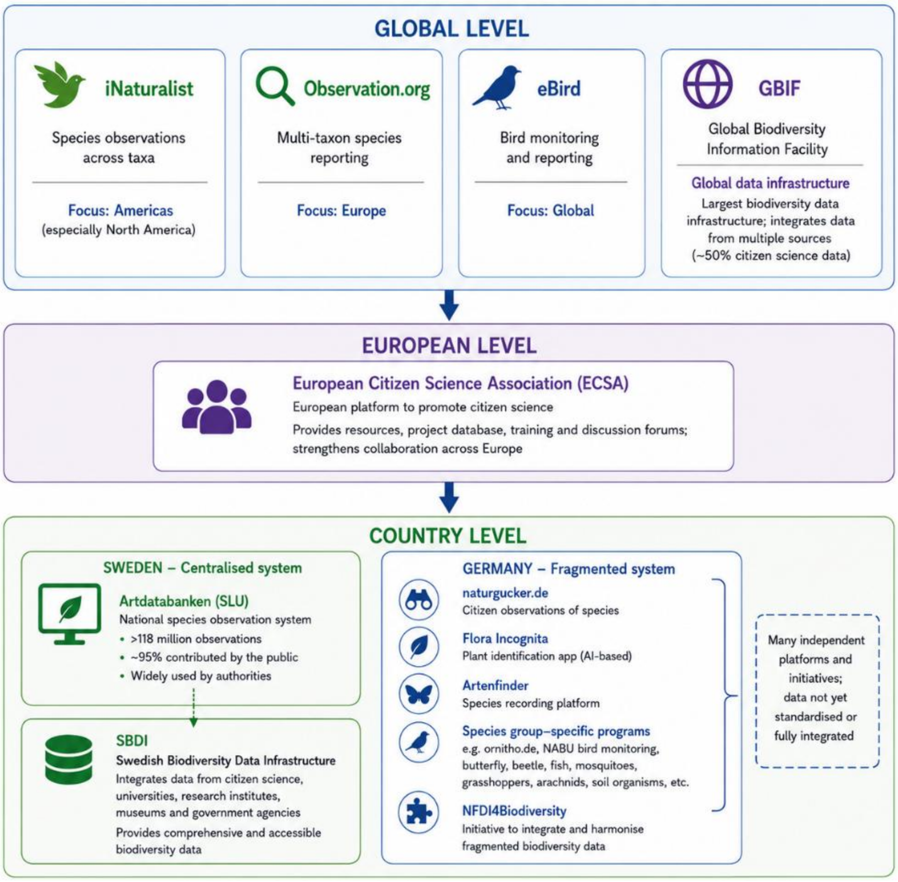

Figure 1. Overview of the CS platform landscape in the biodiversity context across global, European and country scales, highlighting key platforms and data infrastructures as well as the differences between the centralized Swedish and fragmented German systems. Source: AI generated on the basis of the descriptions above.

At the global level, several CS biodiversity platforms play a crucial role in data collection. Platforms such as iNaturalist or observation.org are designed to record a wide range of species, whereas eBird is specialized on birds (Della Rocca et al. 2024). The collected observations are additionally increasingly aggregated in global biodiversity databases, making observations openly and easily accessible for research and management. For instance, the Global Biodiversity Information Facility (GBIF) provides comprehensive biodiversity data from multiple sources, uniting the scattered biodiversity data landscape. Established in 2001, it is the largest international data infrastructure (Garcia-Rosello et al. 2023) and includes around 3.6 billion data references (accessed in March 2026, GBIF 2026 a, n.d. b). GBIF combines biodiversity data from research institutions, museums, monitoring programs and CS data. The latter already accounts for approximately half of the records (GBIF n.d. a). Additionally, the European Citizen Science Association (ECSA) launched the European citizen science platform (ecs) in 2020 to promote connectivity and collaboration within the CS community across Europe. The platform gathers educational materials and publications, gives information about ongoing multidisciplinary projects and provides discussion forums for exchange. Overall, it aims to strengthen and expand the use of CS, while raising awareness and supporting its wider adoption (esc n.d.).

In Sweden, the CS landscape is characterized by a highly centralized system, with Artportalen functioning as the main platform for biodiversity data reporting. Operating since 2000 (SLU 2025a), it is the national species observation system and one of the largest national CS platforms worldwide, containing more than 118 million observations of plants, animals and fungi. The contribution of researchers and professionals accounts for approximately 5% of the data, while the vast majority is generated by the public (SBDI 2023, Jönsson et al. 2024). The operator SLU states that Artportalen is widely used by governmental agencies and is of great importance for environmental monitoring, planning and informed decision-making (SLU 2025b, Kasperowski & Hagen 2022). Other biodiversity related CS initiatives exist, such as the Swedish bird survey or butterfly monitoring programs, but are also integrated into Artportalen (Lunds Universitet n.d., BirdLife Sweden n.d.). Furthermore, these datasets are included in the Swedish Biodiversity Data Infrastructure (SBDI), established in 2021. Alongside CS data, SBDI includes datasets from universities, research institutes, museums and government agencies. Combining these divers sources provides a comprehensive and open accessible overview of the biodiversity patterns and changes, enabling informed environmental planning and supporting conservation efforts (GBIF n.d. c).

In contrast to the Swedish system, Germany´s CS landscape for biodiversity is very fragmented. Numerous platforms exist, including larger, widely used ones such as

Artenfinder, Flora Incognita, mit:forschen.de and naturgucker.de, alongside specific programs for fish, beetles, butterflies, mosquitos, grasshoppers, arachnids or soil organisms and especially birds (e.g. ornitho.de, NABU Stunde der Gartenvögel/Wintervögel, DDA Rebhuhnmonitoring, etc.) (Engel u. a. 2024, GBIF n.d. d). While the platform NDFI4Biodiversity aims to unite them, challenges remain because many CS initiatives are developed for specific purposes, using different methods and maintaining separate databases. These inconsistent standards make it difficult to harmonize data (Hartl et al. 2021; NFDI4 Biodiversity n.d.; Weber et al. 2021).

4.2 Themes

4.2.1 Institutionalization of CS

All four selected cities use CS (see Table 3).
In the Swedish cities[2], CS is deeply embedded in biodiversity governance and functions as a knowledge infrastructure. In particular, the platform Artportalen plays a central role as an open access database for species observations and is described by Uppsala as its "main source" of biodiversity data. After filtering and validating, authorities use it on a daily basis to assess species occurrences, support planning procedures and management decisions and identify conservation priorities. A similar picture can be observed in Stockholm. Since the 1990s, the city has run its own local biodiversity database, Artarken, which initially focused on red-listed species but was gradually expanded to include more species as the need for a broader understanding of urban biodiversity grew. When Artportalen developed into a national platform, data from Artarken was integrated into Artportalen. Nowadays, Stockholm uses Artportalen as its primary data source and as a result, the local infrastructure will be taken down soon. Nevertheless, both systems serve as important knowledge infrastructures and are a "well used tool" (Stockholm representative) to support decision making and long term biodiversity management in Stockholm. Additionally, ecologists conducting professional monitoring across the city are encouraged to upload their observations to Artportalen, ensuring open access to biodiversity data.
Swedish cities do not only rely on CS data but on a combination of CS data with professional monitoring. While CS provides a broad spatial and temporal database, it is not considered sufficient for decision making, especially in the legal context. Instead, it serves as an entry point and is complemented and verified by expert field inventories. In this sense, Artportalen often functions as a source of clues, while professional monitoring provides the formal proof required for decision making.

[2] "Swedish cities/municipalities" or "Sweden" specifically refers to Stockholm and Uppsala. Likewise, "German cities/municipalities" or "Germany" specifically refers to Cologne and Bielefeld.

This hybrid approach is also evident in Uppsala's conservation planning. The city is home to Swedens biggest population of the threatened cinnabar beetle (Uppsala kommun 2024) and therefore carries a significant conservation responsibility. Sightings of the beetle in Artportalen are being verified by experts in order to identify suitable habitats that require further protection. The same applies to Uppsalas compensation practice, which requires a net biodiversity gain of 10 % following land-use changes affecting natural areas (Uppsala kommun 2026b). While expert inventories remain mandatory in the legal context, CS provides valuable long-term observations that help to track the development. It contributes to an extended spatial and temporal data collection, using the "power of many observers" (Stockholm representative). In Stockholm, CS data complement professional inventories, where a city-wide frog monitoring is combined with CS observations as it is impossible to examine "every square meter of a city", making each additional observation valuable for a more comprehensive understanding of urban biodiversity. Both Swedish interviewees emphasize, that "no organization […] has the power and resources to inventory so much as Artportalen offers" (Stockholm representative).

Whereas CS is deeply rooted in Sweden, in Germany it is less systematically integrated in biodiversity governance and remains more species-specific, project-based and historically grown. In Bielefeld, CS activities mainly focus on amphibians and building-nesting birds. During the spring migration, trained volunteers install temporary fences along roads and carry frogs and other species safely across the street. In that process, data on species, sex and number of individuals is collected, allowing long-term monitoring of population trends. These observations provide important insights for local planning and conservation measures, for example, by identifying specific locations where permanent constructions like wildlife tunnels would be needed. Also, a sudden drop of the population size can further indicate that the condition or even existence of spawning grounds has declined. This triggers further investigations and actions to restore these habitats. Furthermore, highly trusted partners such as the Nature and Biodiversity Conservation Union (NABU) are involved in species monitoring. In Bielefeld, volunteers collect data on bats and house martins, which become relevant, when a building is scheduled for demolition. The Biostation Paderborn-Senne also operates its own reporting platform, where observations are manually reviewed before publication, increasing data reliability (Biologische Station Kreis Paderborn – Senne 2026). According to the interviewee it delivers especially valuable data for groups such as "dragonflies and butterflies." All observations, generated by these trusted networks, are incorporated into the municipal mapping systems and used for official decisions and statements whereas observations from public CS platforms are only used occasionally. Ornitho.de is mainly considered to gather indications on building-nesting birds, for example by tracking their return in spring. However, the observations are usually opportunistic sightings. Since Bielefeld works on the breeding ground level, the data is of limited use for this purpose.

In Cologne, several projects are carried out with the help of citizen scientists. Citizens are encouraged to report fireflies, sparrowhawks, swallows, swifts and other building-nesting species through species-specific reporting forms on the website. The collected observations are integrated in mapping tools (Stadt Köln n.d. a, b), which are accessible on the city's website and function as hints for conservation measures. For example swallow observations are used to identify suitable locations for nesting aids. The nature conservation association also coordinates a reptile monitoring via the platform naturgucker.de, contributing to a inventory of local occurrences. Through this initiative, a ruin lizard was recorded for the first time in the region (NABU Stadtverband Köln 2025). Many of these projects also aim to raise awareness for urban biodiversity, the ecological importance of insects and the impacts of light pollution. Fireflies were used as flagship species as their charismatic nature makes them particularly well suited to engage public interest. CS observations also become relevant in planning and permitting procedures. Reports of species such as swallows or bats may influence demolition or renovation approvals, requiring mitigation or compensation measures to maintain the ecological functions. Nevertheless, interviewees of all cities repeatedly stressed that CS data "cannot replace formal ecological inventories" (Uppsala representative). Instead, it provides useful hints that guide further expert assessment, highlighting the hybrid character.

The differences between Sweden and Germany are also visible in relation to the 30*30 conservation target. Sweden uses CS data to identify biodiversity hotspots and to support the designation of protected areas. In Germany, the approach is more strongly based on long established landscape plans and existing municipal knowledge. Since many green areas have been managed consistently over time, there is generally less perceived need for additional CS data.

Despite its strong practical integration into daily administrative practice in Sweden, CS remains absent from formal policy documents. Only Stockholm's biodiversity strategy explicitly emphasizes collaboration with the public and the use of innovative methods, which include CS approaches (Stockholms stad 2024b). Interviewees from both Swedish cities described CS as tool embedded within broader governance processes and therefore not explicitly mentioned in frameworks. At the same time, they argue that CS "should be acknowledged more," (Stockholm representative) not only to recognize its contributions but also serving as kind of promotion, encouraging even greater public engagement, which could further improve data quality and coverage. In Germany, biodiversity strategies are currently still in the developing process. While Bielefeld's work is still at an early stage, Cologne expects participatory approaches to play a stronger role in the future, especially with a focus on environmental education and improving cooperation with private landowners to promote conservation activities on a small scale.

Another interesting aspect is the role of BioBlitz events. Even though all four cities participate in this challenge, the interviews indicate that these events currently only play a limited role in all four cities. Since BioBlitz events take place over a short period of time, the collected data are generally not used systematically for direct monitoring of urban biodiversity. However, unexpected or unusual sighting will be investigated further. Instead, BioBlitzes are primarily valued for their educational and awareness raising function. They encourage citizens to discover species together and promote a greater appreciation for biodiversity with the broader goal to indirectly foster more environmentally conscious behaviour. At the same time, interviewees emphasize that data collection during these events can become highly valuable in the long term, particularly for tracking changes in species distribution and abundance related to climate change. Generally, these events become increasingly popular as the rising numbers of participants over the years show. The events are usually organized by local natural history museums, environmental organizations or civil actors rather than by the municipalities. The role of local authorities is therefore often limited to promotion.

Table 3. Overview of CS initiatives in Stockholm, Uppsala, Cologne and Bielefeld. A short description and the data use and derived measures are included.

City	Description	Data use, derived measures
Stockholm		
Artarken and Artportalen	Local and national species observation database	Both used as starting points for planning (permit procedure) and ecological conservation, triggers professional inventories; complements city wide (frog) monitoring; identification of possible nature reserves
Uppsala		
Artportalen	National species observation database	Starting point for planning (permit procedure) and ecological conservation, triggers professional inventories; special focus on Cinnabar beetle with designation of protected areas; tracking of

		compensation measures; identification of possible nature reserves
Cologne		
Local reporting projects on website	Participatory species reporting with focus on fireflies, sparrowhawk, swallows, swift, sparrows and bats	Overview about populations and abundance; primarily raising awareness; conservation measures, supports placement of nesting aids, informs the permit procedure for demolition/renovation
NABU reptile monitoring	Citizens report reptiles on naturgucker platform	Comprehensive data, no measures
Bielefeld		
Amphibian monitoring	Data collection in spring migration	Track population dynamics, identifies locations for wildlife tunnels and road crossings and habitat restoration, if needed
Neobiota platform	Database of invasive species (federal state)	Removing of individuals, where eradication is possible or a safety hazard is evident
NABU bat and house martins monitoring	Data collection with the help of citizens	Hint in planning processes, informs permits for demolitions
Biostation Paderborn-Senne	Local CS platform	Complement data set
Ornitho.de	Bird reporting platform	Hints for return of swallows etc.
All		
Email, phone, website reportings	Hint on species occurrences	Triggers measures against invasive species and protection measures for endangered species, complementary data

4.2.2 Selective nature of CS data

Not all species groups, conservation statuses or invasive species are receiving equal attention by the municipalities.

Across all interviewed cities, there is a clear focus on endangered and legally protected species. At the same time, cities also include species that are not formally red-listed but are still considered “worthy of protection” (Stockholm representative)

due to their ecological importance. For example, the sparrow hawk in Stockholm is treated as species with special interest. Additionally, Stockholm includes all red listed species in their local database Artarken, but places particular emphasize on 20 species for which detailed fact sheets are available to support citizens in identifying them more easily. This list also includes species that are not threatened such as the crested tit, which serves as indicator species for fragmented coniferous forests (Stockholms stad n.d. b). In Uppsala, attention is strongly focused on the cinnabar beetle (Uppsala kommun 2024), while in Cologne and Bielefeld, the priority species include more charismatic ones, such as fireflies, like amphibians, building-nesting birds (house sparrow, jackdaw, common swift, swallow) and bats, which are historically grown or planning relevant species.
While all municipalities place strong emphasis on endangered and legally protected species, invasive species receive comparatively less attention. However, a change can be observed. Both Swedish cities report an increased use of Artportalen to monitor invasive species based on citizen generated data over the last few years. The two German cities rely on a more diverse mix of data sources, including emails, phone calls and personal communication invasive species reporting. In addition, Bielefeld works with the Neobiota Platform provided by the environmental agency of North Rhine-Westfalia to track observations (LANUK n.d.). These observations are actively followed up by the authorities, who assess each case and initiate appropriate measures. Where feasible, eradication is carried out either by the municipality or designated personnel, particularly for species listed under Article 16 of the EU Invasive Alien Species Regulation. However, for species that are already widely established, management efforts focus on preventing further spread and minimizing additional negative impacts.

CS platforms are generally designed as open access infrastructures, allowing both authorities and the public to access biodiversity data. However, not all species observations are shown openly. In Artportalen, the public only has access to a restricted dataset, containing around 93% of all observations. The hidden data contains sensitive species, including those at high risk of exploitation or poaching, such as birds of prey or orchids. Access to those observations is therefore limited and requires special permission (GBIF 2026b). In Stockholm three employes within the municipality have access to these sensitive data, whereas no such access exists in Uppsala. Also, CS platforms used by the German cities apply similar data protection measures for sensitive species to reduce the risk of disturbances and threats. For example, on iNaturalist and ornitho.de, locations of vulnerable species are not publicly visible and only accessible for users with extended rights (iNaturalist 2026, ornitho n.d.). In the way, the Biostation Paderborn-Senne conceals certain locations on the website (Biologische Station Kreis Paderborn – Senne 2026), while still providing full data to the municipality.

4.2.3 CS biases

While CS provides valuable data for biodiversity governance, several biases were highlighted by all interviewed municipalities. First, there is spatial bias. Observations are concentrated in easily accessible areas, such as hiking trails, parking lots and nature reserves. Consequently, large parts of the landscape remain underrepresented. Second, a taxonomic bias is evident. Certain species groups, especially birds and plants, are well documented, whereas others such as insects or fungi are often underrepresented. Third, most platforms work in an unsystematic and opportunistic way and therefore are highly influenced by personal interest and expertise as well as by the local focus and activities of NGOs. Enthusiasts or NGOs focusing on specific taxa can create local concentrations of data, while other groups remain underrepresented. Beyond that, all interviewed cities point out general limitations of CS, such as the species misidentification, inaccurate localization or the lack of absence data. The latter is especially considered problematic, as all of the platforms only collect presence data. Consequently, the absence of observations does not necessarily indicate that a species is not existent in an area, but rather that "it has not been observed or looked for" (Stockholm representative).

4.2.4 Perceived value and potential

All interviewed city representatives acknowledge that CS is not free from biases and are aware of its limitations. Nevertheless, they see strong potential in the use of CS, particularly because of its ability to generate large biodiversity datasets across broad spatial and temporal scales in a cost efficient way. Both Swedish cities emphasize that "no organization has the resources and capacity to collect as many observations as platforms such as Artportalen" (Uppsala representative) are able to provide. The German cities also observed a growing public interest in CS, with steadily increasing participation. As a result, they expect these datasets "to become more relevant in the future" (Cologne representative), especially as indicator tool for invasive species and climate change, since they can support early detection of shifts in species distribution and phenological changes. At the same time, all interviewees stressed that CS data needs to be interpreted carefully. Ecological expertise is needed to evaluate the observations and detect possible misidentifications. As a result CS is mainly used as complementary data source and "cannot replace professional field inventories" (Stockholm representative), especially when legal requirements or formal planning decisions are involved.

5. Discussion

In the following the main findings are discussed in relation to the research questions. It first explores the institutionalization and selective nature of CS, before addressing biases and limitations as well as the perceived value and potential. This is followed by the study's contribution, methodological limitations and suggestions for future research before concluding the thesis.

5.1 Institutionalization of CS

All four case study cities use CS in biodiversity management, although the degree and form of integration into municipal structures and everyday practice differs. The strongest contrast can be observed between Sweden and Germany, while cities within each country show relatively similar patterns.

Overall, CS primarily supports biodiversity monitoring, environmental awareness raising, conservation and urban planning. In particular, municipalities use CS generated observations to map the local occurrences of endangered and protected species, detect invasive alien species, monitor population trends and support planning decisions. The results support previous studies, that suggest that CS has the potential to contribute to local biodiversity knowledge and to strengthen administrative work (Callaghan et al. 2020b; Cappa et al. 2022).

The findings suggest that CS is more embedded in biodiversity governance in Sweden than it is in Germany. Sweden integrates CS systematically in everyday practices, supported by the centralized platform Artportalen, which enables easy access to biodiversity data in one place. The integration of professionally collected data further strengthens the role of the platform as a routine administrative tool and highlights its standing in Sweden. In contrast, Germany´s CS landscape is highly fragmented with data distributed across multiple platforms and projects. While this fragmentation can also have advantages, such as generating more specialized and potentially robust data for particular species groups, it also complicates data accessibility and integration into administrative work (Johnston et al. 2023). As a result, CS is used more selectively, often within city-specific or project-based contexts and mostly in cooperation with highly trusted partners.

Although centralized infrastructures such as GBIF or the NDFI4Biodiversity already improve access to biodiversity data, their use in governance is still limited. One reason is the difficulty of harmonizing data in Germany in particular, due to the large number of different projects and inconsistent data standardization (Hartl et al. 2021; Engel et al. 2024; Weber et al. 2021). As a result, the database does not include the full range of data yet. Additionally, German authorities remain skeptical about using CS data because of concerns about data quality, representativeness and legal accountability (Jäckel et al. 2023). Nevertheless, centralized databases have the potential to become an useful tool to have all the data aggregated in one place and make CS a valuable complementary data source (Engel et al. 2024). Developing clearer guidelines for how CS data should be formally integrated into decision-making could further support the integration of CS data and increasing its trustworthiness (Hecker et al. 2018; Turbé et al. 2020; Voigt-Heucke et al. 2023). To further realize this potential especially in Germany, future efforts should focus on improving data standardization and strengthening quality assurance. In addition, awareness of existing databases needs to be increased as many authorities are still unfamiliar with the available infrastructures and their potential applications (Bowser et al. 2020).

At the same time, CS is not used as a replacement for professional ecological monitoring, but rather as a complementary approach. In practice, CS data often serves as an entry point or hint, to identify potentially relevant areas or species, while professional surveys remain mandatory for legal obligations and formal planning procedures. The potential of this hybrid approach is well discussed in the literature. Combining both data sources therefore provides the best of both worlds. CS delivers a broad spatial and temporal coverage as well as large volumes of data, whereas expert monitoring ensures reliability (Cuervo-Robayo et al. 2026). Together, they enable more complete datasets and support real-time monitoring of rapidly changing environments (Callaghan et al. 2020b; Feldman et al. 2021; Fraisl et al. 2022; Habel et al. 2025; Cuervo-Robayo et al. 2026).

Overall, this demonstrates that CS is deeply integrated into biodiversity governance, particularly in Swedish municipalities, while its role in Germany remains more limited. Despite its growing importance as supplementary data, the risk of overreliance must be considered. Given that a large share of global biodiversity data is already collected by volunteers (Kelling et al. 2019) and as the reliability increases while being a cost free tool (Machado Toffolo et al. 2026), the temptation to rely more heavily on CS is likely to grow. Nevertheless, CS data cannot replace expert data and should remain in an advisory and complementary role, rather than serving as primary data source for decision making (König et al. 2021), which is repeatedly stressed by all municipalities participating in the study. In the cases of Uppsala, Stockholm, Bielefeld and Cologne, the risk of overreliance on CS data cannot be observed as all cities, critically assess it, only use it as hints and remain very aware of its limitations. Maintaining professional monitoring and not stepping back from legal reporting obligations will therefore remain crucial in the future.

Interestingly, despite the practical integration in both countries, CS remains relatively invisible in formal policy documents. The Swedish municipalities perceive CS as a routine tool within monitoring and planning processes, rather than as an explicit objective. This suggests that CS may already be seen as part of the daily business of biodiversity governance. Therefore, it has an essential role, but is not highlighted in policy frameworks.

While cities in Sweden place strong trust in an environmentally conscious public and the well established Artportalen infrastructure (Kasperowski & Hagen 2022), German cities tend to emphasize the value of CS as a tool for raising awareness about biodiversity. The city of Cologne aims to collect biodiversity observations not only from public areas but also from private spaces such as gardens. This enables the collection of data from locations that would otherwise be difficult or impossible to access. This is especially relevant because urban private gardens form an essential part of urban green infrastructure and contribute to ecological connectivity in cities as stepping stones (De Martino et al. 2023). Additionally, this allows a better understanding of the role of private spaces for urban biodiversity (Callaghan et al. 2020b). However, the ecological value strongly depends on garden size, design and management. Beyond that, it creates the opportunity to indirectly influence homeowners by encouraging more environmentally conscious behaviour and promote biodiversity-friendly gardening practices, which ultimately benefits both ecosystems and residents (Persson et al. 2023; Palma et al. 2024; Stanford et al. 2024). Whether and how effective such indirect influence really is, remains to be researched further (Hanson et al. 2021; Elizalde & Lambertucci 2022).

This awareness raising effect of CS is also reflected in the BioBlitz events. Although the collected observations are currently only of limited importance in urban planning, they play a highly valuable role in encouraging public participation. The short-term commitment and gamified character of BioBlitzes lower the threshold in engaging in biodiversity monitoring and make participation more accessible and enjoyable (Meeus et al. 2023; Hoskins et al. 2026). These events often spark curiosity and can motivate participants to continue recording observations. In fact, the recording activity remains at a higher level than prior to a BioBlitz (Meeus et al. 2023; Palma et al. 2024). A significant contribution can be attributed to the gamification, as the “thrill of discovery” (Kc & Sapkota 2024, p. 11) motivates people to expand their species list and generally encourages interest in biodiversity. Research shows that participation in CS concerning biodiversity often resulted in increased awareness of species, diversity and threats in the region, which is leading to a change in behaviour or attitude in participants. They often started to share their experiences, encourage family and friends and adopt more environmentally and biodiversity supporting practices in their gardens (Parker et al. 2018; Peter et al. 2019; 2021). Therefore, CS can have a big impact on the public and be a substantial key factor in protecting biodiversity.

5.2 Selective nature of CS data

Every day, thousands of new observations are reported through CS platforms. Given this large amount of data, municipalities cannot consider all species equally in planning and conservation processes. Therefore, all interviewed cities mainly focus on endangered and legally protected species. This prioritization is important because biodiversity is fundamental for ecosystem functionality and resilience. The loss of threatened species can disrupt ecological interactions and weakens ecosystem stability, making their protection especially urgent (Hooper et al. 2012; Hong et al. 2022). At the same time, with currently more than 10.000 species red listed in Europe (European Commission 2026), municipalities must make practical decisions as their resources are limited. As a result, authorities put special emphasize on species that are legally protected under the Habitats Directive (European Commission 1992) as well as species that are of local relevance and of historically grown importance.

Although conservation efforts mainly target endangered species, CS data can also be a highly valuable tool for detecting newly arriving alien species early, which is critical for effective control or eradication and the protection of native ecosystems. Because large numbers of citizens continuously collect observations across wide areas, newly spreading species are often spotted earlier than through professional monitoring (Mata et al. 2021; Baudino et al. 2026). This broad and close to real time coverage not only enables faster responses by authorities to implement appropriate measures but also for evaluating the success of IAS management (Pocock et al. 2024). In this way, CS directly supports compliance with the EU Regulation 1143/2014, which requires member states to take action at an early stage when eradication is still possible (EU Parliament and Council 2014). As the spread of IAS accelerates due to a highly connected world and further reinforced by climate change, the need for large scale, affordable monitoring systems becomes evident with CS offering the potential to address this challenge (Pyšek et al. 2020; Montagnani et al. 2026). Integrating fact sheets on IAS, including their characteristics and explanations of why reporting and removing them is important, can strengthen the municipalities management. In New Zealand, a campaign tested the use of fact sheets to support IAS reporting and raise public awareness. It increased surveillance capacity and led to more observations, thereby strengthening IAS management (Pocock et al. 2024). This example shows how simple tools can improve the impact of CS. Building on this, similar approaches could be implemented in other countries or integrated in CS platforms. One possible way would be to send notifications that encourage users to watch out for certain species. However, for these measures to be effective, clear priorities are essential. The main focus should be on acute cases, such as species that pose a safety hazard to people or newly arriving species, where an early detection still allows effective eradication.

The Neobiota platform on the level of the federal state of North Rhine-Westfalia is again an example of the fragmentation in Germany. A nation-wide, more centralized platform could help address the issue of invasive species on a broader scale and raise greater awareness (Johnson et al. 2020).

The handling of sensitive species in CS platforms reflects tensions between transparency and protection (De Sherbinin et al. 2021; Quinn 2021). While restricting species locations limits public access, it is essential for safeguarding sensitive species from disturbance and poaching (Pernat et al. 2024). At the same time, full data access is crucial for authorities to properly evaluate biodiversity and implement effective conservation measures (Kindsvater et al. 2018). Therefore, it is beneficial that each municipality has at least one person with access to sensitive species data to have access to additional, complementary data.
Overall, this suggests that CS is not a neutral representation of the ecological reality and does not provide a complete species list of an area.

5.3 CS biases

CS offers valuable data for informed decision making (Deacon et al. 2023), but several important limitations are acknowledged by all of the interviewed cities. A major issue is the observer related bias, as observations strongly depend on interest, motivation and skill of the participants. Highly active observers can influence local datasets heavily, which makes it difficult to determine whether increased reportings correlate with actual ecological trends in an area (Johnston et al. 2023). Another factor, that neither of the interviewees mentioned, is the unequal participation in CS projects. Participants are often male, middle-aged or older, from higher income households and have a scientific background (Pateman et al. 2021; Strasser et al. 2023b). To ensure broader societal representation, efforts are needed to recruit underrepresented groups, particularly younger generations. For example through targeted social media campaigns and introducing CS in school. In this way, participation becomes more accessible and can support more environmentally conscious citizens (Herodotou et al. 2022).

The unstructured nature of most CS platforms results in uneven samplings. CS shows higher activity on weekends and during favourable weather conditions (Rosário et al. 2025). At the same time, observations are typically concentrated around easily accessible areas, especially urban environments and trails (Binley et al. 2023; Rocchini et al. 2023). This spatial imbalance limits the representativeness of CS data at larger scales, but can be highly valuable for urban biodiversity monitoring and therefore highly beneficial as complementary information for municipalities(Voigt-Heucke et al. 2023). Beyond that, taxonomic biases also occur. Participants tend to focus on species that are easy to detect and identify (Tiago et al. 2017; Di Cecco et al. 2021). Additionally, strong preferences for charismatic species have been observed (McKinley et al. 2017; Callaghan et al. 2020b). This can be particularly helpful for cities, as municipalities can use CS data to monitor specific species more closely and even develop targeted projects around them, which can be seen in both Cologne and Bielefeld. In this way it helps to raise awareness and public engagement.

Generally, citizen scientists provide reliable data for many taxa. Nevertheless, misidentifications cannot always be prohibited, especially when species are similar looking (Callaghan et al. 2017). Therefore, observations should be critically evaluated (Di Cecco et al. 2021; Gorleri & Areta 2022). In Germany, authorities collaborate with trusted partners and often request photographic evidence to support observations. Similarly, Sweden pays particular attention to unusual sightings, such as a toad that is not common in the specific region. To be able to evaluate CS data properly, strong ecological knowledge is required (Baker et al. 2021).

Overall, CS is shaped by human activity, knowledge and interest. As a result, CS data are affected by the observer, spatial and taxonomic bias and must therefore be critically interpreted. The selected cities are well aware of the limitations of CS data and mainly use them as hints or starting points for further investigations, rather than as proof. Authorities therefore remain cautious when working with CS data and treat it as complementary information that supports professional monitoring.

5.4 Perceived value and potential

Despite its limitations, CS is perceived as a valuable tool for biodiversity monitoring by all interviewees, which is in line with the literature (Callaghan et al. 2019; Fraisl et al. 2022). Through large numbers of participants, CS enables the collection of observations across unmatched broad spatial and temporal scales (Callaghan et al. 2020b), resulting in significant contributions to biodiversity monitoring. CS is accounting for more than half of the data collected in GBIF (Chandler et al. 2017; Cappa et al. 2022), for some taxonomic groups it is the biggest data source (Rosário et al. 2025) and has the capacity to generate as much data in two years as professionals over a decade (Troudet et al. 2017). The gamification of biodiversity data collection even further increases public engagement. Integrated leaderboards, a species of the day and species lists, which function as a catalogue of recorded species, are features that encourage citizens to contribute more actively (Callaghan et al. 2019). At the same time, technological developments further increase the potential and accessibility of CS. Growing digitalization enables easy reporting and quick identification, lowering the threshold for public participation (Fraisl et al. 2022). Especially advances in artificial intelligence (AI) simplifies species identification and supports the validation of observations. AI-supported tools may further improve the accuracy of reports (Abdul-Rahman et al. 2025), potentially increasing the trustworthiness and practical relevance of CS data for cities, which might encourages especially the Germany cities to adopt CS more into their daily work. Beyond these applications, AI can also be used internally by authorities to support the identification of relevant observations. It can detect patterns, identify outliers or particularly important observations, and highlight contributors with higher levels of reliability (McClure et al. 2020). For such tasks, AI is more efficient and accurate than humans (Auger et al. 2021; Sandfort et al. 2023), which makes it easier to gain an overview of large and complex datasets. As a result, CS may become even more valuable for urban biodiversity monitoring in the future.

5.5 Significance and contribution of the study

Earlier studies show that CS can play a valuable role in urban biodiversity monitoring by increasing the amount of available species data (Li et al. 2019). It helps to close taxonomical, spatial and temporal gaps and can support urban planning, green space management and the monitoring of invasive or endangered species (Callaghan et al. 2020a; Palma et al. 2024). However, it remained unclear how municipalities actually use CS data in decision-making and how they are translated into conservation measures.

This study explored CS approaches in four cities in Sweden and Germany and shows that CS data are already integrated into local biodiversity governance. In all cases, authorities use CS data to support concrete measures, including invasive species control and urban planning procedures, demonstrating that CS directly informs practical management decisions. The study therefore provides new insights into how cities integrate CS into biodiversity governance. It also improves the understanding of how CS can support urban biodiversity and better-informed decision-making, while creating the opportunity for cities to share and adapt effective practices from one another.

5.6 Constraints

Despite careful methodological considerations of the study design, several constraints should be acknowledged. The desk research was based on the review of city websites and related links with a set of key words. As some projects may not be publicly available, it cannot be ensured that all projects and relevant information were found. Additionally, translation inaccuracies of Swedish sources may have caused incomplete results. While interviews with city representatives were conducted to complement the desk research and to gain further insights into the use of CS for biodiversity monitoring, this approach also contains limitations. The quality of the interview data can be influenced by the interviewers´ skill and experience (Demirci 2024). In this study, limited interviewing experience may have affected the outcome. For the interviews conducted in Sweden, neither the interviewer nor the interviewee were using their native language, which potentially resulted in challenges in expressing and interpretation and may impacted the interviews´ depth and clarity (Young et al. 2018). Furthermore, the interview partners´ involvement in CS projects, their length of employment and willingness to share internal information varied, influencing the level of detail in the responses.

The most important constraint is the limited number of observed cities, so that the study might not be representative. Additionally, five other cities in Germany were contacted. However, no interviews were conducted because CS is currently not part of their practice, highlighting the skepticism towards CS in Germany. Therefore, Bielefeld and Cologne do not represent all German municipalities and are positive examples. Further research is needed to gain a more comprehensive understanding.

5.7 Suggestions for future research

Building on this study, future research could include more cities of different sizes and more countries, to better understand how local priorities, capacities and national frameworks influence the CS use. Beyond that, it would also be interesting, whether and how CS actually improves urban biodiversity management. Also, identifying best practices, that can be adopted in other cities would be highly beneficial. Data quality is another important aspect. Future work should focus on reducing bias and improving reliability. Possible starting points might be validation systems and exploring the potential of AI to support analysis and trust in CS data. Moreover, there is also a need for clear guidelines for the CS integration in cities. Although, organizations like the UN support CS integration (UNEP 2021; Hecker et al. 2018), there is no framework for cities to follow. Creating such guidance could make adoption easier and encourage more cities to integrate CS into their daily work, especially in Germany. Transnational networks such as Eurocities, C40 Cities: Climate Leadership Group or United Cities and Local Governments (Frantzeskaki et al. 2019) could support this process by sharing practical experiences und successful approaches. Finally, more attention should be placed on participants. Research should explore, who takes part, what motivates them and how participation influences their environmental awareness. This could help to engage citizens of all ages, genders and social backgrounds and make CS projects more inclusive and effective.

5.8 Conclusion

The study examined the role of CS in urban biodiversity management, focusing on how citizen-generated data are integrated into municipal planning and decision-making processes in Stockholm, Uppsala, Cologne and Bielefeld.

Across all cities, CS is used as a complementary data source for biodiversity monitoring, conservation planning, invasive species detection and raising awareness. In Sweden, CS is strongly institutionalized and systematically integrated into everyday governance through the centralized platform Artportalen. Whereas in Germany, CS platforms are more fragmented, often species-specific and project based, and mainly used in collaboration with trusted partners, with a strong connection to awareness raising. In none of the cities CS is embedded in formal policy frameworks, although all see clear potential for its use, especially in addressing invasive species and climate change impacts.

However, CS data always requires careful interpretation. The integration of AI offers promising potential to improve data quality and reduce bias. Paired with clear guidelines for data collection and use, this could significantly strengthen trust in CS data, particularly in Germany, where transparency and reliability are central to public and institutional acceptance.

Overall, the study suggests, that CS is becoming an increasingly valuable resource for urban biodiversity governance, that combines large-scale data collection with public engagement. Used alongside professional monitoring and with awareness of its limitations, it can support better-informed decisions and contribute to more sustainable and resilient cities, that support the long-term provision of ES and human well-being.

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7. AI Statement

In this thesis I used generative AI (OpenAI, GPT 5.4) for text refinements, to improve the grammar and help with sentence structure. I did not use the outputs directly, but carefully reviewed them and edited these suggestions to improve the flow of the text. All ideas are my own. In figure 1, I used AI to generate the figure based on the written text of chapter 4.1 with the following prompt: Generate a graphic, showing the CS landscape on a global, European and national scale. Use this as the foundation (see chapter 4.1). After that minor adjustments were made.

8. References

Abdul-Rahman, G., Zwitter, A. & Haleem, N. (2025). A systematic literature review on the role of artificial intelligence in citizen science. *Discover Artificial Intelligence*, 5 (1), 165. https://doi.org/10.1007/s44163-025-00437-z

Abraham, D.M. & Padmakumari, P. (2026). Developing qualitative interview guides: A methodological framework for novice researchers. *Nurse Education Today*, 163, 107116. https://doi.org/10.1016/j.nedt.2026.107116

Adem Esmail, B., Cortinovis, C., Suleiman, L., Albert, C., Geneletti, D. & Mörtberg, U. (2022). Greening cities through urban planning: A literature review on the uptake of concepts and methods in Stockholm. *Urban Forestry & Urban Greening*, 72, 127584. https://doi.org/10.1016/j.ufug.2022.127584

Affinito, F., Williams, J.M., Campbell, J.E., Londono, M.C. & Gonzalez, A. (2024). Progress in developing and operationalizing the Monitoring Framework of the Global Biodiversity Framework. *Nature Ecology & Evolution*, 8 (12), 2163–2171. https://doi.org/10.1038/s41559-024-02566-7

Anhalt-Depies, C., Stenglein, J.L., Zuckerberg, B., Townsend, P.A. & Rissman, A.R. (2019). Tradeoffs and tools for data quality, privacy, transparency, and trust in citizen science. *Biological Conservation*, 238, 108195. https://doi.org/10.1016/j.biocon.2019.108195

Auger, S.D., Jacobs, B.M., Dobson, R., Marshall, C.R. & Noyce, A.J. (2021). Big data, machine learning and artificial intelligence: a neurologist's guide. *Practical Neurology*, 21 (1), 4–11. https://doi.org/10.1136/practneurol-2020-002688

Backstrom, L.J., Callaghan, C.T., Leseberg, N.P., Sanderson, C., Fuller, R.A. & Watson, J.E.M. (2024). Assessing adequacy of citizen science datasets for biodiversity monitoring. *Ecology and Evolution*, 14 (2), e10857. https://doi.org/10.1002/ece3.10857

Baker, E., Drury, J.P., Judge, J., Roy, D.B., Smith, G.C. & Stephens, P.A. (2021). The Verification of Ecological Citizen Science Data: Current Approaches and Future Possibilities. *Citizen Science: Theory and Practice*, 6 (1), 12. https://doi.org/10.5334/cstp.351

Bans-Akutey, A. & Tiimub, B.M. (2021). Triangulation in Research. *Academia Letters*,. https://doi.org/10.20935/AL3392

Baudino, F., Ripa, R.R., Franzese, J. & Werenkraut, V. (2026). Using citizen science as a research prioritization tool to detect co-occurrences of the invasive species *Harmonia axyridis*. *Insect Conservation and Diversity*, 19 (2), 452–459. https://doi.org/10.1111/icad.70029

Belina, A. (2023). Semi-structured interviewing as a tool for understanding informal civil society. *Voluntary Sector Review*, 14 (2), 331–347. https://doi.org/10.1332/204080522X16454629995872

Bibri, S.E. & Krogstie, J. (2020). Smart Eco-City Strategies and Solutions for Sustainability: The Cases of Royal Seaport, Stockholm, and Western Harbor, Malmö, Sweden. *Urban Science*, 4 (1), 11. https://doi.org/10.3390/urbansci4010011

Binley, A.D., Vincent, J.G., Rytwinski, T., Proctor, C.A., Urness, E.S., Davis, S.A., Soroye, P. & Bennett, J.R. (2023). Patterns of community science data use in peer-reviewed research on biodiversity. *Biological Conservation*, 280, 109985. https://doi.org/10.1016/j.biocon.2023.109985

Bonney, R. (2021). Expanding the Impact of Citizen Science. *BioScience*, 71 (5), 448–451. https://doi.org/10.1093/biosci/biab041

Bowen, G.A. (2009). Document Analysis as a Qualitative Research Method. *Qualitative Research Journal*, 9 (2), 27–40. https://doi.org/10.3316/QRJ0902027

Bowser, A., Cooper, C., De Sherbinin, A., Wiggins, A., Brenton, P., Chuang, T.-R., Faustman, E., Haklay, M. (Muki) & Meloche, M. (2020). Still in Need of Norms: The State of the Data in Citizen Science. *Citizen Science: Theory and Practice*, 5 (1), 18. https://doi.org/10.5334/cstp.303

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3 (2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Braun, V. & Clarke, V. (2023). Toward good practice in thematic analysis: Avoiding common problems and be(com)ing a *knowing* researcher. *International Journal of Transgender Health*, 24 (1), 1–6. https://doi.org/10.1080/26895269.2022.2129597

Callaghan, C.T., Lyons, M.B., Martin, J.M., Major, R.E. & Kingsford, R.T. (2017). Assessing the reliability of avian biodiversity measures of urban greenspaces using eBird citizen science data. *Avian Conservation and Ecology*, 12 (2), art12. https://doi.org/10.5751/ACE-01104-120212

Callaghan, C.T., Ozeroff, I., Hitchcock, C. & Chandler, M. (2020a). Capitalizing on opportunistic citizen science data to monitor urban biodiversity: A multi-taxa framework. *Biological Conservation*, 251, 108753. https://doi.org/10.1016/j.biocon.2020.108753

Callaghan, C.T., Poore, A.G.B., Mesaglio, T., Moles, A.T., Nakagawa, S., Roberts, C., Rowley, J.J.L., VergÉs, A., Wilshire, J.H. & Cornwell, W.K. (2020b). Three Frontiers for the Future of Biodiversity Research Using Citizen Science Data. *BioScience*, biaa133. https://doi.org/10.1093/biosci/biaa131

Callaghan, C.T., Rowley, J.J.L., Cornwell, W.K., Poore, A.G.B. & Major, R.E. (2019). Improving big citizen science data: Moving beyond haphazard sampling. *PLOS Biology*, 17 (6), e3000357. https://doi.org/10.1371/journal.pbio.3000357

Cappa, F., Franco, S. & Rosso, F. (2022). Citizens and cities: Leveraging citizen science and big data for sustainable urban development. *Business Strategy and the Environment*, 31 (2), 648–667. https://doi.org/10.1002/bse.2942

Chand, S.P. (2025). Methods of Data Collection in Qualitative Research: Interviews, Focus Groups, Observations, and Document Analysis. *Advances in Educational Research and Evaluation*, 6 (1), 303–317. https://doi.org/10.25082/AERE.2025.01.001

Chandler, M., See, L., Copas, K., Bonde, A.M.Z., López, B.C., Danielsen, F., Legind, J.K., Masinde, S., Miller-Rushing, A.J., Newman, G., Rosemartin, A. & Turak, E. (2017). Contribution of citizen science towards international biodiversity monitoring. *Biological Conservation*, 213, 280–294. https://doi.org/10.1016/j.biocon.2016.09.004

Christian, H.-M. (2023). The Main Drivers of Biodiversity Loss: A Brief Overview. *Journal of Ecology & Natural Resources*, 7 (3). https://doi.org/10.23880/jenr-16000346

Cuervo-Robayo, Á.P., Rodríguez, P., Vázquez-Miranda, H., Vázquez-Flores, M.F., Ramírez-Barahona, S., Nori, J. & Martínez-Meyer, E. (2026). It takes two: the value of integrating citizen science and scientific collections in biodiversity research. *Perspectives in Ecology and Conservation*, 24 (2), 223–230. https://doi.org/10.1016/j.pecon.2026.02.010

Dasgupta, P. (2021). *The economics of biodiversity: the Dasgupta review: full report*. Updated: 18 February 2021. HM Treasury.

De Martino, R., Franchino, R. & Frettoloso, C. (2023). A "Stepping Stone" Approach to Exploiting Urban Density. In: Arbizzani, E., Cangelli, E., Clemente, C., Cumo, F., Giofrè, F., Giovenale, A.M., Palme, M., & Paris, S. (eds) *Technological Imagination in the Green and Digital Transition*. Springer International Publishing. 639–647. https://doi.org/10.1007/978-3-031-29515-7_57

De Sherbinin, A., Bowser, A., Chuang, T.-R., Cooper, C., Danielsen, F., Edmunds, R., Elias, P., Faustman, E., Hultquist, C., Mondardini, R., Popescu, I., Shonowo, A. & Sivakumar, K. (2021). The Critical Importance of Citizen Science Data. *Frontiers in Climate*, 3, 650760. https://doi.org/10.3389/fclim.2021.650760

Deacon, C., Govender, S. & Samways, M.J. (2023). Overcoming biases and identifying opportunities for citizen science to contribute more to global macroinvertebrate conservation. *Biodiversity and Conservation*, 32 (6), 1789–1806. https://doi.org/10.1007/s10531-023-02595-x

Della Rocca, F., Musiani, M., Galaverni, M. & Milanesi, P. (2024). Improving Online Citizen Science Platforms for Biodiversity Monitoring. *Journal of Biogeography*, 51 (12), 2412–2423. https://doi.org/10.1111/jbi.15000

Demirci, J.R. (2024). About Research: Conducting Better Qualitative Interviews. *Journal of Human Lactation*, 40 (1), 21–24. https://doi.org/10.1177/08903344231213651

Di Cecco, G.J., Barve, V., Belitz, M.W., Stucky, B.J., Guralnick, R.P. & Hurlbert, A.H. (2021). Observing the Observers: How Participants Contribute Data to iNaturalist and Implications for Biodiversity Science. *BioScience*, 71 (11), 1179–1188. https://doi.org/10.1093/biosci/biab093

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Brondizio, E., Chan, K.M., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, S.T., Asfaw, Z., Bartus, G., Brooks, L.A., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y. & Zlatanova, D. (2015). The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability*, 14, 1–16. https://doi.org/10.1016/j.cosust.2014.11.002

Elizalde, L. & Lambertucci, S.A. (2022). Private gardens in a town immersed in a National Park: Potential for conservation and highly valued under COVID lockdown. *Landscape and Urban Planning*, 226, 104481. https://doi.org/10.1016/j.landurbplan.2022.104481

Engel, T., Chowdhury, S., Friedrichs-Manthey, M., Gönner, J. von, Herrmann, T., Klenke, R., Koch Sheard, J., Peters, B. & Bonn, A. (2024). Digitalisierung in Citizen Science und Naturschutz - Anwendungsbeispiele aus der Praxis. 1904 KB, 11 pages. https://doi.org/10.19217/NUL2023-06-07

Feldman, M.J., Imbeau, L., Marchand, P., Mazerolle, M.J., Darveau, M. & Fenton, N.J. (2021). Trends and gaps in the use of citizen science derived data as input for species distribution models: A quantitative review. Silva, D.D.P. (ed.) (Silva, D. D. P., ed.) *PLOS ONE*, 16 (3), e0234587. https://doi.org/10.1371/journal.pone.0234587

Fereday, J. & Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, 5 (1), 80–92. https://doi.org/10.1177/160940690600500107

Finger, L., Van Den Bogaert, V., Schmidt, L., Fleischer, J., Stadtler, M., Sommer, K. & Wirth, J. (2023). The science of citizen science: a systematic literature review on educational and scientific outcomes. *Frontiers in Education*, 8, 1226529. https://doi.org/10.3389/feduc.2023.1226529

Fontaine, A., Simard, A., Brunet, N. & Elliott, K.H. (2022). Scientific contributions of citizen science applied to rare or threatened animals. *Conservation Biology*, 36 (6), e13976. https://doi.org/10.1111/cobi.13976

Fraisl, D., Hager, G., Bedessem, B., Gold, M., Hsing, P.-Y., Danielsen, F., Hitchcock, C.B., Hulbert, J.M., Piera, J., Spiers, H., Thiel, M. & Haklay, M. (2022). Citizen science in environmental and ecological sciences. *Nature Reviews Methods Primers*, 2 (1), 64. https://doi.org/10.1038/s43586-022-00144-4

Frantzeskaki, N., Buchel, S., Spork, C., Ludwig, K. & Kok, M.T.J. (2019). The Multiple Roles of ICLEI: Intermediating to Innovate Urban Biodiversity Governance. *Ecological Economics*, 164, 106350. https://doi.org/10.1016/j.ecolecon.2019.06.005

Garcia-Rosello, E., Gonzalez-Dacosta, J., Guisande, C. & Lobo, J.M. (2023). GBIF falls short of providing a representative picture of the global distribution of insects. *Systematic Entomology*, 48 (4), 489–497. https://doi.org/10.1111/syen.12589

Gorleri, F.C. & Areta, J.I. (2022). Misidentifications in citizen science bias the phenological estimates of two hard-to-identify *Elaenia* flycatchers. *Ibis*, 164 (1), 13–26. https://doi.org/10.1111/ibi.12985

Habel, J.C., Huemer, P., Schmitt, T., Rüdisser, J. & Ulrich, W. (2025). Strengths and shortcomings of citizen science data: lessons from Austrian butterflies. *Journal of Insect Conservation*, 29 (4), 60. https://doi.org/10.1007/s10841-025-00696-2

Hanson, H.I., Eckberg, E., Widenberg, M. & Alkan Olsson, J. (2021). Gardens' contribution to people and urban green space. *Urban Forestry & Urban Greening*, 63, 127198. https://doi.org/10.1016/j.ufug.2021.127198

Hartl, N., Wössner, E. & Sure-Vetter, Y. (2021). Nationale Forschungsdateninfrastruktur (NFDI). *Informatik Spektrum*, 44 (5), 370–373. https://doi.org/10.1007/s00287-021-01392-6

Hecker, S., Bonney, R., Haklay, M., Hölker, F., Hofer, H., Goebel, C., Gold, M., Makuch, Z., Ponti, M., Richter, A., Robinson, L., Iglesias, J.R., Owen, R., Peltola, T., Sforzi, A., Shirk, J., Vogel, J., Vohland, K., Witt, T. & Bonn, A. (2018). Innovation in Citizen Science – Perspectives on Science-Policy Advances. *Citizen Science: Theory and Practice*, 3 (1), 4. https://doi.org/10.5334/cstp.114

Hermoso, V., Carvalho, S.B., Giakoumi, S., Goldsborough, D., Katsanevakis, S., Leontiou, S., Markantonatou, V., Rumes, B., Vogiatzakis, I.N. & Yates, K.L. (2022). The EU Biodiversity Strategy for 2030: Opportunities and challenges on the path towards biodiversity recovery. *Environmental Science & Policy*, 127, 263–271. https://doi.org/10.1016/j.envsci.2021.10.028

Herodotou, C., Ismail, N., Aristeidou, M., Miller, G., Benavides Lahnstein, A.I., Ghadiri Khanaposhtani, M., Robinson, L.D. & Ballard, H.L. (2022). Online Community and Citizen Science supports environmental science learning by young people. *Computers & Education*, 184, 104515. https://doi.org/10.1016/j.compedu.2022.104515

Hong, P., Schmid, B., De Laender, F., Eisenhauer, N., Zhang, X., Chen, H., Craven, D., De Boeck, H.J., Hautier, Y., Petchey, O.L., Reich, P.B., Steudel, B., Striebel, M., Thakur, M.P. & Wang, S. (2022). Biodiversity promotes ecosystem functioning despite environmental change. Mori, A. (ed.) (Mori, A., ed.) *Ecology Letters*, 25 (2), 555–569. https://doi.org/10.1111/ele.13936

Hooper, D.U., Adair, E.C., Cardinale, B.J., Byrnes, J.E.K., Hungate, B.A., Matulich, K.L., Gonzalez, A., Duffy, J.E., Gamfeldt, L. & O'Connor, M.I. (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature*, 486 (7401), 105–108. https://doi.org/10.1038/nature11118

Hoskins, L.P., Mason, B.M., Heitmann, J.B., Alvarez-Abreu, O., Bearhs, K., Carnevale, S., Fussell, C.A., Lilkendey, T., Marquis, M., Sellers, B.A., Song, J., Swigris, A., Zuliani, M. & Callaghan, C.T. (2026). Bioblitzes Provide Valuable Biodiversity Data. *Natural Areas Journal*, 46 (2). https://doi.org/10.3375/2162-4399-46.2.4

Hussein, A. (2021). Links Between Biodiversity, Ecosystems Functions and Services: Systematic Review. *International Journal of Ecotoxicology and Ecobiology*, 6 (4), 70. https://doi.org/10.11648/j.ijee.20210604.12

Jäckel, D., Mortega, K.G., Darwin, S., Brockmeyer, U., Sturm, U., Lasseck, M., Moczek, N., Lehmann, G.U.C. & Voigt-Heucke, S.L. (2023). Community engagement and data quality: best practices and lessons learned from a citizen science project on birdsong. *Journal of Ornithology*, 164 (1), 233–244. https://doi.org/10.1007/s10336-022-02018-8

Jóhannsdóttir, A., Cresswell, I. & Bridgewater, P. (2010). The Current Framework for International Governance of Biodiversity: Is It Doing More Harm Than Good? *Review of European Community & International Environmental Law*, 19 (2), 139–149. https://doi.org/10.1111/j.1467-9388.2010.00673.x

Johnson, B.A., Mader, A.D., Dasgupta, R. & Kumar, P. (2020). Citizen science and invasive alien species: An analysis of citizen science initiatives using information and communications technology (ICT) to collect invasive alien species observations. *Global Ecology and Conservation*, 21, e00812. https://doi.org/10.1016/j.gecco.2019.e00812

Johnston, A., Matechou, E. & Dennis, E.B. (2023). Outstanding challenges and future directions for biodiversity monitoring using citizen science data. *Methods in Ecology and Evolution*, 14 (1), 103–116. https://doi.org/10.1111/2041-210X.13834

Jönsson, M., Kasperowski, D., Coulson, S.J., Nilsson, J., Bína, P., Kullenberg, C., Hagen, N., Van Der Wal, R. & Peterson, J. (2024). Inequality persists in a large citizen science programme despite increased participation through ICT innovations. *Ambio*, 53 (1), 126–137. https://doi.org/10.1007/s13280-023-01917-1

Kallio, H., Pietilä, A., Johnson, M. & Kangasniemi, M. (2016). Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing*, 72 (12), 2954–2965. https://doi.org/10.1111/jan.13031

Kasperowski, D. & Hagen, N. (2022). Making particularity travel: Trust and citizen science data in Swedish environmental governance. *Social Studies of Science*, 52 (3), 447–462. https://doi.org/10.1177/03063127221085241

Kc, S. & Sapkota, A. (2024). Can Gamification Save the Planet? Revolutionizing Citizen Science for Biodiversity Conservation. SSRN. https://doi.org/10.2139/ssrn.5008056

Keinath, S., Freyhof, J., Kasper, K., Lutz, M., Velder, R., Riestenpatt, D., Petzold, F., Schwarz, J., Ponick, W., Eidner, R., Meißner, J., Bengsch, S. & Sommerwerk, N. (2025). Towards Global Biodiversity Framework Target 12: mapping urban biodiversity monitoring programmes – a case study for

Berlin, Germany. *Urban Ecosystems*, 28 (4), 146. https://doi.org/10.1007/s11252-025-01760-0
Kelling, S., Johnston, A., Bonn, A., Fink, D., Ruiz-Gutierrez, V., Bonney, R., Fernandez, M., Hochachka, W.M., Julliard, R., Kraemer, R. & Guralnick, R. (2019). Using Semistructured Surveys to Improve Citizen Science Data for Monitoring Biodiversity. *BioScience*, 69 (3), 170–179. https://doi.org/10.1093/biosci/biz010
Kindsvater, H.K., Dulvy, N.K., Horswill, C., Juan-Jordá, M.-J., Mangel, M. & Matthiopoulos, J. (2018). Overcoming the Data Crisis in Biodiversity Conservation. *Trends in Ecology & Evolution*, 33 (9), 676–688. https://doi.org/10.1016/j.tree.2018.06.004
König, A., Pickar, K., Stankiewicz, J. & Hondrila, K. (2021). Can citizen science complement official data sources that serve as evidence-base for policies and practice to improve water quality? *Statistical Journal of the IAOS*, 37 (1), 189–204. https://doi.org/10.3233/SJI-200737
Kowarik, I., Fischer, L.K., Haase, D., Kabisch, N., Kleinschroth, F., Konijnendijk, C., Straka, T.M. & Von Haaren, C. (2025). Promoting urban biodiversity for the benefit of people and nature. *Nature Reviews Biodiversity*, 1 (4), 214–232. https://doi.org/10.1038/s44358-025-00035-y
Li, E., Parker, S.S., Pauly, G.B., Randall, J.M., Brown, B.V. & Cohen, B.S. (2019). An Urban Biodiversity Assessment Framework That Combines an Urban Habitat Classification Scheme and Citizen Science Data. *Frontiers in Ecology and Evolution*, 7, 277. https://doi.org/10.3389/fevo.2019.00277
Li, G., Fang, C., Li, Y., Wang, Z., Sun, S., He, S., Qi, W., Bao, C., Ma, H., Fan, Y., Feng, Y. & Liu, X. (2022). Global impacts of future urban expansion on terrestrial vertebrate diversity. *Nature Communications*, 13 (1), 1628. https://doi.org/10.1038/s41467-022-29324-2
Lim, T.C. (2006). *Doing comparative politics: an introduction to approaches and issues*. Lynne Rienner Publishers.
Liu, H.-Y., Dörler, D., Heigl, F. & Grossberndt, S. (2021). Citizen Science Platforms. In: Vohland, K., Land-Zandstra, A., Ceccaroni, L., Lemmens, R., Perelló, J., Ponti, M., Samson, R., & Wagenknecht, K. (eds) *The Science of Citizen Science*. Springer International Publishing. 439–459. https://doi.org/10.1007/978-3-030-58278-4_22
Lopez, B., Minor, E. & Crooks, A. (2020). Insights into human-wildlife interactions in cities from bird sightings recorded online. *Landscape and Urban Planning*, 196, 103742. https://doi.org/10.1016/j.landurbplan.2019.103742
Lotfian, M., Ingensand, J. & Brovelli, M.A. (2022). AN APPROACH FOR REAL-TIME VALIDATION OF THE LOCATION OF BIODIVERSITY OBSERVATIONS CONTRIBUTED IN A CITIZEN SCIENCE PROJECT. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-4/W1-2022, 271–278. https://doi.org/10.5194/isprs-archives-XLVIII-4-W1-2022-271-2022
MacDonald, H., Comer, C., Foster, M., Labelle, P.R., Marsalis, S., Nyhan, K., Premji, Z., Rogers, M., Splenda, R., Stansfield, C. & Young, S. (2024). Searching for studies: A guide to information retrieval for Campbell systematic reviews. *Campbell Systematic Reviews*, 20 (3), e1433. https://doi.org/10.1002/cl2.1433
Machado Toffolo, M., Meschini, M., Marchini, C., Caroselli, E., Prada, F., Mancuso, A., Lee, C.A., Zanon, M.V. & Goffredo, S. (2026). Citizen science data reliability enhancing scientific research: insights from an 11-year study in the Mediterranean Sea. *Environmental and Sustainability Indicators*, 30, 101203. https://doi.org/10.1016/j.indic.2026.101203
Mason, B.M., Mesaglio, T., Barratt Heitmann, J., Chandler, M., Chowdhury, S., Gorta, S.B.Z., Grattarola, F., Groom, Q., Hitchcock, C., Hoskins, L.,

Lowe, S.K., Marquis, M., Pernat, N., Shirey, V., Baasanmunkh, S. & Callaghan, C.T. (2025). iNaturalist accelerates biodiversity research. *BioScience*, 75 (11), 953–965. https://doi.org/10.1093/biosci/biaf104

Mata, L., Vogel, B., Palma, E. & Malipatil, M. (2021). The arrival and spread of the European firebug Pyrrhocoris apterus in Australia as documented by citizen scientists. Life Sciences. https://doi.org/10.32942/OSF.IO/4A3SH

McClure, E.C., Sievers, M., Brown, C.J., Buelow, C.A., Ditria, E.M., Hayes, M.A., Pearson, R.M., Tulloch, V.J.D., Unsworth, R.K.F. & Connolly, R.M. (2020). Artificial Intelligence Meets Citizen Science to Supercharge Ecological Monitoring. *Patterns*, 1 (7), 100109. https://doi.org/10.1016/j.patter.2020.100109

McKinley, D.C., Miller-Rushing, A.J., Ballard, H.L., Bonney, R., Brown, H., Cook-Patton, S.C., Evans, D.M., French, R.A., Parrish, J.K., Phillips, T.B., Ryan, S.F., Shanley, L.A., Shirk, J.L., Stepenuck, K.F., Weltzin, J.F., Wiggins, A., Boyle, O.D., Briggs, R.D., Chapin, S.F., Hewitt, D.A., Preuss, P.W. & Soukup, M.A. (2017). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation*, 208, 15–28. https://doi.org/10.1016/j.biocon.2016.05.015

Meeus, S., Silva-Rocha, I., Adriaens, T., Brown, P.M.J., Chartosia, N., Claramunt-López, B., Martinou, A.F., Pocock, M.J.O., Preda, C., Roy, H.E., Tricarico, E. & Groom, Q.J. (2023). More than a Bit of Fun: The Multiple Outcomes of a Bioblitz. *BioScience*, 73 (3), 168–181. https://doi.org/10.1093/biosci/biac100

Moersberger, H., Valdez, J., Martin, J.G.C., Junker, J., Georgieva, I., Bauer, S., Beja, P., Breeze, T.D., Fernandez, M., Fernández, N., Brotons, L., Jandt, U., Bruelheide, H., Kissling, W.D., Langer, C., Liquete, C., Lumbierres, M., Solheim, A.L., Maes, J., Morán-Ordóñez, A., Moreira, F., Pe'er, G., Santana, J., Shamoun-Baranes, J., Smets, B., Capinha, C., McCallum, I., Pereira, H.M. & Bonn, A. (2024). Biodiversity monitoring in Europe: User and policy needs. *Conservation Letters*, 17 (5), e13038. https://doi.org/10.1111/conl.13038

Montagnani, C., Sebesta, N., Vegini, E., Daniele, G., Barni, E., Celesti-Grapow, L., Emili, F., Larcher, F., Gentili, R. & Citterio, S. (2026). Invasive alien plants and the city: distribution patterns in response to urban elements and urbanization in three of the largest cities in Italy. *Urban Ecosystems*, 29 (1), 14. https://doi.org/10.1007/s11252-025-01876-3

Morgan, H. (2022). Conducting a Qualitative Document Analysis. *The Qualitative Report*,. https://doi.org/10.46743/2160-3715/2022.5044

Mu, Y., Xiong, K., Zhai, Q. & Xie, Q. (2025). Progress in regulating ecosystem services research: an implication for the Karst World Heritage sites. *npj Heritage Science*, 13 (1), 120. https://doi.org/10.1038/s40494-025-01674-2

Mueller, A.E. & Segal, D.L. (2015). Structured versus Semistructured versus Unstructured Interviews. In: Cautin, R.L. & Lilienfeld, S.O. (eds) *The Encyclopedia of Clinical Psychology*. 1. ed. Wiley. 1–7. https://doi.org/10.1002/9781118625392.wbecp069

Noble, H. & Heale, R. (2019). Triangulation in research, with examples. *Evidence Based Nursing*, 22 (3), 67–68. https://doi.org/10.1136/ebnurs-2019-103145

OECD (ed.) (2020). *Improving Governance with Policy Evaluation: Lessons From Country Experiences*. OECD Publishing. (OECD Public Governance Reviews). https://doi.org/10.1787/89b1577d-en

OECD (2025). *Cities for All Ages*. OECD Publishing. https://doi.org/10.1787/f0c8fefa-en

OECD & Europäische Kommission (eds) (2020). *Cities in the world: a new perspective on urbanisation*. OECD Publishing. (OECD urban studies)
Palma, E., Mata, L., Cohen, K., Evans, D., Gandy, B., Gaskell, N., Hatchman, H., Mezzetti, A., Neumann, D., O'Keefe, J., Shaw, A., Wells, M., Williams, L. & Hahs, A.K. (2024). The city nature challenge: A global citizen science phenomenon contributing to biodiversity knowledge and informing local government practices. *BioScience*, 74 (4), 290–299. https://doi.org/10.1093/biosci/biae012
Parker, S.S., Pauly, G.B., Moore, J., Fraga, N.S., Knapp, J.J., Principe, Z., Brown, B.V., Randall, J.M., Cohen, B.S. & Wake, T.A. (2018). Adapting the bioblitz to meet conservation needs. *Conservation Biology*, 32 (5), 1007–1019. https://doi.org/10.1111/cobi.13103
Pateman, R., Dyke, A. & West, S. (2021). The Diversity of Participants in Environmental Citizen Science. *Citizen Science: Theory and Practice*, 6 (1), 9. https://doi.org/10.5334/cstp.369
Pernat, N., Canavan, S., Golivets, M., Hillaert, J., Itescu, Y., Jarić, I., Mann, H.M.R., Pipek, P., Preda, C., Richardson, D.M., Teixeira, H., Vaz, A.S. & Groom, Q. (2024). Overcoming biodiversity blindness: Secondary data in primary citizen science observations. *Ecological Solutions and Evidence*, 5 (1), e12295. https://doi.org/10.1002/2688-8319.12295
Persson, A.S., Hederström, V., Ljungkvist, I., Nilsson, L. & Kendall, L. (2023). Citizen science initiatives increase pollinator activity in private gardens and green spaces. *Frontiers in Sustainable Cities*, 4, 1099100. https://doi.org/10.3389/frsc.2022.1099100
Peter, M., Diekötter, T., Höffler, T. & Kremer, K. (2021). Biodiversity citizen science: Outcomes for the participating citizens. Mascarenhas, A. (ed.) (Mascarenhas, A., ed.) *People and Nature*, 3 (2), 294–311. https://doi.org/10.1002/pan3.10193
Peter, M., Diekötter, T. & Kremer, K. (2019). Participant Outcomes of Biodiversity Citizen Science Projects: A Systematic Literature Review. *Sustainability*, 11 (10), 2780. https://doi.org/10.3390/su11102780
Pocock, M.J.O., Adriaens, T., Bertolino, S., Eschen, R., Essl, F., Hulme, P.E., Jeschke, J.M., Roy, H.E., Teixeira, H. & De Groot, M. (2024). Citizen science is a vital partnership for invasive alien species management and research. *iScience*, 27 (1), 108623. https://doi.org/10.1016/j.isci.2023.108623
Proudfoot, K. (2023). Inductive/Deductive Hybrid Thematic Analysis in Mixed Methods Research. *Journal of Mixed Methods Research*, 17 (3), 308–326. https://doi.org/10.1177/15586898221126816
Pyšek, P., Hulme, P.E., Simberloff, D., Bacher, S., Blackburn, T.M., Carlton, J.T., Dawson, W., Essl, F., Foxcroft, L.C., Genovesi, P., Jeschke, J.M., Kühn, I., Liebhold, A.M., Mandrak, N.E., Meyerson, L.A., Pauchard, A., Pergl, J., Roy, H.E., Seebens, H., Van Kleunen, M., Vilà, M., Wingfield, M.J. & Richardson, D.M. (2020). Scientists' warning on invasive alien species. *Biological Reviews*, 95 (6), 1511–1534. https://doi.org/10.1111/brv.12627
Quinn, A. (2021). Transparency and secrecy in citizen science: Lessons from herping. *Studies in History and Philosophy of Science Part A*, 85, 208–217. https://doi.org/10.1016/j.shpsa.2020.10.010
Rega-Brodsky, C.C., Aronson, M.F.J., Piana, M.R., Carpenter, E.-S., Hahs, A.K., Herrera-Montes, A., Knapp, S., Kotze, D.J., Lepczyk, C.A., Moretti, M., Salisbury, A.B., Williams, N.S.G., Jung, K., Katti, M., MacGregor-Fors, I., MacIvor, J.S., La Sorte, F.A., Sheel, V., Threfall, C.G. & Nilon, C.H. (2022a). Urban biodiversity: State of the science and future directions. *Urban Ecosystems*, 25 (4), 1083–1096. https://doi.org/10.1007/s11252-022-01207-w

Rega-Brodsky, C.C., Aronson, M.F.J., Piana, M.R., Carpenter, E.-S., Hahs, A.K., Herrera-Montes, A., Knapp, S., Kotze, D.J., Lepczyk, C.A., Moretti, M., Salisbury, A.B., Williams, N.S.G., Jung, K., Katti, M., MacGregor-Fors, I., MacIvor, J.S., La Sorte, F.A., Sheel, V., Threfall, C.G. & Nilon, C.H. (2022b). Urban biodiversity: State of the science and future directions. *Urban Ecosystems*, 25 (4), 1083–1096. https://doi.org/10.1007/s11252-022-01207-w

Revington, N., Zwick, A., Hartt, M. & Schlosser, J. (2023). Universities and urban social structure: gentrification, studentification, and youthification in five United States legacy cities. *Urban Geography*, 44 (1), 83–104. https://doi.org/10.1080/02723638.2021.1985306

Rihoux, B. (2006). Qualitative Comparative Analysis (QCA) and Related Systematic Comparative Methods: Recent Advances and Remaining Challenges for Social Science Research. *International Sociology*, 21 (5), 679–706. https://doi.org/10.1177/0268580906067836

Rosário, I.T., Tiago, P., Chozas, S. & Capinha, C. (2025). When do citizen scientists record biodiversity? Non-random temporal patterns of recording effort and associated factors. *People and Nature*, 7 (4), 860–870. https://doi.org/10.1002/pan3.70017

Rossoni, A.L., De Vasconcellos, E.P.G. & De Castilho Rossoni, R.L. (2024). Barriers and facilitators of university-industry collaboration for research, development and innovation: a systematic review. *Management Review Quarterly*, 74 (3), 1841–1877. https://doi.org/10.1007/s11301-023-00349-1

Roy, H., Groom, Q., Adriaens, T., Agnello, G., Antic, M., Archambeau, A.-S., Bacher, S., Bonn, A., Brown, P., Brundu, G., López, B., Cleary, M., Cogălniceanu, D., De Groot, M., De Sousa, T., Deidun, A., Essl, F., Fišer Pečnikar, Ž., Gazda, A., Gervasini, E., Glavendekic, M., Gigot, G., Jelaska, S., Jeschke, J., Kaminski, D., Karachle, P., Komives, T., Lapin, K., Lucy, F., Marchante, E., Marisavljevic, D., Marja, R., Martín Torrijos, L., Martinou, A., Matosevic, D., Mifsud, C., Motiejūnaitė, J., Ojaveer, H., Pasalic, N., Pekárik, L., Per, E., Pergl, J., Pesic, V., Pocock, M., Reino, L., Ries, C., Rozylowicz, L., Schade, S., Sigurdsson, S., Steinitz, O., Stern, N., Teofilovski, A., Thorsson, J., Tomov, R., Tricarico, E., Trichkova, T., Tsiamis, K., Van Valkenburg, J., Vella, N., Verbrugge, L., Vétek, G., Villaverde, C., Witzell, J., Zenetos, A. & Cardoso, A.C. (2018). Increasing understanding of alien species through citizen science (Alien-CSI). *Research Ideas and Outcomes*, 4, e31412. https://doi.org/10.3897/rio.4.e31412

Sampford, C. (2002). Environmental governance for biodiversity. *Environmental Science & Policy*, 5 (1), 79–90. https://doi.org/10.1016/S1462-9011(02)00027-8

Sandfort, R., Uhlhorn, B., Geissler, G., Lyhne, I. & Jiricka-Pürrer, A. (2023). AI Will Change EA Practice – but Are We Ready for It? A Call for Discussion Based on Developments in Collecting and Processing Biodiversity Data. Environmental and Earth Sciences. https://doi.org/10.20944/preprints202307.1573.v1

Santana, J., Porto, M., Morán-Ordóñez, A., Brotons, L., Junker, J., Kissling, W.D., Lumbierres, M., Moe, S.J., Solheim, A.L., Villero, D., Breeze, T.D., Carvalho, L., Fernández, N., Herrando, S., López-Baucells, A., Shamoun-Baranes, J., Silero, N., Pereira, H.M., Moreira, F. & Beja, P. (2025). Large Biodiversity Monitoring Gaps Remain Across Europe. *Conservation Letters*, 18 (5), e13134. https://doi.org/10.1111/conl.13134

Simkin, R.D., Seto, K.C., McDonald, R.I. & Jetz, W. (2022). Biodiversity impacts and conservation implications of urban land expansion projected to 2050.

Proceedings of the National Academy of Sciences, 119 (12), e2117297119. https://doi.org/10.1073/pnas.2117297119
Somerwill, L. & Wehn, U. (2022). How to measure the impact of citizen science on environmental attitudes, behaviour and knowledge? A review of state-of-the-art approaches. *Environmental Sciences Europe*, 34 (1), 18. https://doi.org/10.1186/s12302-022-00596-1
Soni, H., Yadav, R.K. & Patra, S.K. (2025). Global impact of urbanization on ecosystems: A comprehensive bibliometric analysis. *Natural Hazards Research*, 5 (1), 21–35. https://doi.org/10.1016/j.nhres.2024.04.001
Stanford, H.R., Hurley, J., Garrard, G.E. & Kirk, H. (2024). Exploring the secret gardens of the city: An assessment of human-nature interactions on informal green space using citizen science data. *Urban Forestry & Urban Greening*, 98, 128414. https://doi.org/10.1016/j.ufug.2024.128414
Stansfield, C., Dickson, K. & Bangpan, M. (2016). Exploring issues in the conduct of website searching and other online sources for systematic reviews: how can we be systematic? *Systematic Reviews*, 5 (1), 191, s13643-016-0371–9. https://doi.org/10.1186/s13643-016-0371-9
Strasser, B.J., Baudry, J., Mahr, D., Sanchez, G. & Tancoigne, E. (2018). “Citizen Science”? Rethinking Science and Public Participation. *Science & Technology Studies*, 52–76. https://doi.org/10.23987/sts.60425
Strasser, B.J., Tancoigne, E., Baudry, J., Piguet, S., Spiers, H., Luis-Fernandez Marquez, J., Kasparian, J., Grey, F., Anderson, D. & Lintott, C. (2023a). Quantifying online citizen science: Dynamics and demographics of public participation in science. Silva, D.D.P. (ed.) (Silva, D. D. P., ed.) *PLOS ONE*, 18 (11), e0293289. https://doi.org/10.1371/journal.pone.0293289
Strasser, B.J., Tancoigne, E., Baudry, J., Piguet, S., Spiers, H., Luis-Fernandez Marquez, J., Kasparian, J., Grey, F., Anderson, D. & Lintott, C. (2023b). Quantifying online citizen science: Dynamics and demographics of public participation in science. Silva, D.D.P. (ed.) (Silva, D. D. P., ed.) *PLOS ONE*, 18 (11), e0293289. https://doi.org/10.1371/journal.pone.0293289
Tiago, P., Ceia-Hasse, A., Marques, T.A., Capinha, C. & Pereira, H.M. (2017). Spatial distribution of citizen science casuistic observations for different taxonomic groups. *Scientific Reports*, 7 (1), 12832. https://doi.org/10.1038/s41598-017-13130-8
Tisdell, E.J., Merriam, S.B. & Stuckey, H. (2025). *Qualitative research: a guide to design and implementation*. Fifth edition. Jossey-Bass, a Wiley brand.
Troudet, J., Grandcolas, P., Blin, A., Vignes-Lebbe, R. & Legendre, F. (2017). Taxonomic bias in biodiversity data and societal preferences. *Scientific Reports*, 7 (1), 9132. https://doi.org/10.1038/s41598-017-09084-6
Turbé, A., Barba, J., Pelacho, M., Mudgal, S., Robinson, L.D., Serrano-Sanz, F., Sanz, F., Tsinaraki, C., Rubio, J.-M. & Schade, S. (2020). Correction: Understanding the Citizen Science Landscape for European Environmental Policy: An Assessment and Recommendations. *Citizen Science: Theory and Practice*, 5 (1), 5. https://doi.org/10.5334/cstp.308
UNDP (ed.) (2011). *Towards human resilience: sustaining MDG progress in an age of economic uncertainty*. United Nations Pubns.
Visseren-Hamakers, I.J. & Kok, M.T.J. (eds) (2022). *Transforming Biodiversity Governance*. 1. ed Cambridge University Press. https://doi.org/10.1017/9781108856348
Voigt-Heucke, S.L., Müller, M. & Rostin, J. (2023). How Citizen Science Projects Contribute to Urban Biodiversity Monitoring and Conservation Frameworks—A German Case Study. *Citizen Science: Theory and Practice*, 8 (1), 30. https://doi.org/10.5334/cstp.585
Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. *Proceedings of EASE ’14: 18th*

International Conference on Evaluation and Assessment in Software Engineering, London England United Kingdom, May 13 2014. 1–10. ACM. https://doi.org/10.1145/2601248.2601268

Young, J.C., Rose, D.C., Mumby, H.S., Benitez-Capistros, F., Derrick, C.J., Finch, T., Garcia, C., Home, C., Marwaha, E., Morgans, C., Parkinson, S., Shah, J., Wilson, K.A. & Mukherjee, N. (2018). A methodological guide to using and reporting on interviews in conservation science research. *Methods in Ecology and Evolution*, 9 (1), 10–19. https://doi.org/10.1111/2041-210X.12828

Online resources and reports

Bielefeld University (n.d.). Forschungsprofil. https://www.uni-bielefeld.de/forschung/profil/ (accessed April 17, 2026)

BirdLife Sweden (n.d.). Winter birds on the doorstep. https://vinterfaglar.se/ (accessed March 09, 2026)

Biodiversity Information System for Europe (BISE) (n.d. a). Biodiversity policies at the global level. https://biodiversity.europa.eu/policy/biodiversity-policies-at-the-global-level (accessed April 23, 2026)

Biodiversity Information System for Europe (BISE) (n.d. b). Biodiversity policies at the European level. https://biodiversity.europa.eu/policy/biodiversity-policies-at-the-european-level (accessed April 23, 2026)

Biologische Station Kreis Paderborn – Senne (2026). Beobachtungen. https://bs-paderborn-senne.beobachtungsplattform.de/sichtungen (accessed May 08, 2026)

City of Cologne (n.d.) Studieren in Köln. https://www.stadt-koeln.de/leben-in-koeln/bildung-und-schule/studieren-in-koeln/index.html (accessed April 20, 2026)

City of Cologne (2020): Stadtstrategie 2.0 – Kölner Perspektiven 2030+. https://www.stadt-koeln.de/mediaasset/content/pdf15/kp2030/stadtstrategie.pdf

City of Cologne (2022) Nachhaltigkeitsbericht der Stadt Köln 2022 nach dem Berichtsrahmen Nachhaltige Kommune (BNK) im Kontext der Agenda 2030. https://www.stadt-koeln.de/artikel/72093/index.html (accessed April 12, 2026)

City of Cologne (2023). Voluntary local review 2023 Köln: Implementing the 2030 Agenda and the Sustainable Development Goals at the local level. https://www.stadt-koeln.de/artikel/72093/index.html (accessed April 12, 2026)

Convention on Biological Diversity (2022). Final text of Kunming-Montreal Global Biodiversity Framework available in all languages. https://prod.drupal.www.infra.cbd.int/sites/default/files/2022-12/221222-CBD-PressRelease-COP15-Final.pdf?_gl=1*1d7dmww*_ga*MTE2NDY5MDAxMi4xNzcwNzMxNjAz*_ga_7S1TPRE7F5*czE3NzcwNjEwMDgkbzgkZzEkdDE3NzcwNjEyNzk-kajU4JGwwJGgw

Euro Cities (n.d. a). Cologne. https://eurocities.eu/cities/cologne/ (accessed April 13, 2026)

Euro Cities (n.d. b). Stockholm. https://eurocities.eu/cities/stockholm/ (accessed April 13, 2026)

Euro Cities (n.d. c). Uppsala. https://eurocities.eu/cities/uppsala/ (accessed April 13, 2026)

European Citizen Science Platform (n.d.). About. EU-Citizen.Science. https://citizenscience.eu/about/ (accessed March10, 2026)

European Commission (1992). Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal L 206 , 22/07/1992 P. 0007 - 0050

European Commission (2020a). EU Biodiversity Strategy for 2030: Bringing nature back into our lives (COM(2020) 380 final)

European Commission (2020b). The state of nature in the European Union. Report on the status and trends in 2013 - 2018 of species and habitat types protected by the Birds and Habitats Directives. Brussels, 15.10.2020 COM(2020) 635 final

European Commission (2025). International engagement. https://knowledge4policy.ec.europa.eu/biodiversity/international-engagement_en. (accessed April 23, 2026)

European Commission (2026). European Red List of Threatened Species. https://environment.ec.europa.eu/topics/nature-and-biodiversity/european-red-list-threatened-species_en (accessed May 07,2026)

European Commission (n.d.). The European Green Deal: Striving to be the first climate-neutral continent. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (accessed April 23, 2026)

European Environment Agency (2024). Species protection and conservation. https://www.eea.europa.eu/en/topics/in-depth/nature-protection-and-restoration/species-protection-and-conservation (accessed April 23, 2026)

European Parliament and Council of the European Union (2014).
Regulation (EU) No 1143/2014 of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species.
Official Journal of the European Union, L 317, pp. 35–55

Global Biodiversity Information Facility (n.d. a). Citizen science. https://www.gbif.org/citizen-science (accessed March 09, 2026)

Global Biodiversity Information Facility (n.d. b). What is GBIF? Global Biodiversity Information Facility. https://www.gbif.org/what-is-gbif (accessed March 09, 2026)

Global Biodiversity Information Facility (n.d. c). SBDI. https://www.gbif.se/sbdi/ (accessed March 09, 2026)

Global Biodiversity Information Facility (n.d. d). Datasets published in Germany (search results). https://www.gbif.org/dataset/search?offset=20&publishing_country=DE (accessed March 09, 2026)

Global Biodiversity Information Facility (2026a). Occurrence search (present records).

https://www.gbif.org/occurrence/search?occurrence_status=present (accessed March 09, 2026)

Global Biodiversity Information Facility (2026b). Artportalen. https://www.gbif.se/ipt/resource?r=artdata (accessed May 09, 2026)

Government Offices of Sweden (n.d.). The Swedish model of government administration. https://www.government.se/how-sweden-is-governed/the-swedish-model-of-government-administration/ (accessed May 29, 2026)

Haklay, M. (2015). *Citizen science and policy: A European perspective*. Washington, DC: Woodrow Wilson International Center for Scholars

Husqvarna (n.d.). Uppsala. https://hugsi.green/cities/Uppsala (accessed April 04, 2026)

iNaturalist (2026). What is geoprivacy? What does it mean for an observation to be obscured?. https://help.inaturalist.org/en/support/solutions/articles/151000169938-what-is-geoprivacy-what-does-it-mean-for-an-observation-to-be-obscured- (accessed May 06, 2026)

Information und Technik Nordrhein-Westfalen (IT.NRW) (2024). Bevölkerungsvorausberechnung für NRW 2024 bis 2050/2070. https://statistik.nrw/service/veroeffentlichungen/statistik-kompakt/bevoelkerungs-vorausberechnung-fuer-nrw-2024-bis-2050-2070 (accessed April, 17, 2026)

IPBES (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. 〈https://www.ipbes.net/news/ipbes-global-assessment-summary-policymakers-pdf

IPBES (2024). Summary for policymakers of the thematic assessment of the interlinkages among biodiversity, water, food and health (nexus assessment)

IUCN (n.d.). Summary Statistics. https://www.iucnredlist.org/resources/summary-statistics (accessed May 07, 2026)

Kommunen für biologische Vielfalt (n.d. a). Stadt Köln. https://kommbio.de/label/stadt-koeln-2023/ (accessed April 20, 2026)

Kommunen für biologische Vielfalt (n.d. b). Stadt Bielefeld. https://kommbio.de/label/bielefeld/ (accessed April 20, 2026)

Köln Business (n.d.). Cologne: An epicentre for science, technology and academic inquiry. https://koeln.business/en/research-and-innovation (accessed April 20, 2026)

Landesamt für Natur, Umwelt und Klima Nordrhein-Westfalen (LANUK) (2025). NSG-Statistik der Kreise und kreisfreien Städte im RP Köln.

https://nsg.naturschutzinformationen.nrw.de/nsg/de/fachinfo/statistik/kreise/koeln (accessed April 20, 2026)

Landesamt für Natur, Umwelt und Klima Nordrhein-Westfalen (LANUK) (n.d.). Neobiota in NRW Karte. https://neobiota.naturschutzinformationen.nrw.de/neobiota/de/fundpunkte/webapp (accessed April 29, 2026)

Lunds Universitet (n.d.). Swedish bird survey. https://www.fageltaxering.lu.se/ (accessed March 09, 2026)

NABU Stadtverband Köln (2025). Projekt: Schuppenträger in Köln - wo lebt welches Reptil?. https://www.nabu-koeln.de/projekte/reptilienprojekt/ (accessed May 16, 2026)

Millennium Ecosystem Assessment (2005). Ecosystems and human well-being: Biodiversity synthesis. World Resources Institute. https://www.millenniumassessment.org/documents/document.354.aspx.pdf.

NFDI4 Biodiversity (n.d.). What we do. https://www.nfdi4biodiversity.org/en/what-we-do/ (accessed March 09, 2026)

Ornitho (n.d.). Species partially hidden. https://www.ornitho.ch/index.php?m_id=156 (accessed May 06, 2026)

Convention on Biological Diversity (2011). Convention on Biological Diversity: Text and annexes. Secretariat of the Convention on Biological Diversity, United Nations Environment Programme. https://www.cbd.int/doc/legal/cbd-en.pd

Secretariat of the Convention on Biological Diversity (1992). Convention on Biological Diversity

Secretariat of the Convention on Biological Diversity (2020). Global Biodiversity Outlook 5. Montreal

Stadt Bielefeld (2021). Nachhaltigkeitsstrategie der Stadt Bielefeld (NHS). https://www.bielefeld.de/sites/default/files/datei/2021/NHS.pdf

Stadt Bielefeld (2022). Stadt, Land, Fluss – Flächennutzung in Bielefeld. https://www.bielefeld.de/sites/default/files/datei/2022/Bielefeld_Statistik_kompakt_022022_Fl%C3%A4chennutzung.pdf

Stadt Bielefeld (2024). Nachhaltigkeitsbericht der Stadt Bielefeld: Agenda 2030 auf lokaler Ebene. https://www.bielefeld.de/sites/default/files/datei/2024/Nachhaltigkeitsbericht-der-Stadt-Bielefeld-Marz-2024_0.pdf

Stadt Bielefeld (n.d. a). Landschaftsräume. https://www.bielefeld.de/landschaftsraeume (accessed April 17, 2026)

Stadt Bielefeld (n.d. b). Naturschutzgebiete. https://www.bielefeld.de/node/5178 (accessed April 17, 2026)

Stadt Bielefeld (n.d. c). Wissenschaft und Innovation. Wissenschaft und Innovation | Bielefeld Marketing (accessed April 17, 2026)

Stadt Köln. (n.d. a). Geblendet von der Nacht - Wo sind unsere Glühwürmchen? https://www.stadt-koeln.de/leben-in-koeln/umwelt-tiere/gluehwuermchen-kartierung/index.html (accessed April 23, 2026)

Stadt Köln (n.d. b). Karten zu Klima, Umwelt und Tieren. https://www.stadt-koeln.de/artikel/73538/index.html (accessed April 23, 2026)

Statistika centralbyrån (2026). Lägsta folkökningen på 25 år. Statistika centralbyrån (SCB). https://www.scb.se/pressmeddelande/lagsta-folkokningen-pa-25-ar/ (accessed April 12, 2026)

Statista (2026). Gesamtfläche der Stadt Köln nach Flächennutzungsarten im Jahr 2022. https://de.statista.com/statistik/daten/studie/1195905/umfrage/flaechennutzung-koeln/ (accessed April 20, 2026)

Statistisches Bundesamt (2026). GENESIS-Online database: Table 12411-0015. Statistisches Bundesamt. https://www-genesis.destatis.de/datenbank/online/table/12411-0015 (accessed April 07, 2026)

Stockholms stad (n.d. a). Proposed measures for biodiversity. https://miljobarometern.stockholm.se/natur/atgardsforslag-for-biologisk-mangfald/ (accessed April 08, 2026)

Stockholms stad (n.d. b). Welcome to ArtArken. https://artarken.stockholm.se/ (accessed May 07, 2026)

Stockholms stad (n.d. c). Handlingsplan för biologisk mångfald i Stockholm stad. https://meetingspublic.stockholm.se/welcome-sv/namnder-styrelser/ostermalms-stadsdelsnamnd/mote-2020-09-24/protocol/bilaga-handlingsplan-for-biologisk-mangfald-i-stockholmpdf?downloadMode=open

Stockholms stad (2019). Soil types and water 2019. https://miljobarometern.stockholm.se/natur/alla-indikatorer-natur/fordelning-av-marktyper-och-vatten-2019/ (accessed April 05, 2026)

Stockholms stad (2021). Handlingsplan för klimatanpassning 2022–2025. https://start.stockholm/globalassets/start/om-stockholms-stad/politik-och-demokrati/styrdokument/handlingsplan-for-klimatanpassning-2022-2025_ta.pdf

Stockholms stad (2024a). Climate Action Plan 2030 A just transition for a Stockholm with no global carbon footprint. https://start.stockholm/globalassets/start/om-stockholms-stad/politik-och-demokrati/styrdokument/climate-action-plan-2030.pdf

Stockholms stad (2024b). Environment Programme 2030. environment-programme-2030.pdf (accessed April 05, 2026)

Stockholms stad (2024c). Uppföljning av Stockholms stads miljöprogram och klimatbudget 2023. https://start.stockholm/globalassets/start/om-stockholms-stad/utredningar-statistik-och-fakta/utredningar-och-rapporter/hallbarhet/klimat-och-miljo/uppfoljning-av-stockholms-stads-miljoprogram-och-klimatbudget-2023.pdf.

Stockholms stad (2025). Hållbarhetsrapport 2025. https://start.stockholm/om-stockholms-stad/utredningar-statistik-och-fakta/utredningar-och-rapporter/hallbar-het/ (accessed April 05, 2026)

Stockholm University (n.d.) About the university. https://www.su.se/eng-lish/about-the-university (accessed April 08, 2026)

Swedish Biodiversity Data Infrastructure (2023). Artportalen - The Swedish Spe-cies Observation System. https://collections.biodiversitydata.se/public/show/co3 (accessed March 13, 2026)

Swedish University of Agricultural Sciences (n.d.). Welcome to SLU. Swedish University of Agricultural Sciences. https://www.slu.se/ (accessed April 05, 2026)

Swedish University of Agricultural Sciences (2025a). Artportalen – The Swedish Species Observation System. Swedish University of Agricultural Sciences. https://www.slu.se/en/environment/statistics-and-environmental-data/environmen-tal-data-catalogue/artportalen/ (accessed March 13, 2026)

Swedish University of Agricultural Sciences (2025b). Observations. https://www.slu.se/en/slu-swedish-species-information-centre/species-observa-tions/ (accessed March 13, 2026)

The federal Government (n.d.). Structure and tasks. https://www.bundesregier-ung.de/breg-en/federal-government/structure-and-tasks-470508#tar-1. (accessed May 29, 2026)

UNEP (2021). Measuring progress: environment and the SDGs.

United Nations (2015). Transforming our world: The 2030 Agenda for Sustainable Development. A/RES/70/1

Uppsala University (n.d.). Vision, goals and strategies. Uppsala University. https://www.uu.se/en/about-uu/vision-goals-and-strategies (accessed April 04, 2026)

Uppsala kommun (2021). Uppsala and Agenda 2030: Voluntary Local Review 2021. Uppsala Municipality. https://www.uppsala.se/conten-tassets/cfd3db5376084b168bce67e57ce73dcc/uppsala_and_agenda_2030_vlr-rap-port_2021.pdf

Uppsala kommun (2024). The cinnabar beetle in urban development. https://www.uppsala.se/cinnoberbagge (accessed May 09, 2026)

Uppsala kommun (2025). Environmental and Climate Programme. https://www.uppsala.se/contentassets/5d36faebce83404888c3a4677bad5584/environment-and-climate-programme.pdf

Uppsala kommun (2026a). Grönblå Grön- och strukturplan blåstrukturplan Del av översiktsplanen- del av översiktsplaneringen. https://www.uppsala.se/contentassets/9ebb930e26364751bd9b298c5d6b9725/antagandehandling-gron--och-blaststrukturplan.pdf

Uppsala kommun (2026b). Guideline for nature conservation and ecological compensation in the event of land use change. https://www.uppsala.se/kommun-och-politik/sa-arbetar-vi-med-olika-amnen/sa-arbetar-vi-med-grona-fragor/riktlinje-for-naturhansyn-och-ekologisk-kompensation-vid-forandrad-markanvandning/ (accessed April 26, 2026)

Uppsala kommun (n.d. a). Climate and energy 2025-2027. Uppsala Municipality. https://www.uppsala.se/kommun-och-politik/kommunens-mal-och-budget/mal-och-budget/fokusmal/3.-uppsala-ska-leda-klimatomstallningen/ (accessed April 04, 2026)

Uppsala kommun (n.d. b). Biodiversity. Uppsala Municipality. https://www.uppsala.se/kommun-och-politik/sa-arbetar-vi-med-olika-amnen/sa-arbetar-vi-med-grona-fragor/biologisk-mangfald/ (accessed April 04, 2026)

Weber, Judith Sophie et al. (2021). NFDI4BioDiversity– NFDI-Konsortium für Biodiversitäts-, Ökologie- und Umweltdaten. Bausteine Forschungsdatenmanagement. Empfehlungen und Erfahrungsberichte für die Praxis von Forschungsdatenmanagerinnen und-managern Nr. 2/2021: S. 98-109. DOI: 10.17192/bfdm.2021.2.8334

9. Appendix

9.1 Interview guide

1) **General questions about the interviewee**
   - What educational background or degree forms the basis of your current position?
   - How long have you been working in the city administration?
   - Could you briefly describe your current tasks related to biodiversity?
   - Since when has citizen science been part of your area of responsibility?
   - What role does citizen science play in your daily work?

2) **Questions on citizen science in the field of biodiversity**

- Is citizen science used in your city in the field of biodiversity?
- Since when?
- Does your city run any own projects? What kind of projects are these? How many? Are they short-term or long-term initiatives?
- Are you taking public CS platforms into account?
- For what purposes are citizen science data used (e.g. planning and management, establishing conservation measures (for specific species), raising public awareness, etc.)?
- Sweden: In the biodiversity strategy, CS is not mentioned as a source of biodiversity data. What is the reason for that? Germany: You are currently working on a biodiversity strategy. Could you give me insights into whether and how CS will be integrated into this strategy, and what role it could play in the future?
- Which actors primarily initiate citizen science projects (city, universities, NGOs, private individuals, or joint initiatives)?
- What challenges or limitations exist (e.g. staff, funding, technical infrastructure, data quality and quantity, biases)?
- Are there species (groups) you prioritize?
- Are CS data used in the context of the EU Regulation No. 1143/2014 on invasive alien species or the Habitats Directive?
- Do you think that citizen science is gaining importance for achieving biodiversity goals?

- Do such projects increase public awareness? Does participation lead to further engagement in environmental protection?

3) If projects already exist

- What are the main objectives?
- How long has the project been running?
- What is the level of participation? How many citizens are involved? Who participates (e.g. private individuals, students, retirees)? How frequently?
- Are participants trained or provided with detailed guidelines?
- How are the data collected and documented (e.g. website, app, email)?
- How reliable are the data? How are they verified?
- Are direct conservation measures derived from the collected data?
- How are the projects promoted to the public?
- What impact have the collected data had on research, policy, or management decisions?

9.2 City overview

Table 4. Overview of the case study cities, including population size, key land-use characteristics, nature protection area, main sustainability and biodiversity goals and academic context.

City	Population	Key land-use	Nature Protection share of city area [%]	Main Sustainability and Biodiversity Goals	Academic Context
Stockholm	1 Million	28 % urban infrastructure, 59 % green spaces and 13 % water	20 %	Climate positive by 2030 and fossil-free by 2040; protection of ecosystem services; sustainable water, waste and transport systems	Internationally recognized research and innovation hub with five universities
Uppsala	230,000	30 % urban infrastructure, 56 % green and blue infrastructure	21 %	Sustainable urban growth; pollinator-friendly planting, habitat creation, ecological corridors, increased tree cover	Leading universities with strong expertise in life and environmental sciences

City	Population	Key land-use	Nature Protection share of city area [%]	Main Sustainability and Biodiversity Goals	Academic Context
Cologne	1 Million	54 % urban infrastructure, 44 % vegetated area, 5 % blue infrastructure	8.4 %	Climate neutrality by 2035; promotion of sustainable mobility, energy and urban planning; expansion of green spaces and urban trees, strengthening ecological connectivity	Major research and university city with 100.000 students and 31 higher education and research institutions
Bielefeld	330,000	45 % urban infrastructure, 54 % vegetated area	8 %	Climate neutrality by 2030; promotion of renewable energy and green mobility; ecosystem restoration and biodiversity conservation	Regional university center with strong interdisciplinary research

9.3 Policy documents

Table 5. Overview of evaluated online resources and policy documents, including city websites, biodiversity, climate, sustainability or/and city development strategies as well as reports.

Websites	
Stockholm	https://start.stockholm/
	https://www.miljodatastockholm.se/
Uppsala	https://www.uppsala.se/
Cologne	https://www.stadt-koeln.de/
	https://www.klimaschutz-monitoring.koeln/
Bielefeld	https://www.bielefeld.de/

Strategies

Stockholm	Stockholms stad. (2021). Handlingsplan för klimatanpassning 2022–2025. https://start.stockholm/globalassets/start/om-stockholms-stad/politik-och-demokrati/styrdokument/handlingsplan-for-klimatanpassning-2022-2025_ta.pdf.
	Stockholms stad. (2024a). Climate Action Plan 2030 A just transition for a Stockholm with no global carbon footprint. https://start.stockholm/globalassets/start/om-stockholms-stad/politik-och-demokrati/styrdokument/climate-action-plan-2030.pdf
	Stockholms stad (2024b). Environment Programme 2030. environment-programme-2030.pdf (accessed April 05, 2026).
	Stockholms stad. (n.d. c). Handlingsplan för biologisk mångfald i Stockholm stad. https://meetingspublic.stockholm.se/welcome-sv/namnder-styrelser/ostermalms-stadsdelsnamnd/mote-2020-09-24/protocol/bilaga-handlingsplan-for-biologisk-mangfald-i-stockholmpdf?downloadMode=open.
Uppsala	
	Uppsala kommun. (2025). Environmental and Climate Programme. https://www.uppsala.se/contentassets/5d36faebce83404888c3a4677bad5584/environment-and-climate-programme.pdf.
	Uppsala kommun. (2026a). Grönblå Grön- och strukturplan blåstrukturplan Del av översiktsplanen- del av översiktsplaneringen. https://www.uppsala.se/contentassets/9ebb930e26364751bd9b298c5d6b9725/antagandehandling-gron--och-blastrukturplan.pdf.
Cologne	City of Cologne (2020): Stadtstrategie 2.0 – Kölner Perspektiven 2030+. https://www.stadt-koeln.de/mediaasset/content/pdf15/kp2030/stadtstrategie.pdf.
Bielefeld	Stadt Bielefeld. (2021). *Nachhaltigkeitsstrategie der Stadt Bielefeld (NHS)*. https://www.bielefeld.de/sites/default/files/datei/2021/NHS.pdf.

Reports	
Stockholm	Stockholms stad (2025). Hållbarhetsrapport 2025. https://start.stockholm/om-stockholms-stad/utredningar-statistik-och-fakta/utredningar-och-rapporter/hallbarhet/ (accessed April 05, 2026). Stockholms stad. (2024c). Uppföljning av Stockholms stads miljöprogram och klimatbudget 2023. https://start.stockholm/globalassets/start/om-stockholms-stad/utredningar-statistik-och-fakta/utredningar-och-rapporter/hallbarhet/klimat-och-miljo/uppfoljning-av-stockholms-stads-miljoprogram-och-klimatbudget-2023.pdf.
Uppsala	Uppsala kommun. (2021). Uppsala and Agenda 2030: Voluntary Local Review 2021. Uppsala Municipality. https://www.uppsala.se/contentassets/cfd3db5376084b168bce67e57ce73dcc/uppsala_and_agenda_2030_vlr-rapport_2021.pdf.
Cologne	City of Cologne. (2022) Nachhaltigkeitsbericht der Stadt Köln 2022 nach dem Berichtsrahmen Nachhaltige Kommune (BNK) im Kontext der Agenda 2030. https://www.stadt-koeln.de/artikel/72093/index.html (accessed April 12, 2026). City of Cologne. (2023). Voluntary local review 2023 Köln: Implementing the 2030 Agenda and the Sustainable Development Goals at the local level. https://www.stadt-koeln.de/artikel/72093/index.html (accessed April 12, 2026).
Bielefeld	Stadt Bielefeld. (2024). *Nachhaltigkeitsbericht der Stadt Bielefeld: Agenda 2030 auf lokaler Ebene*. https://www.bielefeld.de/sites/default/files/datei/2024/Nachhaltigkeitsbericht-der-Stadt-Bielefeld-Marz-2024_0.pdf.

9.4 Coding example

Table 6. Coding example based on an excerpt from the interview with the city representative of Uppsala. The left column presents the original interview passage, while the right column contains some comments. Institutionalization is marked bold, biases and limitations in red and potential in green.

For species specifically, I think, **Artportalen is the main resource for us and for everyone else managing forests**. But of course, if you want to make a real management plan and say we decided that this piece of forest is going to have a nature conservation purpose, then we have to **complement this with actual professional field inventories from professionals**. Often the species observations in Artportalen can be really good, but there also quite few examples that it is wrong. Either the species is wrongly identified or on the wrong spot. So, you have to **maintain an awareness** if this is likely to be correctly inventoried or is it long time ago.	**Integrated into municipal work for species monitoring** **Artportalen as primary source of information, established and wide used tool** **Hybrid approach, need for expert validation for law related topics** Acknowledgement of data quality But also data inaccuracies, error potential (species misidentification, spatial inaccuracies) **→ critical evaluation of data, expert judgement required, data validation processes**

Popular science summary

Today, collecting species is a bit like catching Pokémon, just in real life. With a smartphone in hand, we are now recording plants, birds, insects and other animals around us, playfully contributing to science, simply by taking a photo or uploading an observation. Yet, the more we look, the more we notice, what is disappearing.
Healthy ecosystems are essential for human health and well-being, providing clean air and water, food, recreational values and climate regulation. Biodiversity is the foundation of these ecosystem services. However, biodiversity is currently declining at an unprecedented rate due to urban growth, habitat loss and climate change. To understand and protect it, we need reliable data about where species are found and how their populations are changing over time. While professional monitoring is often costly and time-consuming, citizen science offers a useful complement. Through apps and online platforms, thousands of people document the species they encounter in parks, gardens, forests and even on city streets, creating a large dataset across space and time. Although these datasets can be uneven or contain errors, they still provide highly valuable information for research and conservation.

This thesis examined how citizen-generated observations are actually used by city authorities, focusing on Stockholm, Uppsala, Cologne and Bielefeld. The results show that citizen science is no longer just a hobby activity. It is directly used to support biodiversity monitoring, track species distributions and inform urban planning and conservation decisions. In Sweden, a national platform called Artportalen makes it easy for municipalities and researchers to access and use citizen observations in a structured way. In Germany, the situation is more fragmented, with many different local initiatives that are often species-specific or project-based, making integration more dependent on local networks and resources.
Importantly, citizen science is not replacing professional science. Experts still play a key role in verifying data and conducting detailed ecological surveys, while citizen observations help fill in gaps across space and time. Together, they create a more complete and dynamic picture of urban nature. The integration of AI offers further potential to improve data quality and reduce bias, though careful interpretation of citizen science data always remains essential. Clear guidelines for data collection and use could significantly strengthen trust in this data source, particularly in Germany, where transparency and reliability are central to public and institutional acceptance.
Ultimately, citizen science shows how environmental knowledge is becoming something more shared and participatory. It connects everyday life with scientific research and turns simple encounters with nature into valuable information. By engaging with the species around them, citizens can make a meaningful contribution to the environments they live in, not only for today, but for future generations. In a

time when biodiversity is under pressure, this combination of public involvement and scientific expertise may become an increasingly important part of how cities understand and protect nature around them.

Publishing and archiving

☒ YES, I, Alina Strangfeld, have read and agree to the agreement for publication and the personal data processing that takes place in connection with this