TITLE

SUBTITLE

JAKOB WORM, 202004405

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Advisor: Peter Gall Krogh

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JAKOB WORM

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Jakob Worm: *Title,* Master’s Thesis © April 2025

ABSTRACT

Short summary of the contents in English...

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ACRONYMS

HCI Human Computer Interaction
SHCI Sustainable Human-Computer Interaction
SID Sustainable Interaction Design
SDG Sustainable Development Goals

1 INTRODUCTION

1.1 GENERATIVE AI DECLARATION

For this thesis, I have used Generative AI as a programming aid. The models used in order of magnitude are Claude 3.7 Sonnet, GPT3 and GPT4 in the form of GitHub CoPilot, and ChatGPT 4. All three have been used to provide suggestions and improvements to the codebase and for code generation and completion. GPT4 have also been used to create BibTeX citations for websites with prompts like *https://www.inaturalist.org/ Can you create a BibTeX citation for this website*

1.2 (WHAT IS THIS THESIS ABOUT TEMP TITLE)

In this thesis, I investigate an aesthetic auditory map experience called Urban Echoes and its potential to engage users in their local bird wildlife. Furthermore, I detail the application's creation, decisions, and underlying work, along with discussions on related work and how my work differs. Lastly, the thesis covers the evaluation and results thereof including prospects for future work.

The idea for Urban Echoes is a continuation of a previous idea developed in a 10 ECTS project on more than human-centred design[6] that I conducted together with Magnus Lasse Lund Bentsen, a fellow IT product development master's student, last semester. The 10 ECTS project ended with a report and a rough prototype of this original idea, which can be found in Appendix A.1 and Appendix A.2 respectively. However, the continuation into a master's thesis has seen many alterations in the idea, and as such, the original work is not required to understand the concept.

Urban Echoes lets the user take on two roles, that of the observer and listener. When observing users can make sightings/observations of birds by either seeing or hearing them. Users observe the type of bird and amount the application will then save this along with the geospatial location, date and time of day. The observations are saved in a central database. The listener role allows users to explore the auditory map created using the observations. A point will represent the observation located at the position where it was recorded. The point will have a radius of 50 meters and sounds of the observed bird will play depending on the time of day and increase in loudness the closer towards the centre a listener might be. Observation points can overlap with up to three points playing simultaneously.

1.3 USING AESTHETIC AUDITORY EXPERIENCES FOR ENGAGING PEOPLE IN LOCAL BIRDLIFE

Urban Echoes is a communally crafted audio mapping of local bird wildlife created to engage urban residents in local bird wildlife. It's built upon the belief, that an increased engagement will help with conservation and reintegration efforts. Birds have been chosen as the subject for the application because of their prevalence worldwide and the diversity and perceived pleasant qualities of their soundscapes. Bird sounds have even been found to help with stress and attention recovery[23] showcasing the beneficial effect their presence can have on humans. It's important to note that the types of sounds that have these effects depend on personal preference and experience [23]. One of the aspects cited as restorative is the feeling of being connected with nature[23]—something I wish to test if Urban Echoes recreate despite digitalized audio. Similar auditory work by Lawton et al.[14] used speakers in a forested area to play bird sounds. They found that nature soundscapes have many beneficial effects even when digitalised, such as making people pay more attention to their visual surroundings, increasing their perceived enjoyment, and making them think about the loss of nature[14]. The Urban Echoes application is geared towards urban dwellers, as urban soundscapes have considerably more noise pollution[22] than rural areas. As a primarily audio-based application, it seeks to create a memorable experience through the aesthetics of use[21]. Mabey I should write some more about aesthetics and also mention storytelling in this part

1.4 THE ROLE OF TECHNOLOGY IN THE PRESERVATION OF LOCAL ENVIRONMENTS

The call for climate action and nature conservation has in recent years gained more attention, and rightly so. With the global community behind on 41 out of 42 indicators to achieve the 2030 goals of the Paris Agreement[2] the prospects of achieving these goals become more and more difficult.

Within Human-Computer Interaction Human Computer Interaction (HCI), the challenge for climate action has been seized, and the resulting fields, of Sustainable HCI Sustainable Human-Computer Interaction (SHCI) and Sustainable Interaction Design Sustainable Interaction Design (SID), were created after two influential papers by Eli Blevis

[1, 16]. These new fields had a newfound focus on using technology to promote sustainability in the user's life across many sectors, such as the environment, social justice, public health, and other areas concerning building a sustainable future.

A literature review by Hansson et al. (2021) surveying the field of SHCI found that research in this area is linked to a broad range of the United Nations' Sustainable Development Goals Sustainable Development Goals (SDG), with published work addressing 6 out of the 17 goals. This highlights the interdisciplinary and wide-reaching nature of the field [11]. Much of the research focuses on the direct application of technology to address specific SDG-related challenges. For example, Hansson et al. Hansson, Cerratto Pargman, and Pargman [11] report that of the 26 studies mapped to SDG Target 12.2—"By 2030, achieve the sustainable management and efficient use of natural resources"—the majority (18 papers) explored eco-feedback or eco-visualisation systems. These systems aim to make resource consumption more visible and understandable, to promote more sustainable behaviours.

In contrast the paper "Have We Taken On Too Much?: A Critical Review of the Sustainable HCI Landscape" by Bremer et al. argues that SHCI is not suited to create large-scale change across large and complex problem areas involving various disciplines with the direct application of technology. Instead, they argue that SHCI researchers should seek to incorporate Green policy informatics[3] into their projects. Green policy informatics is the idea that technology should help promote climate action by providing tools for transparency and supporting complex decision-making. Beyond that, it should encourage communities and support the push for green policies.

I believe that both ways of thinking have their merits. My project is closer to the more direct application school of thought of SHCI as there are no direct pathways to incite policy changes or form communities but rather a focus on inciting the individual's interest in local wildlife. This stems from a focus on individual interest and emotional experiences rather than actively pushing for radical changes or community creation although, ideally, communities could arise around it as a result of use. However, there are no mechanics in the actual prototype that encourage an organized community. Instead, the prototype creates a common but anonymous creation to elicit emotions connected to the local nature. I will discuss this further in Chapter 4. To justify my decision to prioritize individual emotions and focus primarily on those living in urban environments, I will point to the global development of increasing urbanization. According to UN projections, 68% of the world's population is expected to live in urban settings by 2050[28]. As wild nature is more scarce in urban environments than in rural areas it follows that contact with wild nature will for an increasing amount of people be something to actively seek out instead of something they passively encounter. This section in my opinion needs a lot more work

The connection with nature and the experiences we associate with it matter to our ability to take climate action as shown in work by Chawla et al. [4] who found that formative experiences with wild nature are needed to develop a good sense of environmental sensitivity the interest to learn, take care of and feel concern for the environment[4]. Exacerbating the scarcity of wild nature in urban settings problematic is the fact that key urban-dwelling animals who thrive in cities such as pigeons, racoons, and rats, have poor reputations leading to negative or indifferent meetings between urban dwellers and the local wildlife[8]. Although many birds are commonly positively received, Urban Echoes aim to create memorable and positive experiences with all birds, even the more unpopular ones, such as gulls and pigeons.

1.5 HOW WILL THE WORK BE DONE?

2 RELATED WORK (CHAPTER FAR FROM DONE)

In this thesis section, I present related work that has inspired or reflected my project. Furthermore, I discuss similar commercial and scientific apps, their contributions and how Urban Echoes differs.

2.1 ENGAGING WITH NATURE THROUGH AUDIO CONTENT

This section and the following subsections is somewhat copied and rewritten from the pigeon report should I do some kind of citation of reference or simply delete or do a major rewrite Audio-based technologies are promising for fostering connections between humans, animals, and the environment. Several studies demonstrate how soundscapes and audio-augmented experiences can engage participants while raising awareness about ecological systems.

2.1.1 Nature soundscapes: an audio augmented reality experience

Lawton et al. demonstrate how augmented reality with audio has the potential to highlight the loss of nature[14] and make people reflect. To reintegrate animals and keep the ones we have, we need to be aware of the animals, how they adapt to humans and cities and what we can do to create spaces for all. Participants in their project became more aware of the loss of nature, with the soundscapes having the added benefit of fostering feelings of calmness and engagement with the local environment. However, certain trade-offs must be considered in implementing soundscape experiences. Although binaural audio through headphone playback is mentioned as an area of interest in Lawton's, it's also presented as having some limitations. As noted by Lawton et. al; "binaural audio, via headphone reproduction, detaches the listener from the real-world sounds in the environment" [14].

For any similar project like Urban Echoes, maintaining a connection to the immediate natural environment is a critical element of the augmented acoustic reality (AAR) experience. Encouraging participants to pay greater attention to the natural environment aligns with the objectives of Urban Echoes, however, in this project, the audio will be fully detached from the present physical environment and instead represent an event that has occurred. This partly stems from a desire to balance goals with ecological and practical considerations. Playing soundscapes in communal spaces, such as cities, can harm wildlife's natural behaviourNeed to find a reference or remove this sentence. By focusing on individual immersive experiences rather than communal sound installations. We minimize ecological disturbance while allowing participants to focus on the presented audio content, albeit at the cost of their immediate auditory surroundings. The design tries to remedy this by including the observer role to encourage users to experience real-world sounds and create observations in content-less areas. Additionally, I have a hypothesis that increased sonic awareness also increases the user's visual awareness of nature around themNeed to see if somebody has looked into this.

2.1.2 Interactive audio content: The use of audio for a dynamic museum experience

Dynamic, adaptive audio experiences also offer inspiration for engaging participants. Wakkary's work on interactive museum exhibits used audio icons and soundscapes to create personalized exploratory experiences for visitors [29]. This approach emphasizes the importance of designing adaptive, context-aware systems that respond to user interactions - an idea that we aim to incorporate into our project's use of audio to engage with urban ecosystems.

2.1.3 Audio-enabled locative media

write something about audio walks (Cardiff and Miller 1991) "placed sound" (Behrendt 2012) "situated sound" (Fagerjord 2011)

2.2 APPLICATIONS FOR ENGAGEMENT WITH BIRDS

There is a plethora of free applications on, identification, and engagement with local bird wildlife. The most prominent app in the field is Merlin ID[19], developed by Cornell Lab of Ornithology. The app allows users to identify birds based on their calls and songs. Furthermore, users can take images or describe the bird using pre-made queues and then get shown suggestions based on their answers. Looking at their app page it's apparent that the goal of the app is to engage people in birding and make the hobby more accessible to hobbyists and casual users alike. To ensure accuracy MerlinID suggestions are based on regional sightings made on eBird[25], one of the large citizen science[12] websites where birders can upload bird sightings.

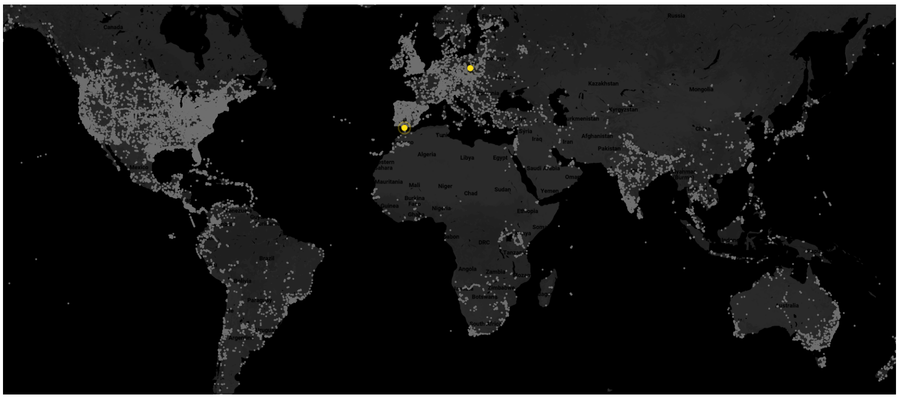

Figure 2.1: A screenshot of the eBird live map the 31-03-2025[31]

2.2.1 Citizen science and bird observation

Citizen science allows regular people to contribute to scientific projects by gathering data on a scale scientists would otherwise be unable to do[5]. The adoption of citizen science within the bird observation community has allowed researchers to increase their understanding of bird migration patterns and populations. Since eBirds operate on a global scale it allows for wider information than regional observation sites like the Danish DOFbasen[7]. Looking at the real-time map of eBirds, we can see that the global north is overrepresented compared to the global south indicating a disparity in the amount of data gathered, as seen in Figure 2.1, the light grey dots indicate a recording. Also write something about Bird Sounds global[10].

Merlin Bird ID, Lyden af Danmark, iNaturalist, Gobird and eBird. Mabey also echoes for the audio walk

Inaturalist[32] is another citizen science application with an accompanying website which focuses on the documentation of wildlife, plants and fungi and thus encompasses a much larger field than eBirds. To keep people engaged, Inaturalist encourages sharing and discussion of nature on the website and application. It lends itself to a more communal experience than the more individual-focused eBird and Merlin ID. This section needs more work

2.3 THE POWER OF MAPS

Needs some kind of introduction I think What does this map tell us? It will not be a mapping of the real world or of where the birds are, instead, it will show where the users choose to engage with the app. Cities could be overrepresented compared to rural areas, with a lower number of users but conceivably larger bird populations. This follows a view of the interaction as something not just between the application and the user but the wider circumstances surrounding the design[26]. Similarly, the app's functionality relies on a stable connection and can therefore more so be used to represent the internet connection rather than the bird population. This can be misleading if I do not clarify that this is not a direct mapping of the local birds.

Used as a sound of maps[27] Either remove or expand

The sound enhanced the traditional map viewing experience[13]. They augmented a digital map of a hiking area by mapping sound files to areas of the map users when moving their cursor above a certain area like the forest would hear the associated sound. This both helped people with impaired vision gain something from the map-viewing experience and improved the general perception of use. weak section remove or expand

This section should end with what kind of power the urban Echoes map would have expand

2.4 DIGITAL STORYTELLING

Perhaps write something about biobliztz in a previous chapter or introduce it here

During a research project aimed at creating an app for finding a rare cicada using citizen science and audio recordings. The researchers found a large reluctance toward digital applications among both professional and amateur naturalists who participate in bioblizt[17] who preferred more traditional tools such as pen and paper. Nature appreciation was one of the mentioned reasons for this preference. With UrbanEchoes the goal is to highlight the nature that exists within cities.

They found that the user had problems with orientation and GPS fidelity, which encouraged them to use a marker-based solution for the videos instead[18]. When the GPS did not function as expected, the user spent a lot of time looking at the phone instead of the environment, this could hint at a lesson for Urban Echoes about not relying too much on the fidelity of the GPS to create the experience. Another feature of the seven-stories prototype I might learn from is using vibrations to indicate that content is available at a given location. They found this was pleasantly experienced for the users and could indicate the potential for the life beat earlier discussed (I need to have discussed this)

Similarly, another audio guide using only auditory media found that removing the map and instead guiding the user using sound decreased screen usage and increased observation and engagement[20].

Maybe some more on digital storytelling Look at communal stuff

Aesthetics interactions(ref this) The bird-bath and feeders quasi-social relationship between birds and humans

2.5 AUDIO BASED INTERFACES

3 ANALYSIS

3.1 AUDIO DESIGN

A quality audio design is essential for the application's user experience. When starting the project, I considered the audio quality in terms of sampling rate and bitrate. This perspective changed after discussing my project with audio experts in sound study and sound aesthetics. They pointed me in the direction of soundscapes[24] and acoustic ecology[24, 30]. Both soundscapes and acoustic ecology hint at the interplay between sounds and how these affect each other to form a complete impression, much akin to how each instrument in the orchestra forms the coherent listening experience. Transposing a sound file with all its acoustic ecology to be played at a place we intricately know has a vastly different acoustic ecology creates a dissonance in the experience. Imagine, for example, walking down a street in a European city while a recording of the Common Swift is playing. The sound of the bird might be familiar and fit in as the common swift can be found in European cities. Still, if the soundscape of the sound files is that of the sub-Saharan rainforest with all its associated sounds, it is clear that the soundscape does not belong to the street you are walking on. As I seek to give users an affiliation with their local nature through sound, the soundscape must fit with what we expect.

Looked at how landscapes changed the perception of the soundscape[15]. They found that spatial arrangement matters more than individual elements when it comes to perception.

For my rough prototype, I found specific sound files with as little background noise as possible so I could transpose them. However, for the final prototype, I decided to use the initial approach of randomly selected quality A files as the other approach was to time-consuming. However, for future work the implementation of a filter could increase audio quality and user experience significantly.

4 DESIGN OF ARCHITECTURE AND EVALUATION

4.1 ROUGH PROTOTYPE (WRITE SOME STUFF ABOUT DESIGN AS RESEARCH)

To experience how the prototype would feel I decided to test a rough implementation capable of playing the observations to create a listener experience.

This presents itself as a vertical slice of the final application capable of all the features relating to the audio walk part but lacking features such as observation recording, logging on and sending, plus tracking the trip.

To find out what kind of birds I would use for the rough prototype I went on a walk in the area, and listened to the sounds of the birds. I found that the neighbourhood of the villa, where there are many large gardens with trees, had significantly more birds. Observing the birds, I also found a lot more than when going for a regular walk, highlighting the potential of the observer role as it encourages greater sonic awareness to identify the birds. I found that the birds at long periods did not produce any sounds, which I initially wanted to emulate for the prototype before I decided on a more exaggerated approach. Additionally, I thought about the radius, and I think somewhere between 30 and 50 meters seems fine without having tested it further. These sounds drown out the birds near the road or during construction work.

The birds I encountered during my short walk were the following:

- Eurasian Blackbird (Turdus merula)
- European Herring Gull (Larus argentatus)
- Common Wood Pigeon (Columba palumbus)
- Eurasian Blue Tit (Cyanistes caeruleus)
- Rook (Corvus frugilegus)
- Common Gull (Larus canus)
- Eurasian Tree Sparrow (Passer montanus)
- European Greenfinch (Chloris chloris)

These were inserted as points into the database with the relevant coordinates and times.

I tested the rough prototype with my advisor and later with a fellow IT product development master student. A bug related to the GPS functionality hindered the evaluation of the prototype somewhat with the GPS updating infrequently causing certain observations to play for either an extended time and others from playing at all. However, both tests allowed me to reflect on both successes and what needed to be improved. One finding related to the exaggerated nature of the calls in the application when compared to real life sightings the audio recordings would be both louder and of higher intensity than the actual calls and song.Perhaps i should write a bit more about findings and what changes this led to in te actual protoype

4.2 BACKEND

The backend is a fast-API Python backend running on Microsoft Azure.

4.3 AUDITORY WORK AND HOW IT TRANSLATES TO CODE(SHOULD BE IN ANOTHER SECTION MAYBE)

5 IMPLEMENTATION

5.1 BACKEND STUFF

The backend runs on a student subscription to Azure. It's a fast API backend with a Postgres database with one table for observations. I run an Azure storage blob for the sound files. All sound files have been collected from xeno-carto[9]. Furthermore, I use the eBird[25] to populate the database I technically don't do this anymore but for the final prototype might want to so I should be aware and make adjustments based on this

I use the scientific names for the backend as they are language-independent, lending to a more scalable approach.

6 EVALUATION

6.1 FUTURE WORK

To use the sightings as a reliable database, it's necessary to have verification of the sightings. A few approaches to this could be the use of cross-referencing the sightings with eBird and other users. A user with a history of making high-credibility observations could have a higher certainty measure when uploading an observation. Another approach for verification could use AI for sound identification or image recognition, but this would also force users to either take a picture or recording.

Another interesting avenue of work would be integrating the features of Urban Echoes into large birding applications like MerlinID or GoBirds. Integrating UrbanEchoes into MerlinID, for example, would allow observations to be created when the user records a bird for identification.

7 CONCLUSION

FINITO

Part I

APPENDIX

A PROJECT WORK ON MORE THAN HUMAN CENTRED DESIGN

A.1 THE REPORT FROM THE PROJECT WORK

I am unsure if I should the whole report or just a link for now I go with the link. **Link to a GitLab project containing the report Link:** `https://gitlab.au.dk/pigeon-project/exploring-multi-species-perspectives-in-hci-through-`

A.2 THE EARLY PROTOTYPE FOR URBAN ECHOES

Link to GitLab containing the source code for the project prototype Link: `https://gitlab.au.dk/pigeon-project/audioapp`

BIBLIOGRAPHY

[1] Eli Blevis. "Sustainable interaction design: invention & disposal, renewal & reuse." In: *Proceedings of the SIGCHI conference on Human factors in computing systems*. 2007, pp. 503–512.

[2] Sophie Boehm, Louise Jeffery, Judit Hecke, Clea Schumer, Joel Jaeger, Claire Fyson, Kelly Levin, Anna Nilsson, Stephen Naimoli, Emily Daly, et al. "State of climate action 2023." In: (2022).

[3] Christina Bremer, Bran Knowles, and Adrian Friday. "Have We Taken On Too Much?: A Critical Review of the Sustainable HCI Landscape." In: *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. CHI '22. New Orleans, LA, USA: Association for Computing Machinery, 2022. ISBN: 9781450391573. DOI: 10.1145/3491102.3517609. URL: https://doi.org/10.1145/3491102.3517609.

[4] Louise Chawla. "Significant life experiences revisited: A review of research on sources of environmental sensitivity." In: *The Journal of environmental education* 29.3 (1998), pp. 11–21.

[5] Jeffrey P Cohn. "Citizen science: Can volunteers do real research?" In: *BioScience* 58.3 (2008), pp. 192–197.

[6] Paul Coulton and Joseph Galen Lindley. "More-than human centred design: Considering other things." In: *The Design Journal* 22.4 (2019), pp. 463–481.

[7] Dansk Ornitologisk Forening. *DOFbasen - Dansk Ornitologisk Forening*. Accessed: 2025-03-31. 2025. URL: https://dofbasen.dk/.

[8] Robert R. Dunn, Michael C. Gavin, Monica C. Sanchez, and Jennifer N. Solomon. "The Pigeon Paradox: Dependence of Global Conservation on Urban Nature." In: *Conservation Biology* 20.6 (2006), pp. 1814–1816. ISSN: 08888892, 15231739. URL: http://www.jstor.org/stable/4124710 (visited on 11/08/2024).

[9] Xeno canto Foundation and Contributors. *Xeno-canto: Sharing bird sounds from around the world*. Accessed: 2024-03-06. 2024. URL: https://xeno-canto.org.

[10] Bird Sounds Global. *Bird Sounds Global*. Accessed: 2025-03-24. 2025. URL: https://bsg.laji.fi/.

[11] Lon Åke Erni Johannes Hansson, Teresa Cerratto Pargman, and Daniel Sapiens Pargman. "A Decade of Sustainable HCI: Connecting SHCI to the Sustainable Development Goals." In: *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. CHI '21. Yokohama, Japan: Association for Computing Machinery, 2021. ISBN: 9781450380966. DOI: 10.1145/3411764.3445069. URL: https://doi.org/10.1145/3411764.3445069.

[12] Alan Irwin. *Citizen science: A study of people, expertise and sustainable development*. Routledge, 2002.

[13] Mari Laakso and L Tiina Sarjakoski. "Sonic maps for hiking—use of sound in enhancing the map use experience." In: *The Cartographic Journal* 47.4 (2010), pp. 300–307.

[14] Mark Lawton, Stuart Cunningham, and Ian Convery. "Nature soundscapes: an audio augmented reality experience." In: *Proceedings of the 15th International Audio Mostly Conference*. 2020, pp. 85–92.

[15] Jiang Liu, Jian Kang, Holger Behm, and Tao Luo. "Effects of landscape on soundscape perception: Soundwalks in city parks." In: *Landscape and urban planning* 123 (2014), pp. 30–40.

[16] Jennifer C Mankoff, Eli Blevis, Alan Borning, Batya Friedman, Susan R Fussell, Jay Hasbrouck, Allison Woodruff, and Phoebe Sengers. "Environmental sustainability and interaction." In: *CHI'07 extended abstracts on Human factors in computing systems*. 2007, pp. 2121–2124.

[17] Stuart Moran, Nadia Pantidi, Tom Rodden, Alan Chamberlain, Chloe Griffiths, Davide Zilli, Geoff Merrett, and Alex Rogers. "Listening to the forest and its curators: lessons learnt from a bioacoustic smartphone application deployment." In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '14. Toronto, Ontario, Canada: Association for Computing Machinery, 2014, 2387–2396. ISBN: 9781450324731. DOI: 10.1145/2556288.2557022. URL: https://doi.org/10.1145/2556288.2557022.

[18] Valentina Nisi, Enrico Costanza, and Mara Dionisio. "Placing Location-Based Narratives in Context Through a Narrator and Visual Markers." In: *Interacting with Computers* 29.3 (July 2016), pp. 287–305. ISSN: 0953-5438. DOI: 10.1093/iwc/iww020. eprint: https://academic.oup.com/iwc/article-pdf/29/3/287/11149005/iww020.pdf. URL: https://doi.org/10.1093/iwc/iww020.

[19] Cornell Lab of Ornithology. *Merlin Bird ID App*. 2025. URL: https://merlin.allaboutbirds.org/.

[20] Tilde Pedersen, Edith Terte Andersen, and Anders Sundnes Løvlie. "Designing a "no interface" audio walk." In: *Museums and the Web*. 2019.

[21] Marianne Graves Petersen, Ole Sejer Iversen, Peter Gall Krogh, and Martin Ludvigsen. "Aesthetic interaction: a pragmatist's aesthetics of interactive systems." In: *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques*. 2004, pp. 269–276.

[22] Manon Raimbault and Danièle Dubois. "Urban soundscapes: Experiences and knowledge." In: *Cities* 22.5 (2005), pp. 339–350. ISSN: 0264-2751. DOI: https://doi.org/10.1016/j.cities.2005.05.003. URL: https://www.sciencedirect.com/science/article/pii/S0264275105000557.

[23] Eleanor Ratcliffe, Birgitta Gatersleben, and Paul T. Sowden. "Bird sounds and their contributions to perceived attention restoration and stress recovery." In: *Journal of Environmental Psychology* 36 (2013), pp. 221–228. ISSN: 0272-4944. DOI: https://doi.org/10.1016/j.jenvp.2013.08.004. URL: https://www.sciencedirect.com/science/article/pii/S0272494413000650.

[24] R Murray Schafer. *The soundscape: Our sonic environment and the tuning of the world*. Simon and Schuster, 1993.

[25] Brian L. Sullivan, Christopher L. Wood, Marshall J. Iliff, Richard E. Bonney, Daniel Fink, and Steve Kelling. "eBird: A citizen-based bird observation network in the biological sciences." In: *Biological Conservation* 142 (2009), pp. 2282–2292.

[26] Alex Taylor. "After interaction." In: *Interactions* 22.5 (Aug. 2015), 48–53. ISSN: 1072-5520. DOI: 10.1145/2809888. URL: https://doi.org/10.1145/2809888.

[27] Samuel Thulin. "Sound maps matter: expanding cartophony." In: *Social & Cultural Geography* 19.2 (2018), pp. 192–210. DOI: 10.1080/14649365.2016.1266028. eprint: https://doi.org/10.1080/14649365.2016.1266028. URL: https://doi.org/10.1080/14649365.2016.1266028.

[28] United Nations, Department of Economic and Social Affairs, Population Division. *2018 Revision of World Urbanization Prospects*. Accessed: 2025-03-17. 2018. URL: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html.

[29] Ron Wakkary, Kenneth Newby, Marek Hatala, Dale Evernden, and Milena Droumeva. "Interactive audio content: The use of audio for a dynamic museum experience through augmented audio reality and adaptive information retrieval." In: *Museums and the Web 2004: Selected Papers from an International Conference, Vancouver, Canada*. Simon Fraser University. 2004, pp. 55–60.

[30] Kendall Wrightson. "An introduction to acoustic ecology." In: *Soundscape: The journal of acoustic ecology* 1.1 (2000), pp. 10–13.

[31] eBird. *eBird Live Subscriptions*. Accessed: 2025-03-31. 2025. URL: https://ebird.org/livesubs.

[32] iNaturalist. *iNaturalist: A Community for Naturalists*. Accessed: April 8, 2025. 2025. URL: https://www.inaturalist.org/.