Implications of Interface Design

A Case Study of the Global Flyway Network and Movebank

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Abstract

Currently, the world is facing an internationally-recognized biodiversity crisis. This crisis can be averted by promoting efforts to halt biodiversity loss and increase knowledge-based management. To achieve these goals, global cooperation and local action are needed. Interactive biodiversity databases can help this cause. Therefore, this research examines the implications of interface design for biodiversity databases in foregrounding different types of knowledge and engaging users. The case study focuses on the Global Flyway Network and Movebank, two organizations dedicated to halting biodiversity loss and advancing ecological research efforts by facilitating the public with an interactive animal movement tracking map. Analysis reveals that while both interfaces focus on taxonomic data, a more holistic understanding of ecosystem functioning can also be obtained by addressing multispecies data. Additionally, the importance of creating inclusive and well-designed biodiversity interfaces is underlined.

Keywords: biodiversity databases, interface design, knowledge foregrounding, user engagement, animal movement tracking

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Introduction

Biodiversity is one of the most important building blocks of a strong and healthy ecosystem. Since human and planetary health also highly correlate to ecosystem health, it is vital for humans to protect biodiversity (*Biodiversity*, n.d.; Russell, 2019). However, the world is currently facing a biodiversity crisis, possibly even the sixth mass extinction (Ceballos et al., 2015). The importance of biodiversity is internationally recognized and included in the Sustainable Development Goals (SDGs), specifically in SDG target 15.5, which states "to halt the loss of biodiversity" (*Goal 15 | Department of Economic and Social Affairs*, n.d.). Additionally, the Aichi Biodiversity Targets advocate for, among other goals, a halt of biodiversity loss and increased knowledge-based management (Secretariat of the Convention on Biological Diversity, 2020). Lastly, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) assesses the state of global biodiversity and publishes reports for policy-making regarding halting biodiversity loss (*About | IPBES Secretariat*, n.d.).

Both global cooperation and local action are needed to achieve these goals, and interactive biodiversity data interfaces can contribute to this. An interface can be defined as an organized space between a system and an agent, such as a website (Cramer & Fuller, 2008). It could be beneficial for such biodiversity data interfaces to be open and accessible for both researchers and the public. This is to ensure that as many members of society as possible are involved, interested and educated in the conservation of biodiversity (Canhos et al., 2015; Leonelli, 2022). However, the literature also states to be cautious in opening databases for the wide public; the reasoning behind this statement will be touched upon in the following sections (Leonelli, 2022). Next to this, not only the predominantly used taxonomic biodiversity data is needed, but also knowledge about interspecies relations is necessary to obtain a better

understanding of how biodiversity should be conserved in order to foster healthy ecosystems and counter the biodiversity crisis (König et al., 2019).

How biodiversity databases and their respective interfaces are designed has a big influence on the type of knowledge created and the different users that will engage with the data (Turnhout & Boonman-Berson, 2011). Therefore, the following research question will be answered in this research project: "What are the implications of interface design of biodiversity databases for foregrounding different kinds of knowledge and for engagement of different kinds of users?" This will be done by performing a case study of the Global Flyway Network and Movebank through structural analysis of their respective interfaces.

Firstly, the Global Flyway Network (GFN) is a community of researchers working on the understanding and conservation of long-distance migratory shorebirds (*About*, n.d.). The GFN's website is currently aimed at providing information for other researchers, but it is not as easily understandable to the general public. Recently, the GFN stated they wish to update their website in order to make certain improvements. These improvements would include, among others, attracting a more diverse group of users, introducing a field app, and shifting the focus from data mainly recognizing species to data describing interspecies relations and natural processes.

Secondly, Movebank is a global, open-access online database for animal tracking data coordinated by the Max Planck Institute of Animal Behavior (*Movebank*, n.d.-a). Their aim is in many ways similar to the GFN: tracking animals and using this knowledge to understand animal movement as well as promoting conservation. However, their website has a different focal point, as they focus on all types of animals, whereas the GFN only looks at long-distance migratory shorebirds.

The current paper will first introduce literature surrounding the implications of foregrounding different kinds of knowledge and engaging different kinds of users. Additionally,

literature concerning interface design will be reviewed. Then, the walkthrough method, as presented by Light et al. (2016), will be thoroughly discussed as it is the basis for the execution of the website analyses. Next, the results from the analyses of both the GFN and Movebank interfaces will be presented and examined. Additionally, the two websites will be compared shortly to discuss the analyses' main points. Lastly, a concluding section will concretely answer the research question.

Literature Review

Implications of Foregrounding Different Kinds of Knowledge

There are different ways in which knowledge about biodiversity can be sorted and published. One is through systematics, which consists of three components: taxonomy, phylogenetics, and classification (Keogh, 1995). Taxonomy is the science of documenting biodiversity through collecting, discovering, and describing different species. Phylogenetics is the study of relationships between species determined by evolution. Classification combines the first two components resulting in the grouping of species based on taxonomic data and evolutionary characteristics (Keogh, 1995). Systematics can be useful in understanding the extent of the biodiversity crisis as it delivers insights into species population sizes as well as information about the increase and decrease of different species groups (Keogh, 1995; Lagomarsino & Frost, 2020). Additionally, in the current age of accumulating data on biodiversity, systematics can help bring order to this abundance of data (König et al., 2019). Furthermore, conservation, policy-making and evaluating the effectiveness of policies can benefit from systematics as it can help understand global biodiversity patterns (Lagomarsino & Frost, 2020). However, systematics as a single discipline cannot paint the whole picture of biodiversity, partly due to gaps in the data available. Additionally, within taxonomic data, there is also a bias present (Troudet et al., 2017). This bias entails that certain species are overrepresented in research while

others are underrepresented. Consequently, certain species, especially those that are favoured by society, receive extra funding (Troudet et al., 2017).

It can be beneficial to increase the number of data publications to fill the gaps in the currently available data on biodiversity (Costello et al., 2015). This would mean publishing data (sets) and making it freely available for all possible users in order to promote communication and collaboration between different institutions and organizations concerned with biodiversity (Costello et al., 2015). However, despite the numerous advantages of open data, it should still be approached with a certain extent of caution (Janssen et al., 2012; see also Appendix A). Reasons for this are, for example, discussed by Leonelli (2022). She argues that open science does not leave room for sufficient epistemic diversity. This is partly because in order to make different datasets compatible, they all have to assume the same format. This means a certain amount of diversity in research practices gets lost (Turnhout & Boonman-Berson, 2011). Leonelli, therefore, encourages debates around epistemic practices in open science about, for example, scaling and categorization of the data and openness to innovation in practices (Leonelli, 2022). There are additional concerns specifically for openly publishing data related to biodiversity. A main concern is that publishing, especially georeferenced, biodiversity data might disturb species, which can have destructive consequences, particularly for threatened species (Ganzevoort et al., 2017; Tulloch et al., 2018).

Additionally, data gaps can be filled by collecting data on biodiversity with different foci. Practically, these could include a focus on, for instance, traits or characteristics of species, interactions between species, or ecosystem functioning (Geijzendorffer et al., 2016). Efforts to understand multispecies or interspecies data can be beneficial to understanding biodiversity in a broader sense, resulting in more effective input for conservation efforts (Root et al., 2003). Multispecies and interspecies are foci referring to data focused on the coexistence of different species. Multispecies data refers specifically to the coexistence of species within a particular

environment, such as an ecosystem, whereas interspecies data focuses on the nature of relations between different species, for instance, parasitism or mutualism (Alatalo, 1981; Root et al., 2003). Realising such a shift in focus gives a more holistic and comprehensive overview of biodiversity. Next to that, it provides useful insights for policy-makers and conservationists (Geijzendorffer et al., 2016).

Lastly, the type of knowledge that is available strongly influences the type of questions that are asked (Beaulieu & Leonelli, 2021). For instance, if an interface only publishes systematic data, they might only inspire researchers to continue adding additional species, potentially exacerbating the already existing taxonomic bias. Similarly, a shift in focus of data type might result in trying to get a more holistic understanding of ecosystem functioning.

Implications of Engaging Different Kinds of Users

Citizen science can be an effective way of gathering more data on biodiversity (Ganzevoort et al., 2017; Wilson et al., 2020). It can therefore be beneficial to conservation efforts. Additionally, participation in citizen science projects regarding biodiversity can lead to an increased sense of connection with nature, improved skills in scientific conduct, increased interest in the environment and science, and heightened awareness of the biodiversity crisis in participants (Ekström, 2021; Ganzevoort et al., 2017).

Citizen science is a broad concept and can be divided into different levels. Haklay (2013) developed a framework consisting of four levels (see Appendix B for an illustration of the framework). Firstly, ‘crowdsourcing’, where citizens act as sensors and “cognitive engagement is minimal” (Haklay, 2013, p. 116). The second level is called ‘distributed intelligence’, where participants are basic interpreters of data and there is, to a certain extent, a communication flow from the participant to the researcher. The next level is ‘participatory science’, which entails that experts consult citizens for problem definition and data collection. The fourth level is

‘extreme citizen science’, where citizens can be completely integrated into the research. They can choose their level of engagement but can potentially be involved in any step of the research. An alternative framework regarding citizen science levels was developed by Arnstein (1969), comprising of eight levels with three overarching categories (see Appendix B for an illustration of the framework). First, she identified the category of ‘nonparticipation’, where citizens are not genuinely involved in the research but are rather objects for the researcher to “‘educate’ or ‘cure’” (Arnstein, 1969, p. 217). The second overarching category is ‘tokenism’, where citizens are involved but have no decision-making power or substantial insurance that their input will be used. ‘Citizen power’ is the last category, in which the extent of citizen participation ranges from partnerships with the expert to research where citizens have full control.

The degree to which an interface allows for citizen science determines what the organization will gain from involving citizens. When an organization allows citizens to be highly involved, there is potentially a continuous feedback process where the organization can learn from the participants’ experiences with the interface. Whereas, when an organization only allows citizens to be sensors, there will not be a two-way conversation between the parties. This example suggests that the most important aspect is the degree to which communication between the organization and the participants as facilitated by the interface (Jolibert & Wesselink, 2012).

Next to the level of citizen science accommodated for, it is important to consider the type of people that can engage with an interface. Many stakeholders are involved in halting biodiversity loss and increasing conservation efforts (Maxwell et al., 2018). Therefore, to reach this goal, an inclusive interface is needed. Not only should one of the stakeholders should feel inclined to engage with the interface, but it should also appeal to all people involved in order to yield the most relevant results (Jolibert & Wesselink, 2012; Maxwell et al., 2018).

Interface Design Choices for Biodiversity Databases

One of the most important aspects of interface design is to consider how to improve the user experience (UX). Luna et al. (2018) suggest several ways to facilitate this. Firstly, they recommend keeping the user interface simple and clean without too many distractions. Secondly, they emphasize the importance of using buttons and symbols familiar to the general public. Thirdly, limiting the amount of clicks necessary to arrive at the desired page will reduce the number of users leaving the website prematurely. All in all, increasing UX will ensure that users stay on the interface to engage with the content available.

If an organization wishes to have an active network of citizen scientists, it should facilitate this on the interface. As stated previously, it is imperative to have a two-way communication between researchers and participants to encourage citizen scientists. Additionally, the interface should allow for communication between participants to increase the feeling of belonging to a community of like-minded people. This network of communications can make users get a real sense of contributing to science (Luna et al., 2018).

There are endless options for interface design, even when limiting the options by looking at biodiversity data interfaces only. Due to the scope of this research, it is not feasible to go in-depth into all the different possibilities. However, it should be noted that each design will portray the data differently way and "render digital biodiversity through different lenses: as mobile or static, singular or multiple, orderly or chaotic" (Whitelaw & Smaill, 2021, p.1). By organising data differently on an interface or showing different pictures or visualisations associated with the data, the user will pick up on different relations and structures within the data. One of the most common (and conventional) ways to present biodiversity is by categorizing the data according to species. However, many other options exist, such as presenting the data according to geographical location or animal communities (Whitelaw & Smaill, 2021). Lastly, data, including biodiversity data, is in itself abstract. This means that

interfaces have the freedom to portray the data in any way they see fit for the narrative they want to exhibit (Drucker, 2011).

Methodology

Walkthrough Method

In this paper, I have used a (variant of) walkthrough method to analyse the GFN and Movebank websites structurally. The original cognitive walkthrough method was developed by Polson et al. in 1992. This cognitive walkthrough aimed to evaluate the ease of use and learning when interacting with an interface. This evaluation was done by dissecting seemingly simple, everyday tasks and evaluating the different steps and the links between these steps (Polson et al., 1992). In 2018, Light et al. developed an updated walkthrough method specially designed for mobile applications (apps). "The walkthrough method is a way of engaging directly with an app's interface to examine its technological mechanisms and embedded cultural references to understand how it guides users and shapes their experiences" (Light et al., 2018, p. 882). This walkthrough method is made up of two parts. First, the environment of expected use is defined and then the technical walkthrough is performed (Light et al., 2018). The methodology used in this paper mainly draws on the walkthrough method developed by Light et al., and even though their method is designed for apps, it is also applicable for websites as there are many similarities between those types of interfaces. I have performed a walkthrough for both the GFN (https://www.globalflywaynetwork.org/) and Movebank (https://www.movebank.org/cms/movebank-main) websites separately to be able to compare and contrast the two websites and identify unexpected practices.

In order to define the environment of expected use, Light et al. (2018) recommend discussing the organization's vision, operating model, and governance. The interface's vision involves its purpose, target group and suggestions for its use. The operating model includes the

economic strategy of the organization, which has implications for the political and economic interests and motivations. The governance of the interface relates to the management and regulation of user activity to execute the vision and sustain the operating model.

During the technical walkthrough, I placed myself in the position of user of the interface in order to critically analyse the user experience of the websites, with a focus on the websites' respective tracking interfaces. The technical walkthrough consisted of three different phases: registration and entry, everyday use, and app suspension, closure and leaving. In the process of walking through these steps, I executed several tasks.

These two parts of the walkthrough method have both been performed for the current report. However, only the aspects of the interfaces deemed relevant to the three overarching themes of this report have been included and discussed in the website analysis. The analysis section is a combination of both presenting the results and discussing them simultaneously. The overarching themes are knowledge foregrounding, user engagement, and interface design. For both interfaces, an analysis was performed in which these three themes are discussed. Additionally, the analyses of these interfaces are compared and contrasted in a final section of the analysis to discover and discuss outstanding aspects of the interfaces and possible improvement points.

Ethical Considerations

Concerning the execution of a walkthrough method of an interface with registered users, there are two main ethical considerations to be made (Light et al., 2018). Firstly, despite the fact that interaction with other users is not part of the walkthrough, creating an account for the sole purpose of performing a walkthrough may disturb other users, for example, when other users attempt to engage with the researcher's dummy account. The main strategy to avoid ethical complications is to not interact with other users, at least for the duration of the research.

Secondly, during registration, the user shares personal information, that is (partly) visible to other users. As a researcher, using this personal data that could be used to identify users would require obtaining informed consent. Data from the interface involving other users can only be used when it is completely anonymised. To conclude, overall, the ethical risks are relatively low.

Analysis

Analysis GFN Interface

Knowledge Foregrounding

The GFN is a global collaboration between researchers that work on studying long-distance migratory shorebirds (*About*, n.d.). Their interface consists of a regular website with explanations about, among other items, the GFN's goals, publications, team, and funding. The full list is shown in *figure 1*. Next to that, the website has a tracking interface, depicted in *figure 2*, where users can engage with a world map to explore viewing the movement tracks of different birds.

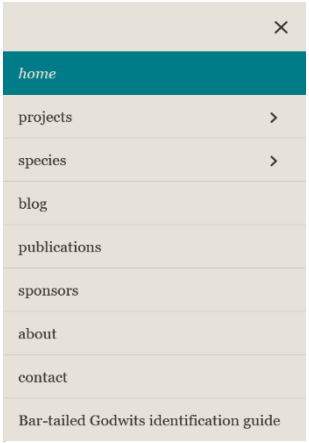


Figure 1: Left side menu GFN

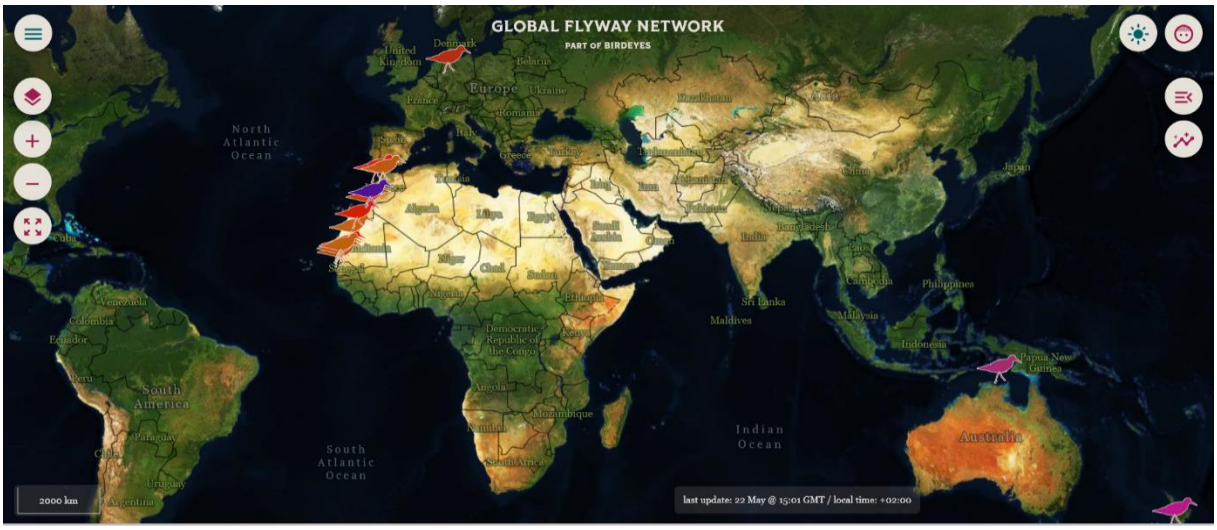


Figure 2: Tracking interface GFN

On the home page (*figure 3*), there is a strong focus on showing taxonomic data, which is visible in the way that users immediately see a selection of seven bird species. They can

choose to view the tracks of each of these species separately, but there is no option to view a map with all the different species on the map. Additionally, only seven species are being tracked on the GFN interface, which narrows the breadth of the GFN focus significantly. The common aspect between these species is that they are all long-distance migratory shorebirds, which the GFN identifies as their research focus. They also state to conduct research about understanding global climate change from a bird's point of view, specifically long-distance migratory shorebirds (*About*, n.d.). This means it makes sense that they only focus on a relatively small selection of species. However, the choices for these particular species are nowhere explained.

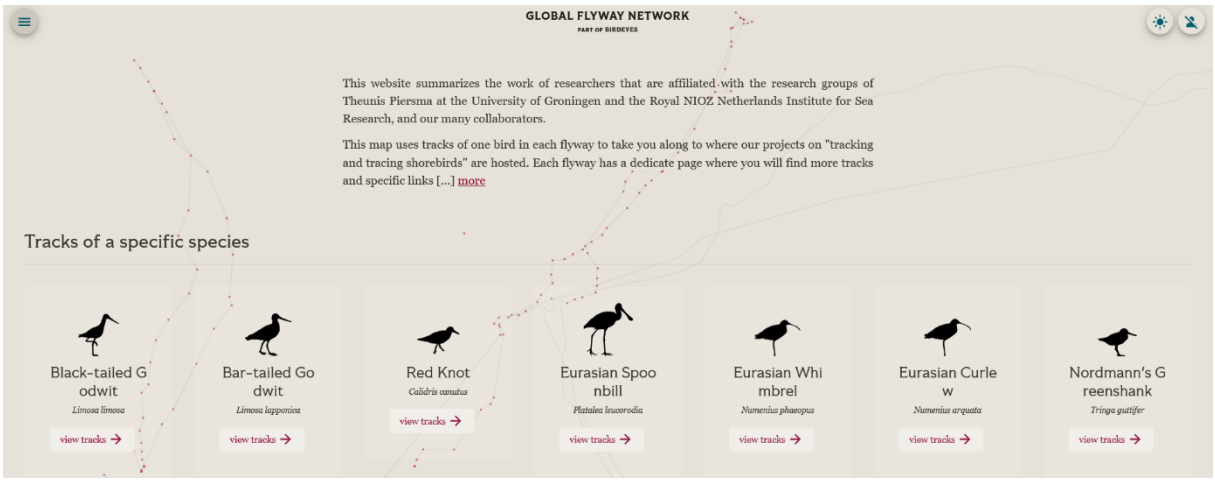


Figure 3: Home page GFN

Including the rationale could help users understand the aims of the GFN better and give context to exploring the tracking interface. Additionally, there does not seem to be a focus on multispecies data on the (tracking) interface. Literature claims that multispecies data can improve conservation efforts (Geijzendorffer et al., 2016), and as the GFN states that one of their main goals is to preserve long-distance migratory shorebirds (*About*, n.d.), including non-taxonomic data might help these efforts. However, despite the fact that multispecies-oriented data is not immediately available on the tracking interface for users, the publications the GFN depicts on their website seem to have a multidisciplinary approach (*Blog - Global Flyway Network*, n.d.; *Publications - Global Flyway Network*, n.d.), which according to the Convention on Biological Diversity (CBD) is also an effective way to counter biodiversity loss (Secretariat

of the Convention on Biological Diversity & UNEP World Conservation Monitoring Centre, 2006).

Next to categorizing data according to species, there are other ways in which the data can be grouped on the interface. Other ways to pull up certain data on the map are shown further down on the home page, in the left side menu (*figure 1*), and on the tracking interface. Users can choose to view tracks per separate project associated with the GFN or look for birds near a certain location. Overarching these different data categorizations is the fact that all data used on the interface is shown as tracking data. This shapes the way researchers and users approach the birds and the kinds of questions they ask. For example, without tracking data, it might not have been possible to provide answers to questions about whether flying routes are nature or nurture for godwits or which grasslands godwits prefer to breed on (Li et al., 2023; Loonstra et al., 2023). These questions might not even have been asked without this data available.

On the GFN website, there are no explicit mentions of aiming to facilitate open science or open data sharing. However, the tracking interface is open to everyone and there is no need to sign up in order to use it. This means that anyone interested in tracking any of these seven bird species, can do exactly that. Users can, as described before, search for birds in their near location. Four of the seven bird species listed on the GFN website are threatened according to the IUCN Red List (*The IUCN Red List of Threatened Species*, n.d.). Meaning that openly publishing tracking data should be done with caution (Ganzevoort et al., 2017; Tulloch et al., 2018). Not only people with good intentions can find the location of the birds, but it can also lead to people disturbing the birds (intentionally or not).

User Engagement

The GFN aims to inform and engage researchers and laypeople to promote conservation efforts for several threatened bird species (*Mission Statement - ANBI Status*, n.d.). Rather than being aimed at facilitating citizen science, the interface seems more focused on being a tool for

exploration and education. There is only relatively passive engagement for the user; they can read articles or blog posts, or explore the tracking interface. Even on the tracking interface, most of the time, context is missing. When users look at the map, they can, as discussed before, choose how to categorize the date. However, on the tracking interface itself there is rarely any information about the category they choose for filtering the data. At most, the user will receive some basic information about a single bird (see *figure 4*) or get insight into how many birds are part of a particular project. In order to be able to read more about different projects, users have to go to the home page and scroll down. However, there are no instructions given about this anywhere on the website. In general, there are only limited instructions given for users. The path to the tracking interface is relatively clear. However, on that interface, there is only a short (and hidden) 'help' guide. Even after following the help guide, many of the functions on the interface remain unexplained. This may cause confusion amongst users and might lead to suboptimal use of the tracking interface.

Figure 4: Information individual bird

The GFN interface is one of the GFN's main modes of communication, next to Twitter, which is also highlighted on their website. However, this is only a one-way communication channel. The GFN team posts information, highlights publications, shares 'latest news' on their website and ensures the tracking interface is working and up to date. Users can read this information and use the interface, but there is no direct communication channel back from the users to the researchers. There is a 'contact' page, but it does not seem that to be meant for regular communication. Moreover, there is also no way for users to communicate with each other. In order to foster a stronger community feeling, such communication channels are vital

(Jolibert & Wesselink, 2012; Luna et al., 2018). In addition to creating a community feeling, such communication can facilitate stakeholders to contact each other, which can reinforce conservation efforts (Maxwell et al., 2018). Therefore, this lack of communication channels means that the potential alignment of stakeholders is missed out on as users do not know of each other's existence.

The website is highly accessible as it does not require users to register or log in before being able to fully use the interface. Only one option is unavailable to unregistered users and only becomes functional when users are logged in. This particular function is that users can reinstate certain filtering settings on the map that they had set in a previous visit to the interface. This can be useful to regular users. For example, farmers living in an area where one of the bird species breeds might be interested in regularly checking whether the birds have already come back to their fields. This is related to the risks of openly published georeferenced data, however, in this case, it could benefit the birds as the farmer might plan their activities around the breeding season of the birds and stop potentially harmful activities as long as the birds are in the farmer's field.

Despite the fact that the website is aimed at a large audience, certain people are still excluded from using the interface. Most significantly, certain people may not be able to use the interface due to a language barrier. The website is mainly in English, with the exception of certain twitter messages and publications. This means that those who do not speak English will not be able to use the interface to its full potential. For example, certain communities that might not speak English but are highly connected to the birds tracked by the GFN could potentially be excluded from using the interface. However, to a certain extent, the tracking interface is also understandable for those who do not speak English, as it is quite intuitive. This is mainly due to the use of icons and other visual aspects, such as the tracks, instead of words.

Interface Design

The GFN has a focus on global research and seeing the world from a bird's perspective. This means that there are many interesting and innovative ways to show this focus in the design of the interface. One example relates to a design choice made for the tracking interface. Currently, one of the first things that caught my eye is that the map is still designed with a focus on topography and borders between countries. However, the world taken from a bird's point of view does not exist out of countries, but out of places to feed and breed and routes to fly. It is conventional to design a map like that (Drucker, 2011), but in the spirit of creativity and transcending the human narrative, it could be interesting to have another map that would be visualised in a way that is more based on how a bird would see the world (Whatmore, 2002). For example, a map that shows distances according to how long it takes a bird to get from one place to another as well as how long they stay in one place. This could be perceived as interesting by users, leading to a better understanding of birds in the general public and higher engagement.

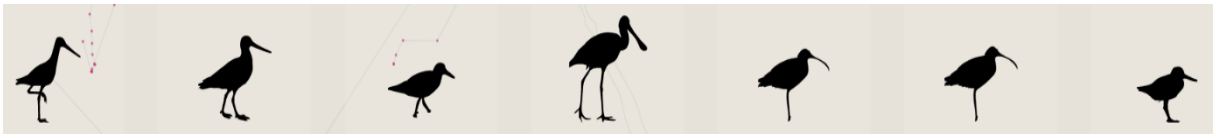


Figure 5: Icons depicting the seven different bird species as used by GFN: 1) Black-Tailed Godwit, 2) Bar-Tailed Godwit, 3) Red Know, 4) Eurasian Spoonbill, 5) Eurasian Whimbrel, 6) Eurasian Curlew, and 7) Nordmann's Greenshank.

Another noticeable design choice is the use of icons to visualize individual birds or bird species, such as the ones depicted in *figure 5* or used on the tracking interface. Only a few pictures of the birds as they look in real life are found on the website. On the one hand, the icons increase recognisability and simplicity as they quickly show the user what a bird species looks like approximately without overcomplicating the information presented to users (Wang et al., 2007). On the other hand, two of the icons (number five and six) are the same, despite the fact that different bird species are meant to be visualized, which can be confusing. Next to the question about whether these icons increase or decrease the recognisability of the birds, a discussion about anonymity versus individualism of the birds can be held. The black silhouette-

icons give a sense of anonymity of the birds (Whitelaw & Smaill, 2021), there are no specific feather-patterns to identify the birds with; all the birds in one species are visualized by this single icon. This stands in contrast to the individualistic approach to the birds' identities on the map, where each bird can be individually selected. After clicking on a single bird on the map (which is also visualized by the icon used for the species it belongs to), it will show the bird's location and tracks as well as its given name and other characteristics.

Analysis Movebank Interface

Knowledge Foregrounding

On the home page of Movebank, the organization describes itself as "a free, online database of animal tracking data" (*Movebank*, n.d.-a). The main goals of Movebank, as stated on their website, are to archive biodiversity tracking data, enable collaborations between users and other stakeholders, help scientists address new questions, promote open access, and allow the public to explore. By doing this, they aim to document change over time and contribute to global challenges, such as climate change, biodiversity loss and wildlife trafficking (Kays et al., 2022; Kranstauber et al., 2011). Almost their entire website is aimed at supporting users to understand and be able to engage with the tracking interface, which is shown in *figure 6*.

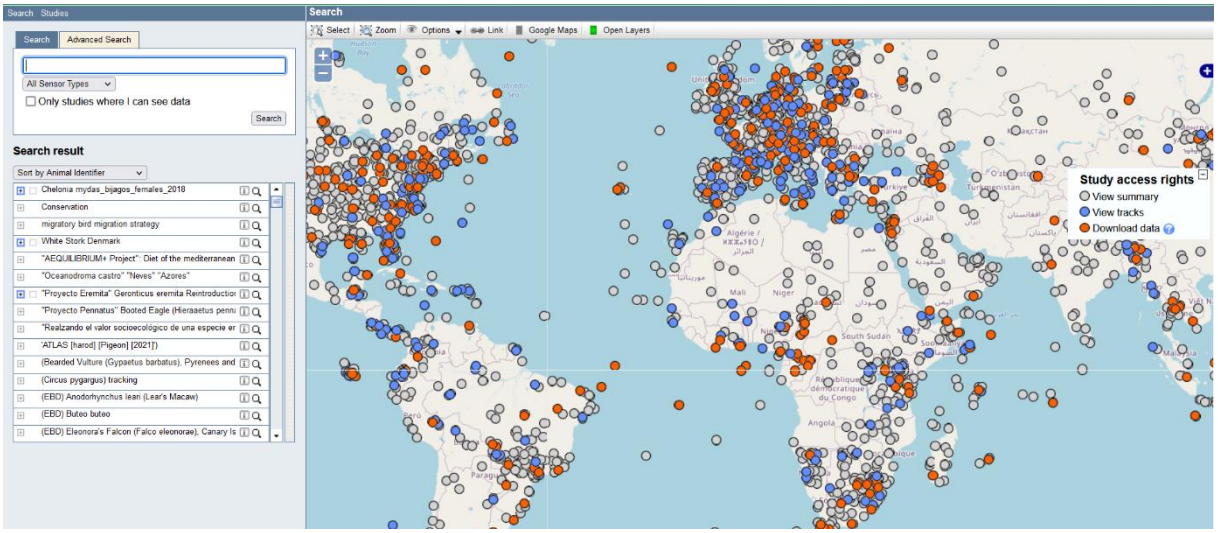


Figure 6: Tracking interface Movebank

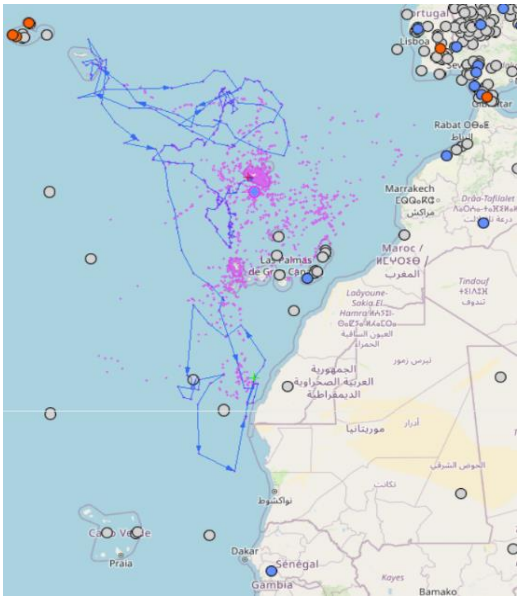


Figure 7: Visualization of a single study's tracking data

All the data portrayed on the Movebank interface is taxonomic data. The data is divided into different studies, and each separate study is represented as a dot on the map. The strong focus on taxonomic data can exacerbate the taxonomic bias (Troudet et al., 2017). Looking at the list of studies shown on Movebank, most focus on mammals, birds, or reptiles, which are already overrepresented in biodiversity studies (Troudet et al., 2017). Each study consists of tracking data of several individual animals of one or more species. Additionally, other sensor data related to the animals can be published, however, this will not be shown on the map. Users can potentially view and use this data when they download it (*Movebank*, n.d.-b). When selecting a particular study on the map, the tracking data is visualized as depicted in *figure 7*. The particular study shown in *figure 7* consists of tracking data for four different species. The blue line shows the movement of one individual animal for the duration of the study. It is only possible to see the movement of either one animal or all individuals included in the study. This means is not possible to see, for example, whether there are relations between a certain selection of individuals. It is also not possible to view the tracking data of two or more studies simultaneously on the map, which, again, excludes the possibility of visually comparing multiple studies. If Movebank would increase its inclusion of multispecies-focused data, the conservation efforts it aims to contribute to, might benefit more (Geijzendorffer et al., 2016).

One of Movebank's main objectives is to promote and facilitate open science. They value open science as it enables collaborations between stakeholders, helps researchers investigate innovative questions, and facilitates exploration and education among the general

public (Kays et al., 2022; Kranstauber et al., 2011). Within Movebank's database, users themselves can decide to what extent their data is accessible to other users. It seems like Movebank still encourages users to openly publish their data, at least to a certain extent. When users make their data completely private, it can only be stored temporarily, except when users contact the Movebank support team asking for a longer storage period. However, this is an extra step users would have to take, when it would be easier to open up the data to the public, which Movebank implicitly tells them in the user manual (*Movebank*, n.d.-c). Movebank also recognizes the threat open-access biodiversity data poses to certain (threatened) species (Ganzevoort et al., 2017; *Movebank*, n.d.-c; Tulloch et al., 2018). The interface's user manual states: " We encourage data owners to make their tracks visible to the public in the Tracking Data Map if it does not pose a threat to the study population." (*Movebank*, n.d.-c). This is quite a heavy responsibility to give to users, as they may not be aware of the conservation status of certain species in their data, leading to unintentionally posing a risk for already threatened species.

Movebank, one of the biggest animal movement tracking databases, offers an array of research opportunities. Not only can it grant researchers the opportunity to perform immense temporal and spatial analyses on, for example, the influence of climate change on animal migration, but the interface itself can also be used as a research object. Due to the size of the database and the extensive societal reach, it can increase the understanding of what such large-scale databases have to offer the practices of conservation and citizen science, among others.

User Engagement

Movebank aims to accommodate both researchers and the general public. This means multiple user options are available, such as uploading, viewing, or downloading data. On the home page, users are guided to determine what action on the website would suit them best. This ensures a high rate of user engagement as there is relevant content for a large range of potential users

(Garett et al., 2016). Movebank does this by saying: “Are you a researcher, journalist, student or developer? Get headed in the right direction.” (*Movebank*, n.d.-a), which is accompanied by a link leading to an information page about the various ways to engage with the Movebank interface. As the tracking interface is the most important part of the website, all actions are in some way connected to that interface, ultimately leading all users to engage with it.

Part of the users of the Movebank interface can be referred to as citizen scientists. This is because many users are contributing to Movebank’s database by uploading tracking data gathered by them. Per the framework developed by Haklay (2013), the citizen scientists of Movebank can be categorized in level one ‘crowdsourcing’, as they only act as sensors. The second framework of citizen science discussed in this paper is by Arnstein (1969) and is based more on the type of communication between the researchers/organization and the citizens. Communication channels within the Movebank interface are limited. Communication from the organization to the user is done throughout the whole interface as it is their medium of informing their users. The only communication possible on the interface itself from the users to the organization is through reaching out to one of the contact persons listed on their website (*Movebank*, n.d.-d). Due to this lack of a two-way communication channel, the citizen science of Movebank can be classified as level 3 ‘informing’ in Arnstein’s framework. Higher levels of citizen science do not only benefit conservation efforts, but also provide relevant feedback to the organization engaging these citizen scientists (Ganzevoort et al., 2017; Jolibert & Wesselink, 2012).

Additionally, there is also only limited opportunity for users to communicate with each other. The only communication between users encouraged by Movebank is to ask other users for access to their data or to inform peers of mistakes in their dataset. The Movebank interface does not have a forum page where users can freely communicate with each other. This has a negative impact on the possible formation of a community feeling amongst Movebank users.

Additionally, stakeholder alignment based on communication through the interface is missed out on. An improvement of both would increase the potential contribution to global causes, such as conservation (Jolibert & Wesselink, 2012; Luna et al., 2018).

It seems that one of the main concerns (and seemingly prides) of Movebank is the fact that they ensure that users maintain ownership of their data. This means that they can decide whom to share their data with and how this data can be used by other users (Kays et al., 2022; Kranstauber et al., 2011). These guarantees are elaborately discussed in Movebank's policies and guidelines, for example, in the user manual (*Movebank*, n.d.-c). A strong data ownership policy can, on the one hand, increase the attractiveness of the database (Kays et al., 2022), while at the same time hinder open accessibility of the data (Ganzevoort et al., 2017).

As with many global databases, the main language used is English. As Movebank does not offer any translated versions of their interface, except for the 'about' page, people that do not have an understanding of English are excluded from using the interface. Another excluding factor relates to the possibility of being a citizen scientist for Movebank. Equipment necessary for gathering tracking data is relatively expensive (Robertson et al., 2012), meaning that people with less monetary means might not be able to afford to be a citizen scientist. Many countries with low gross domestic product seem to have high rates of biodiversity (*GDP Ranked by Country 2023*, n.d.; *The Top 10 Most Biodiverse Countries*, 2016). This could mean that due to the monetary requirements, regions with high biodiversity might be underrepresented in the database. This bias can already be seen in *figure 6* as most of the studies are located in Europe and North America, which are generally considered wealthy regions.

Interface Design

When designing an interface, a balance between usability, meeting user needs, and visual attractiveness must be found (Janicki et al., 2016; Roth et al., 2015; Roth & Harrower, 2008). After clicking on opening the Movebank tracking interface, the page, as depicted in *figure 8*, is

presented. The first eye-catching item is the Movebank logo in the top bar, which takes up relatively much space. Next to that, the many dots on the map attract attention. However, compared to the rest of the screen, only a relatively small part of the space is assigned to the map. According to a study performed by Janicki et al. (2016), this can lead to reduced usability of the interface as users have to take more steps to get a good overview of the functionalities of the map. Additionally, the tracking interface is visually not very appealing, mainly due to the fact that its design is slightly old-fashioned and quite complex, and there are almost no familiar icons for users to rely on for navigation (Whitelaw & Smaill, 2021).

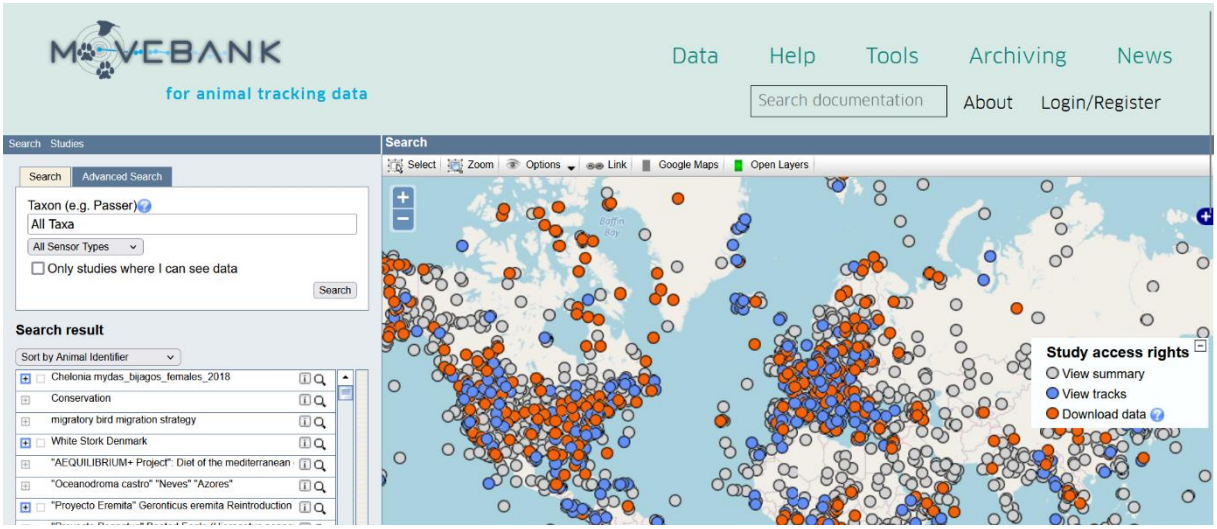


Figure 8: Tracking interface Movebank as visible after initial opening

The tracking interface relies heavily on users having read the user manual, which is available elsewhere on the Movebank website. However, for high user engagement, such interfaces should also (at least partly) be understandable for users without prior knowledge or experience (Roth & Harrower, 2008). Many of the items on the interface require users to be familiar with the terminology equipped by Movebank. Even the information provided about the studies is quite technical, as

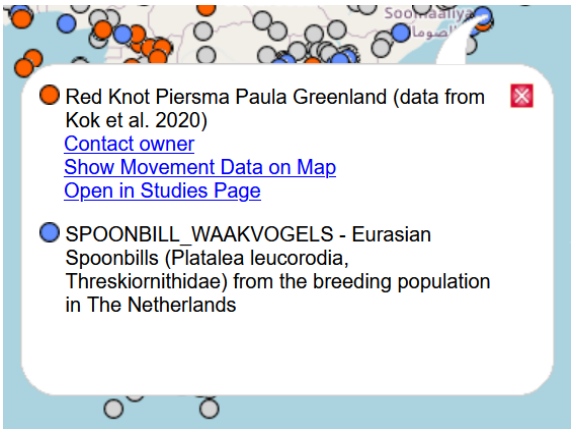


Figure 9: Study information dialogue

can be seen in *figure 9*. This use of jargon is continued on the 'studies page', as shown in *figure 10*. The studies page is comprises of textual content, with no icons to clarify the content presented. This decreases both the usability and attractiveness of the interface. However, it may contribute to meeting user needs as all the information about a particular study is presented on one page.

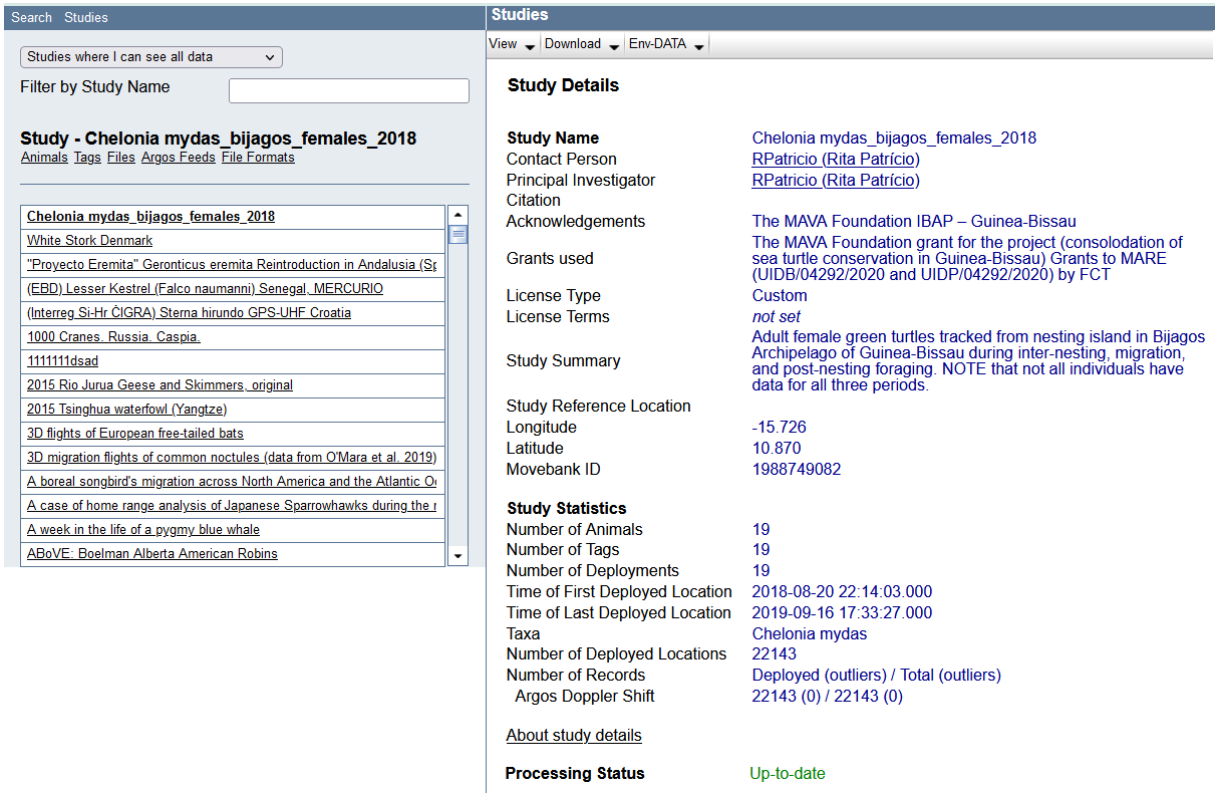


Figure 10: Studies page

A last noticeable design choice on the entire Movebank interface is the extensive use of the colour blue. Many studies have been conducted on the psychology of colours. Specifically, the literature on the use of colours in interface design is relevant for this report. According to a study performed by Kuo et al. (2022), three distinct shades of blue (royal blue, slate blue, and dark blue) are, objectively speaking, the most suitable for interactive webpages, which is what Movebank's tracking interface can be categorized as. Blue is associated with calm, peacefulness, and nature. Additionally, it makes users feel like they are in a stable and reliable environment (Clarke & Costall, 2008; Kuo et al., 2022). This can increase the UX and prime users to trust Movebank as a safe place to store and retrieve data.

Comparison of the Interfaces

The following section compares the interfaces of the GFN and Movebank and draws on the analysis performed on the respective interfaces. As can be inferred from the previous analysis, the GFN and Movebank have several similarities. For example, both organizations focus on animal movement tracking data and portray this data on their main interface consisting of a map where movement tracks are visualized. The two organizations are also entangled as the data shown on the GFN interface is retrieved from Movebank, and therefore, the same data is also visible on the Movebank interface. GFN, as well as Movebank, focuses on taxonomic data, either categorized according to species or according to research project or study. Additionally, both websites state to have the wish to contribute to global problems by promoting conservation efforts and gaining a better understanding of climate change by having an interface that accommodates for both researchers and the general public. The organizations also share the desire to inspire researchers to study new (innovative) questions based on the data they present. However, oftentimes, the way these two organizations portray these similar messages or wishes on their interfaces differs greatly.

One of the most obvious differences between the organizations is the breadth of the focus they have in terms of species. The GFN strongly focuses on understanding the world from the viewpoint of a select set of long-distance migratory shorebirds, such as the black-tailed godwit. This is "with the aim to understand and analyse the factors determining shorebird numbers in a rapidly changing world" (*About*, n.d.). Whereas the GFN aims to get this better understanding of the world through in-depth research of seven bird species, Movebank focuses on "movement ecology research, wildlife management, and to address challenges such as climate and land use change, biodiversity loss, invasive species, wildlife trafficking and infectious disease" (*Movebank*, n.d.-e) by openly publishing an extensive collection of animal movement tracking data concerning all species on the world. Despite these different approaches

to contributing to global problems and differences in breadth, both organizations have a global orientation. This is made apparent by having tracking data from all over the world.

Throughout this paper, the debate around openly publishing data has been mentioned more than once: there is a trade-off between openly publishing data and advancing scientific endeavours while also potentially posing risks for threatened species (Tulloch et al., 2018). Despite the fact that the GFN interface concerns several threatened bird species, they make no mention of the risks of openly publishing this data. On the other hand, even though Movebank acknowledges the risk, it still assigns all responsibility for assessing the potential threat openly publishing data poses to the users uploading the respective data. Neither organization shows an active approach to addressing this trade-off. This is unexpected, as, for one, Movebank states to wish to act against wildlife trafficking while allowing for openly published, potentially harmful data. Also, the GFN writes on their website that the birds it researches are partly threatened, yet no action is taken. As both organizations are growing, an active role in addressing this risk is necessary to diminish future risks of openly published data (Tulloch et al., 2018).

Another significant difference between the GFN and Movebank is their approach to engaging users. In general, both organizations aim to accommodate for all different types of audiences. However, Movebank additionally allows for citizen science. The GFN only publishes data gathered by people who are part of their team. Movebank allows all people to upload data onto their database. This is likely related to their vision of how to contribute to global problems. GFN focuses on a select group of birds, whereas Movebank aims to gather as much data as possible to allow for extensive temporal and spatial analyses. As a study by Dickinson et al. (2012) states, citizen science allows for the expansion of the boundaries of what is possible in ecological research. Therefore, if the aim of an organization is to advance

research endeavours, citizen scientists should be welcomed into the community rather than excluded.

The GFN and Movebank are biodiversity databases focusing on animal movement tracking data, albeit in their own ways. The interfaces, therefore, serve many similar user needs and could potentially have comparable design aspects. However, it seems like only the general design of the tracking interface is similar in the sense that they are both maps and that the animal tracks are depicted on that map. Apart from that, the main design aspects display few similarities. For example, both interfaces are based on a different colour palette, and the placement of buttons on the map is completely different for both interfaces. Additionally, the organizations seem to have a different attitude towards the use of icons. As discussed before, the GFN interface is filled with icons, whereas the Movebank interface has made very limited use of icons. This impacts the extent to which users can quickly understand the interfaces' functioning, with more conventional and familiar icons increasing usability (Wang et al., 2007). By increasing usability, user engagement also grows, which contributes to the causes the GFN and Movebank stand behind. Lastly, the design of both interfaces aligns with conventional 'rules'. This is despite the fact that many innovative design opportunities can be explored (Drucker, 2011). An example of this was given in the analysis of the GFN interface. This idea can be more widely applied to interfaces accommodating databases, such as Movebank and the GFN, to increase user engagement and encourage researchers to ask new questions about the data (Drucker, 2011).

Limitations

The main method used for gathering empirical data for the analyses was the walkthrough method, as developed by Light et al. (2018). According to Wharton et al. (1994), the walkthrough can be performed by both an individual as well as by a group. Both constellations have their respective advantages and disadvantages. In the case of this report, the walkthrough

was performed by an individual. As the analyses of the interfaces are relatively dependent on subjective observations and judgements, the data may be limited since these choices were all made by an individual.

Due to the scope of the current report, only a limited selection of topics was evaluated in the analyses of the websites. These were knowledge foregrounding, user engagement, and interface design choices. Many more aspects of the website could have been examined to create a more comprehensive assessment of the interfaces.

Conclusion

The current report aimed at answering the following research question: "What are the implications of interface design of biodiversity databases for foregrounding different kinds of knowledge and for engagement of different kinds of users?" The method used for answering was performing a structural analysis of the interactive biodiversity database interfaces of the Global Flyway Network and Movebank. Both organizations aim to contribute to global problems by promoting conservation efforts and gaining a better understanding of climate change. The three main themes of the analyses were knowledge foregrounding, user engagement, and interface design. Firstly, both organizations displayed a focus on presenting taxonomic data categorized by species. On the one hand this increases the understanding of biodiversity and the extent of conservation efforts needed. On the other hand, using solely taxonomic data leads to an incomplete understanding of ecosystem functioning. This can be improved by, for example, taking on a more multispecies-focused approach. Secondly, the two organizations wish to accommodate researchers as well as laypeople and their interfaces are designed for that purpose. The organizations also differ in this regard as Movebank also engages in citizen science, albeit on a low level. This can positively contribute to the conservation efforts Movebank wants to contribute to. Thirdly, the main aspect of both interfaces is the interactive animal movement tracking map, where users can explore biodiversity and migration. The

design of these interfaces is in its basic idea similar, but the way the specifics are designed differs greatly, with its respective influences on user experience and engagement.

This research aimed to contribute to the existing literature on interface design by performing a case study of two interactive biodiversity interfaces. The results and conclusions presented in this paper can give insights into the different design options available for such interfaces to improve the functioning of these interfaces. Creating well-functioning and inclusive biodiversity interfaces can contribute to halting biodiversity loss and gaining a better understanding of a changing world.

References

About. (n.d.). Global Flyway Network. Retrieved 15 May 2023, from https://www.globalflywaynetwork.org/page/about

About | IPBES secretariat. (n.d.). Retrieved 15 May 2023, from https://www.ipbes.net/about

Alatalo, R. V. (1981). Interspecific Competition in Tits Parus spp. and the Goldcrest Regulus regulus: Foraging Shifts in Multispecific Flocks. *Oikos*, *37*(3), 335–344. https://doi.org/10.2307/3544125

Arnstein, S. R. (1969). A Ladder Of Citizen Participation. *Journal of the American Institute of Planners*. https://doi.org/10.1080/01944366908977225

Beaulieu, A., & Leonelli, S. (2021). *Data and Society: A Critical Introduction*. SAGE Publications Sage CA: Los Angeles, CA.

Biodiversity. (n.d.). Retrieved 15 May 2023, from https://education.nationalgeographic.org/resource/biodiversity

Blog—Global Flyway Network. (n.d.). Global Flyway Network. Retrieved 1 June 2023, from https://www.globalflywaynetwork.org//blog

Canhos, D. A. L., Sousa-Baena, M. S., Souza, S. de, Maia, L. C., Stehmann, J. R., Canhos, V. P., Giovanni, R. D., Bonacelli, M. B. M., Los, W., & Peterson, A. T. (2015). The Importance of Biodiversity E-infrastructures for Megadiverse Countries. *PLOS Biology*, *13*(7), e1002204. https://doi.org/10.1371/journal.pbio.1002204

Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., & Palmer, T. M. (2015). Accelerated modern human–induced species losses: Entering the sixth mass extinction. *Science Advances*, *1*(5), e1400253. https://doi.org/10.1126/sciadv.1400253

Clarke, T., & Costall, A. (2008). The emotional connotations of color: A qualitative investigation. *Color Research & Application*, *33*, 406–410. https://doi.org/10.1002/col.20435

Costello, M. J., Vanhoorne, B., & Appeltans, W. (2015). Conservation of biodiversity through taxonomy, data publication, and collaborative infrastructures. *Conservation Biology: The Journal of the Society for Conservation Biology*, *29*(4), 1094–1099. https://doi.org/10.1111/cobi.12496

Cramer, F., & Fuller, M. (2008). Interface. *Software Studies: A Lexicon*, 149–152.

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., Phillips, T., & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*, *10*(6), 291–297. https://doi.org/10.1890/110236

Drucker, J. (2011). Humanities Approaches to Graphical Display. *Digital Humanities Quarterly*, *005*(1).

Ekström, B. (2021). A niche of their own: Variations of information practices in biodiversity citizen science. *Journal of Documentation*, *78*(7), 248–265. https://doi.org/10.1108/JD-07-2021-0146

Ganzevoort, W., van den Born, R. J. G., Halffman, W., & Turnhout, S. (2017). Sharing biodiversity data: Citizen scientists' concerns and motivations. *Biodiversity and Conservation*, *26*(12), 2821–2837. https://doi.org/10.1007/s10531-017-1391-z

Garett, R., Chiu, J., Zhang, L., & Young, S. D. (2016). A Literature Review: Website Design and User Engagement. *Online Journal of Communication and Media Technologies*, *6*(3), 1–14.

GDP Ranked by Country 2023. (n.d.). Retrieved 4 June 2023, from https://worldpopulationreview.com/countries/by-gdp

Geijzendorffer, I. R., Regan, E. C., Pereira, H. M., Brotons, L., Brummitt, N., Gavish, Y., Haase, P., Martin, C. S., Mihoub, J.-B., Secades, C., Schmeller, D. S., Stoll, S., Wetzel, F. T., & Walters, M. (2016). Bridging the gap between biodiversity data and

policy reporting needs: An Essential Biodiversity Variables perspective. *Journal of Applied Ecology*, *53*(5), 1341–1350. https://doi.org/10.1111/1365-2664.12417

Goal 15 | Department of Economic and Social Affairs. (n.d.). Retrieved 15 May 2023, from https://sdgs.un.org/goals/goal15

Haklay, M. (2013). Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation. In D. Sui, S. Elwood, & M. Goodchild (Eds.), *Crowdsourcing Geographic Knowledge* (pp. 105–122). Springer Netherlands. https://doi.org/10.1007/978-94-007-4587-2_7

Janicki, J., Narula, N., Ziegler, M., Guénard, B., & Economo, E. P. (2016). Visualizing and interacting with large-volume biodiversity data using client–server web-mapping applications: The design and implementation of antmaps.org. *Ecological Informatics*, *32*, 185–193. https://doi.org/10.1016/j.ecoinf.2016.02.006

Janssen, M., Charalabidis, Y., & Zuiderwijk, A. (2012). Benefits, Adoption Barriers and Myths of Open Data and Open Government. *Information Systems Management*, *29*(4), 258–268. https://doi.org/10.1080/10580530.2012.716740

Jolibert, C., & Wesselink, A. (2012). Research impacts and impact on research in biodiversity conservation: The influence of stakeholder engagement. *Environmental Science & Policy*, *22*, 100–111. https://doi.org/10.1016/j.envsci.2012.06.012

Kays, R., Davidson, S. C., Berger, M., Bohrer, G., Fiedler, W., Flack, A., Hirt, J., Hahn, C., Gauggel, D., Russell, B., Kölzsch, A., Lohr, A., Partecke, J., Quetting, M., Safi, K., Scharf, A., Schneider, G., Lang, I., Schaeuffelhut, F., … Wikelski, M. (2022). The Movebank system for studying global animal movement and demography. *Methods in Ecology and Evolution*, *13*(2), 419–431. https://doi.org/10.1111/2041-210X.13767

Keogh, J. S. (1995). *The importance of systematics in understanding the 8 biodiversity crisis: The role of biological educators: Journal of Biological Education: Vol 29, No 4*. https://www.tandfonline.com/doi/abs/10.1080/00219266.1995.9655463

König, C., Weigelt, P., Schrader, J., Taylor, A., Kattge, J., & Kreft, H. (2019). Biodiversity data integration—The significance of data resolution and domain. *PLOS Biology*, *17*(3), e3000183. https://doi.org/10.1371/journal.pbio.3000183

Kranstauber, B., Cameron, A., Weinzerl, R., Fountain, T., Tilak, S., Wikelski, M., & Kays, R. (2011). The Movebank data model for animal tracking. *Environmental Modelling & Software*, *26*(6), 834–835. https://doi.org/10.1016/j.envsoft.2010.12.005

Kuo, L., Chang, T., & Lai, C.-C. (2022). Affective psychology and color display of interactive website design. *Displays*, *71*, 102134. https://doi.org/10.1016/j.displa.2021.102134

Lagomarsino, L. P., & Frost, L. A. (2020). The Central Role of Taxonomy in the Study of Neotropical Biodiversity1. *Annals of the Missouri Botanical Garden*, *105*(3), 405–421. https://doi.org/10.3417/2020601

Leonelli, S. (2022). Open Science and Epistemic Diversity: Friends or Foes? *Philosophy of Science*, *89*(5), 991–1001. https://doi.org/10.1017/psa.2022.45

Li, Y., Piersma, T., Hooijmeijer, J. C. E. W., & Howison, R. A. (2023). Land-use intensity impacts habitat selection of ground-nesting farmland birds in The Netherlands. *Ecological Solutions and Evidence*, *4*(1), e12201. https://doi.org/10.1002/2688-8319.12201

Light, B., Burgess, J., & Duguay, S. (2018). The walkthrough method: An approach to the study of apps. *New Media & Society*, *20*(3), 881–900. https://doi.org/10.1177/1461444816675438

Loonstra, A. H. J., Verhoeven, M. A., Both, C., & Piersma, T. (2023). Translocation of shorebird siblings shows intraspecific variation in migration routines to arise after fledging. *Current Biology*. https://doi.org/10.1016/j.cub.2023.05.014

Luna, S., Gold, M., Albert, A., Ceccaroni, L., Claramunt, B., Danylo, O., Haklay, M., Kottmann, R., Kyba, C., Piera, J., Radicchi, A., Schade, S., & Sturm, U. (2018). Developing Mobile Applications for Environmental and Biodiversity Citizen Science: Considerations and Recommendations. In A. Joly, S. Vrochidis, K. Karatzas, A. Karppinen, & P. Bonnet (Eds.), *Multimedia Tools and Applications for Environmental & Biodiversity Informatics* (pp. 9–30). Springer International Publishing. https://doi.org/10.1007/978-3-319-76445-0_2

Maxwell, J., Allen, S., Brooks, T., Cuttelod, A., Dudley, N., Fisher, J., Langhammer, P., Patenaude, G., & Woodley, S. (2018). Engaging end-users to inform the development of the global standard for the identification of key biodiversity areas. *Environmental Science & Policy, 89*, 273–282. https://doi.org/10.1016/j.envsci.2018.07.019

Mission statement—ANBI status. (n.d.). Global Flyway Network. Retrieved 15 May 2023, from https://www.globalflywaynetwork.org/page/anbi

Movebank. (n.d.-a). Retrieved 15 May 2023, from https://www.movebank.org/cms/movebank-main

Movebank. (n.d.-b). Retrieved 3 June 2023, from https://www.movebank.org/cms/movebank-content/create-study-overview

Movebank. (n.d.-c). Retrieved 3 June 2023, from https://www.movebank.org/cms/movebank-content/permissions-and-sharing

Movebank. (n.d.-d). Retrieved 3 June 2023, from https://www.movebank.org/cms/movebank-content/about-movebank#contacts

Movebank. (n.d.-e). Retrieved 4 June 2023, from https://www.movebank.org/cms/movebank-content/about-movebank

Polson, P. G., Lewis, C., Rieman, J., & Wharton, C. (1992). Cognitive walkthroughs: A method for theory-based evaluation of user interfaces. *International Journal of Man-Machine Studies*, *36*, 741–773. https://doi.org/10.1016/0020-7373(92)90039-N

Publications—Global Flyway Network. (n.d.). Global Flyway Network. Retrieved 1 June 2023, from https://www.globalflywaynetwork.org//publications

Robertson, B., Holland, J., & Minot, E. (2012). Wildlife tracking technology options and cost considerations. *Wildlife Research*, *38*, 653–663. https://doi.org/10.1071/WR10211

Root, K. V., Akçakaya, H. R., & Ginzburg, L. (2003). A Multispecies Approach to Ecological Valuation and Conservation. *Conservation Biology*, *17*(1), 196–206. https://doi.org/10.1046/j.1523-1739.2003.00447.x

Roth, R., & Harrower, M. (2008). Addressing Map Interface Usability: Learning from the Lakeshore Nature Preserve Interactive Map. *Cartographic Perspectives*, 46–66. https://doi.org/10.14714/CP60.231

Roth, R., Ross, K., & MacEachren, A. (2015). User-Centered Design for Interactive Maps: A Case Study in Crime Analysis. *International Journal of Geo-Information*, *4*, 262–301. https://doi.org/10.3390/ijgi4010262

Russell, K. (2019, May 10). *More than a 'nice to have': Integrating indigenous biodiversity into agroecosystems in New Zealand* [Text]. NZES. https://newzealandecology.org/nzje/3372

Secretariat of the Convention on Biological Diversity. (2020, September 18). *Aichi Biodiversity Targets*. Secretariat of the Convention on Biological Diversity. https://www.cbd.int/sp/targets/

Secretariat of the Convention on Biological Diversity, & UNEP World Conservation Monitoring Centre (Eds.). (2006). *Global biodiversity outlook 2*. Secretariat of the Convention on Biological Diversity.

The IUCN Red List of Threatened Species. (n.d.). IUCN Red List of Threatened Species. Retrieved 1 June 2023, from https://www.iucnredlist.org/en

The top 10 most biodiverse countries. (2016, May 21). Mongabay Environmental News. https://news.mongabay.com/2016/05/top-10-biodiverse-countries/

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

Tulloch, A. I. T., Auerbach, N., Avery-Gomm, S., Bayraktarov, E., Butt, N., Dickman, C. R., Ehmke, G., Fisher, D. O., Grantham, H., Holden, M. H., Lavery, T. H., Leseberg, N. P., Nicholls, M., O'Connor, J., Roberson, L., Smyth, A. K., Stone, Z., Tulloch, V., Turak, E., … Watson, J. E. M. (2018). A decision tree for assessing the risks and benefits of publishing biodiversity data. *Nature Ecology & Evolution*, *2*(8), 1209–1217. https://doi.org/10.1038/s41559-018-0608-1

Turnhout, E., & Boonman-Berson, S. (2011). Databases, Scaling Practices, and the Globalization of Biodiversity. *Ecology and Society 16 (2011) 1, 16*. https://doi.org/10.5751/ES-03981-160135

Wang, H. F., Hung, S. H., & Liao, C. C. (2007). A survey of icon taxonomy used in the interface design. *Proceedings of the 14th European Conference on Cognitive Ergonomics: Invent! Explore!*, 203–206. https://doi.org/10.1145/1362550.1362591

Wharton, C., Rieman, J., Lewis, C., & Polson, P. (1994). The cognitive walkthrough method: A practitioner's guide. In *Usability inspection methods* (pp. 105–140). John Wiley & Sons, Inc. https://www.colorado.edu/ics/sites/default/files/attached-files/93-07.pdf

Whatmore, S. (2002). *Hybrid Geographies: Natures Cultures Spaces*. https://doi.org/10.4135/9781446219713

Whitelaw, M., & Smaill, B. (2021). Biodiversity data as public environmental media: Citizen science projects, national databases and data visualizations. *Journal of Environmental Media*, *2*, 79–99. https://doi.org/10.1386/jem_00041_1

Wilson, J. S., Pan, A. D., General, D. E. M., & Koch, J. B. (2020). More eyes on the prize: An observation of a very rare, threatened species of Philippine Bumble bee, Bombus irisanensis, on iNaturalist and the importance of citizen science in conservation biology. *Journal of Insect Conservation*, *24*(4), 727–729. https://doi.org/10.1007/s10841-020-00233-3

Appendix A – Debate Open Data

The benefits and barriers of having open-access data as formulated by Janssen et al (2012):

TABLE 1
Overview of benefits of open data

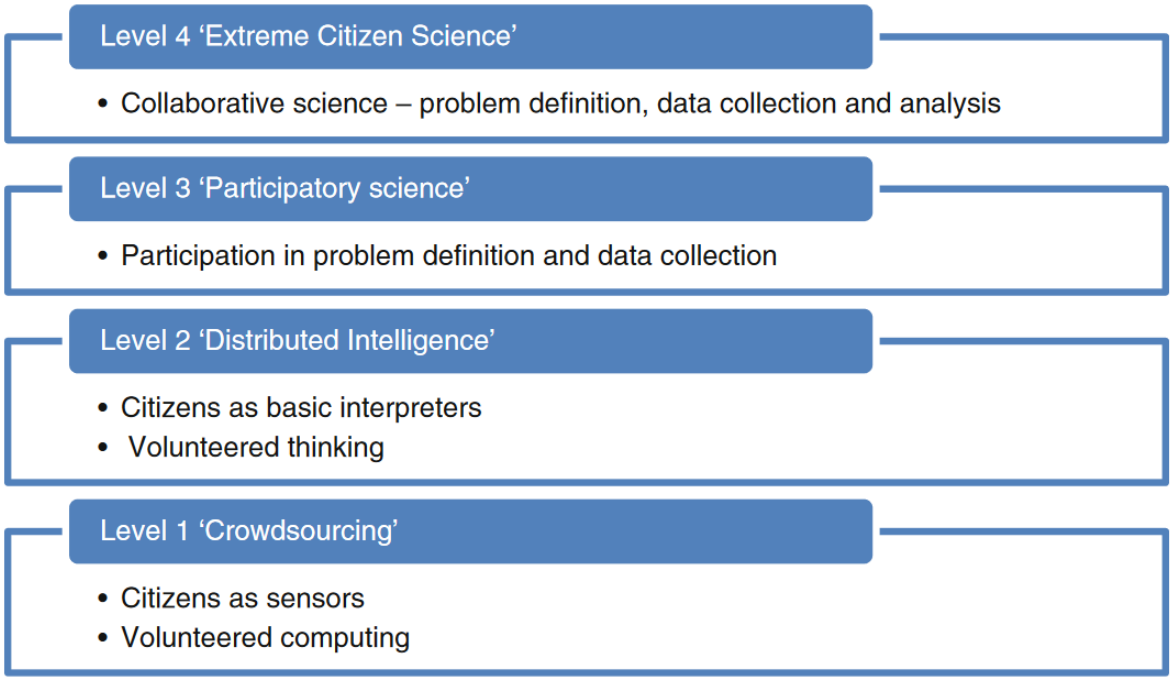
Category	Benefits
Political and social	More transparency
	Democratic accountability
	More participation and self-empowerment of citizens (users)
	Creation of trust in government
	Public engagementScrutinization of data
	Equal access to data
	New governmental services for citizens
	Improvement of citizen services
	Improvement of citizen satisfaction
	Improvement of policy-making processes
	More visibility for the data provider
	Stimulation of knowledge developments
	Creation of new insights in the public sector
	New (innovative) social services
Economic	Economic growth and stimulation of competitiveness
	Stimulation of innovation
	Contribution toward the improvement of processes, products, and/or services
	Development of new products and services
	Use of the wisdom of the crowds: tapping into the intelligence of the collective
	Creation of a new sector adding value to the economy
	Availability of information for investors and companies
Operational and technical	The ability to reuse data/not having to collect the same data again and counteracting unnecessary duplication and associated costs (also by other public institutions)
	Optimization of administrative processes
	Improvement of public policies
	Access to external problem-solving capacity
	Fair decision-making by enabling comparison
	Easier access to data and discovery of data
	Creation of new data based on combining data
	External quality checks of data (validation)
	Sustainability of data (no data loss)
	The ability to merge, integrate, and mesh public and private data

TABLE 2
Adoption barriers for not publicizing data

Categories	Barriers
Institutional	Emphasis of barriers and neglect of opportunities
	Unclear trade-off between public values (transparency vs. privacy values)
	Risk-averse culture (no entrepreneurship)
	No uniform policy for publicizing data
	Making public only non-value-adding data
	No resources with which to publicize data (especially small agencies)
	Revenue system is based on creating income from data
	Fostering local organizations' interests at the expense of citizen interests
	No process for dealing with user input
	Debatable quality of user input
Task complexity	Lack of ability to discover the appropriate data
	No access to the original data (only processed data)
	No explanation of the meaning of data
	No information about the quality of the open data (see category "Information Quality")
	Apps hiding the complexity but also potential other use of open data
	Duplication of data, data available in various forms, or before/after processing resulting in discussions about what the source is
	Difficulty in searching and browsing due to no index or other means to ensure easy search for finding the right data
	Even if data can be found, users might not be aware of its potential uses
	Data formats and datasets are too complex to handle and use easily
	No tooling support or helpdesk
	Focus is on making use of single datasets, whereas the real value might come from combining various datasets
	Contradicting outcomes based on the use of the same data
	Invalid conclusions
Use and participation	No incentives for the users
	Public organizations do not react to user input
	Frustration at the existence of too many data initiatives
	No time to delve into the details, or no time at all
	Having to pay a fee for the data
	Registration required before being able to download the data
	Unexpected escalated costs
	No time to make use of the open data
	Lack of knowledge to make use of or to make sense of data
	Lack of the necessary capability to use the information
	No statistical knowledge or understanding of the potential and limitations of statistics
	Threat of lawsuits or other violations
Legislation	Privacy violation
	Security
	No license for using dataLimited conditions for using data
	Dispute and litigations
	Prior written permission required to gain access to and reproduce data
	Reuse of contracts/agreements
Information Quality	Lack of information
	Lack of accuracy of the information
	Incomplete information, only part of the total picture shown or only a certain range
	Obsolete and non-valid data
	Unclear value: information may appear to be irrelevant or benign when viewed in isolation, but when linked and analyzed collectively it can result in new insights
	Too much information to process and not sure what to look at
	[Essential] Information is missing
	Similar data stored in different systems yields different results
Technical	Data must be in a well-defined format that is easily accessible: while the format of data is arbitrary, the format of data definitions needs to be rigorously defined
	Absence of standards
	No central portal or architecture
	No support for making data available
	Lack of meta standards
	No standard software for processing open data
	Fragmentation of software and applications
	Legacy systems that complicate the publicizing of data

Appendix B – Citizen Science Frameworks

Framework developed by Haklay (2013) to illustrate four different levels of citizen science:



Framework developed by Arnstein (1969) to show eight levels of citizen science: