



# Discovering urban nature: citizen science and biodiversity on a university campus

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## Abstract

Preserving biodiversity is a paramount global concern and, in this regard, monitoring urban biodiversity has increasingly taken on a significant role. Citizen science has emerged as a resource for addressing this challenge, offering a cost-effective approach capable of producing extensive data while promoting public engagement. In this work, a Lisbon university campus was used to determine the effectiveness of a citizen science project launched on the BioDiversity4All/iNaturalist platform to monitor urban biodiversity and analyse the influence of different engagement actions on biodiversity observations. The data analysis was based on biodiversity observations, including the temporal evolution of observations, the most frequently observed taxonomic groups, and the impact of promotional actions on project data. Additionally, the profiles of the observers were analyzed to assess their level of engagement and continued involvement in citizen science. The project had an effect on the increase in the number of observers and observations, and it was also possible to see a positive effect of the organized activities. The two indices used showed that Researchers and Students were the observer categories responding the most to the project, followed by Naturalists and Others. The results highlighted the capacity of citizen science to increase interest in biodiversity among both the university community and the general public. Furthermore, this work underlines the role of different strategies such as BioBlitzes, social media campaigns, and formal education activities to reduce the impact of relevant limitations associated with citizen science, namely taxonomic, aesthetic, and temporal biases.

**Keywords** Biodiversity monitoring · BioDiversity4All · Citizen science · iNaturalist · Sustainability · Urban biodiversity

## Introduction

Bruntland defined sustainability as the "ethical and moral motivation that aims to meet the current human needs without compromising the satisfaction of future needs" (Bruntland 1987). However, the notion of sustainability is multifaceted, and it is required to address its social, economic, and environmental components (Kuhlman and Farrington 2010). The social component is linked to the balanced distribution of natural resources among present and future generations, while the economic component relates to the capacity for production, distribution, and equitable use of wealth produced by humans. The environmental component is directly linked to

the present work and is associated with the conservation and protection of the natural environment. Biodiversity, which refers to the variety and variability of life on Earth, is a fundamental element of this component, it serves as a pillar supporting ecosystems, their services, and consequently, human well-being (Mace et al. 2012). Biodiversity is currently under significant pressure, with numerous species facing extinction at an unprecedented rate (Cowie et al. 2022). This pressure stems from various human activities such as urbanization, intensive agriculture, deforestation, introduction of invasive species and pollution (Tilman et al. 2017). Additionally, human-induced climate change is also contributing significantly to the loss of biodiversity (IPBES 2019). Addressing this global challenge, the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) has emphasized in its latest report the necessity of biodiversity monitoring for all countries, and biodiversity conservation has emerged as a top priority in several international strategic documents. In fact, nature and biodiversity conservation are global priorities, as reflected in various international strategic documents

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(Ruckelshaus et al. 2020; European Commission 2021; Stephenson and Carbone 2021; UNECE 2023).

Citizen science, defined as the active involvement of scientists together with citizen communities to advance science (Ceccaroni et al. 2017), is increasingly becoming a mainstream approach for gathering information and data on various scientific subjects (Kullenberg & Kasperowski 2016). Citizen science fills two important gaps in current scientific activities, namely projects that address ecological questions at scales that professional science alone would be unable to accomplish, and initiatives that scientists would not undertake on their own, such as those that are too localised or limited in scope to be of interest to a wider audience (Miller-Rushing et al. 2012). The advent of mobile technologies and the widespread utilization of smartphones have greatly facilitated citizen science through the development of mobile apps (Lemmens et al. 2021). These digital tools integrate data from multiple sources in real-time, allowing a wide range of individuals to engage with science and contribute to expanding scientific knowledge (Tiago et al. 2017a). Biodiversity and its monitoring are among the scientific fields that have attracted a significant number of citizen scientists, and the quantity and scope of data collected increase significantly when using this methodology (Chandler et al. 2017b).

Despite the growing use of citizen science in biodiversity studies, many authors have addressed the biases associated with this approach, which include: **sampling bias** (citizen science data may be skewed towards easily accessible locations, leading to an underrepresentation of more remote or inaccessible areas) (Ward 2014), **taxonomic bias** (participants often have preferences for certain taxa, resulting in uneven data coverage across different groups of species (Chozas et al. 2023), **aesthetic bias** ("charismatic" or visually appealing species may receive more attention compared to others) (Ward 2014), **observer bias** (different levels of expertise among participants can influence the accuracy and reliability of observations, potentially introducing inconsistencies in data quality) (Fitzpatrick et al. 2009); **spatial bias** (citizen science projects tend to be more prevalent in urban or densely populated areas, which can lead to an overrepresentation of urban biodiversity and less representation of rural or remote areas) (Kelling et al. 2015), and **temporal bias** (sampling efforts may be influenced by seasonal or temporal factors, resulting in variations in data collection frequency throughout the year) (Courter et al. 2013).

On the other hand, citizen science, besides significantly increasing the collection of biodiversity data, has already brought new species to science by involving millions of people worldwide in locations where scientists are not always present in the field (e.g. Guzmán-Guzmán & Plata-Torres 2023). Moreover, from a social perspective, citizen science offers numerous advantages, besides an increase in scientific literacy (enhanced knowledge about species) (Queiruga-Dios

et al. 2020) and environmental democracy (information sharing) (Reis 2020), it also fosters community involvement in resolving local environmental issues (Socientize Consortium 2013). This engagement of people with nature is crucial in its contribution to connecting citizens with the environment (Peter et al. 2021) and promoting society's appropriation of natural values being one of the most important pillars of biodiversity conservation (Maund et al. 2020).

Due to the fact that the majority of the world's population is expected to live in urban areas by 2030 (projected at 60%) (UN 2018), these areas present the greatest challenge for ecosystem management. The green infrastructures of cities, as urban gardens, tree-lined streets, and residual forests, not only harbour significant biodiversity, but also play a vital role in maintaining the functionality of urban ecosystems and the delivery of ecosystem services and should be integrated into urban policies and planning (Pinho et al. 2016). They also offer a valuable opportunity to foster citizen engagement in understanding biodiversity and the ecosystem services it supports. Cities also offer unique opportunities for learning and education about resilient and sustainable future and have enormous potential to generate innovations and governance tools, taking a leadership role in sustainable development (Baker et al. 2014). In fact, several approaches have emerged to monitor biodiversity in urban environment, and citizen science has become an incredibly valuable tool in addressing this issue as a relatively cost-effective method that can provide a large quantity of observations and contribute to monitor biodiversity (Callaghan et al. 2020).

The main goal of this article was to evaluate the effectiveness of a citizen science project to monitor urban biodiversity, using a university campus as a case study. We also analysed the impact of various engagement measures on this monitoring and the reduction of the impact of relevant biases associated with citizen science. Additionally, we analysed how different categories of observers: Researchers, Students, Naturalists and Others, engaged in the project.

## Methods

### The project

The project "+ Biodiversity@CIÊNCIAS: Mobilizing the CIÊNCIAS Community for Sustainability Promotion on Campus" emerged as a response to the challenge launched by the Faculty of Sciences of the University of Lisbon (CIÊNCIAS) through its first edition of the Ideas for Sustainability Competition. This contest aims to identify and promote initiatives by members of CIÊNCIAS that can contribute to sustainability in its various aspects on campus and in its interaction with the city of Lisbon. In this context, the project aimed to monitor campus' biodiversity over

time, involving the university community, as well as the citizens living and working in the area. Having received the award in early 2020, the project had to be delayed to September of the same year with some adjustments due to the COVID-19 pandemic: in particular, Bioblitz events or other biodiversity sampling activities that required gathering participants had to be cancelled since Portuguese government imposed several restrictions that limited activities in public spaces and the free movement of people, with some critical periods even forbidding leaving home. In Portugal, these restrictions began precisely in March 2020, when it was strictly forbidden to leave home except for some essential reasons.

The project + Biodiversity@CIÊNCIAS was launched on BioDiversity4All, the Portuguese node of the global iNaturalist platform. iNaturalist is a social network that connects naturalists, citizen scientists, and biologists, facilitating the mapping and sharing of biodiversity observations. It serves as an online platform where individuals can share biodiversity information to collectively learn about nature. iNaturalist can be accessed through its website or mobile app, and the community of iNaturalist users validates the observations submitted. The platform enables the creation of both open-access and registration-restricted projects.

The project area encompassed the CIÊNCIAS university campus of the Faculty of Sciences of the University of Lisbon and the surrounding area, which included other faculties, an urban garden, a residential area, a sports facility, a hospital, and primary, middle, and high schools (Fig. 1).

In this context, to achieve the project goal of monitoring the campus biodiversity over time, two methodological

approaches were adopted: citizen science using the iNaturalist App and classic biodiversity sampling conducted by experts (by direct observation/counting and using technological equipment as camera traps and acoustic recorders). Concurrently, promotional activities were conducted to encourage people's involvement in citizen science species recording. Both data collected through citizen science and classic sampling methods were uploaded to the + Biodiversity@CIÊNCIAS project (see Supplement 1).

### Promotional activities

After the project launch and throughout its development, various actions were taken to promote species recording in the defined area (see Supplement 2). These included the organization of **BioBlitz** events (an event that focuses on finding and identifying as many species as possible in a specific area over a specific time period) (Tweddle et al. 2012). Two BioBlitzes events were conducted in collaboration with a museum associated with the Lisbon City Council (Museum of Lisbon), and two more were held as part of the European Researchers' Night by another university institution whose area of action is within the scope of the project. Two BioBlitzes were organized on CIÊNCIAS campus, the first in October 2021 and the second in May 2022, involving researchers, students, and CIÊNCIAS community. Additionally, some Iberian-level BioBlitz events organized by other entities were carried out, which focused on recording flora or invasive species and included the study area. All these initiatives aimed to engage participants and raise awareness about biodiversity through interactive and educational activities.

**Fig. 1** Study area in the city of Lisbon. This includes CIÊNCIAS university campus of the Faculty of Sciences of the University of Lisbon and the surrounding area, delimited in red. The red diamonds represent the main facilities



Throughout the project, **social media campaigns** were also developed to promote its visibility and raise awareness about specific taxonomic groups. This was done, for example, to encourage the recording of less observed taxa or in favourable seasons (such as mushroom recording in the autumn and orchid recording in the spring). A promotional film was created by the Communication and Image office of the faculty to promote the project on the institution's social media platforms. An opinion article was written, along with two reports in environmental magazines (National Geographic Portugal and Wilder). Additionally, eight lectures were delivered at scientific events, like the Ciências Open Day and Research Day. These efforts aimed to disseminate the project's findings and raise awareness among a wider audience, including the scientific community and the general public.

The project was also promoted through formal **education activities**. Students of the bachelor's degrees in Biology (CIÊNCIAS) (Chozas et al. 2023) and in Geography (Institute of Geography and Spatial Planning of the University of Lisbon, IGOT) performed activities of biodiversity sampling on the campus using the BioDiversity4All/iNaturalist platform in the context of the disciplines of Ecology (CIÊNCIAS) and Global Changes Ecology and Landscape Ecology (IGOT).

### Classic data sampling

Classic sampling campaigns were carried out to complement data collection by citizen science. These campaigns occurred from April to July 2021 and focused on birds, bats, and lichens. Birds were sampled on two dates in April, using 5-min point counts at 19 points distributed in the area of the project: 5 points were located within the limits of CIÊNCIAS and the other 14 in the surrounding area, covering different habitats and separated by at least 250m to avoid individual duplication. Bats were sampled using a hand-held bat detector during June in a transect done at nightfall that covered most of the project area. Lichen field sampling was conducted on July 5–7 by two expert lichenologists aiming to document the most prevalent species on the campus (Munzi et al. 2023).

Moreover, between May 10 and May 21, four automatic sound recorders, *Audiomoth* (<sup>®</sup>*Open Acoustics*), were placed in CIÊNCIAS, to register bats and birds, and two camera traps were settled in the same places to register mammals.

### Data analysis

The data used for this article covers the area of the project in two periods: two years **before** the implementation of the project (from the 1st of September 2018 to 31st August

2020) and **during** two years of the project (between the 1st of September 2020 and 31st December 2022), so that it is possible to evaluate its impact. The data was downloaded from the BioDiversity4All/iNaturalist platform in January 2023, selecting biodiversity observations from all taxonomic groups, both validated and non-validated. The extracted file included: observation date, observer's name, scientific name of the species, and the iconic group to which it belongs (an automatic designation from the platform that includes groups as bacteria, amphibia, mollusca and plantae). Subsequently, additional information was extracted, such as the observer's entry date into the platform BioDiversity4All/iNaturalist, and the total number of observations made by each observer since signing up on the platform.

To assess the impact of the project on biodiversity monitoring, the number of observations, species and observers were compared before and during the project, as well as the temporal evolution of observations and recorded species throughout the year by taxonomic group. The impact of promotional activities on the number of observations was also evaluated.

The profiles of the observers were analysed to assess their level of engagement and continued involvement in citizen science. Four categories of observers were defined in terms of their relationship with science, the project, and the BioDiversity4All/iNaturalist platform: Naturalists (observers with more than 100 observations, some of which were made prior to the start of the project), Researchers (observers linked to Academia), Students (observers attending any course at the University of Lisbon), and Others (all the other observers that do not fit in any of the three categories described previously). Researchers who actively and consistently participate in citizen science events were the first to be identified; the remaining researchers were spotted through their iNaturalist's public profiles and validated by looking at the ORCID database (<https://orcid.org/>) and the ResearchGate social network (<https://www.researchgate.net/>). Similarly, students actively participating in the formal education activities were identified at first, followed by a search of iNaturalist's public profiles to detect any other students.

Additionally, three indices were used to compare these profiles: i) the iNaturalist Fidelity Index, developed in the course of this work, ii) the *Daily Observation Index*, estimated as the number of total observations divided by the number of days each observer made at least one observation (Kishimoto & Kobori 2021) and the *Retention Rate* (Martellos et al 2021), calculated on the basis of the dates of the first and the last observation registered by each user within the project, and measured in months. iNaturalist Fidelity Index measures the percentage of a user's observations that are not included in the project out of the user's total observations: (User Observations Not Included in the Project / Total User Observations) \* 100. iNaturalist Fidelity

Index ranges from 0 to 100%, where 0% means all observations are included in the project, so the user did not use the citizen science platform beyond the implementation project area, and 100% indicates that no observations are part of the project, meaning that the project had no impact on the relationship of the user with the platform. Next, Wilcoxon tests, incorporating Bonferroni correction for p-value adjustment, were employed to conduct pairwise comparisons of the iNaturalist Fidelity Index, Daily Observation Index, and Retention Rate among the four user categories, with the goal of analysing the different responses of the observers, before and during the project. Finally, Wilcoxon tests were also used to assess the project's impact on each user category, before and during the project, by conducting pairwise comparisons of the Daily Observation Index.

## Results

### Biodiversity observations

The project had a positive effect on the number of observers using the BioDiversity4All/iNaturalist platform in the studied area, with an increase from 81 observers before the beginning of the project to 366 after (Fig. 2). This increase in the number of observers had a direct impact on the number of observations and registered species, with 8018 new observations and 716 new species recorded (a total of 1019 species registered from the 1st of September 2020 until 31st December 2022).

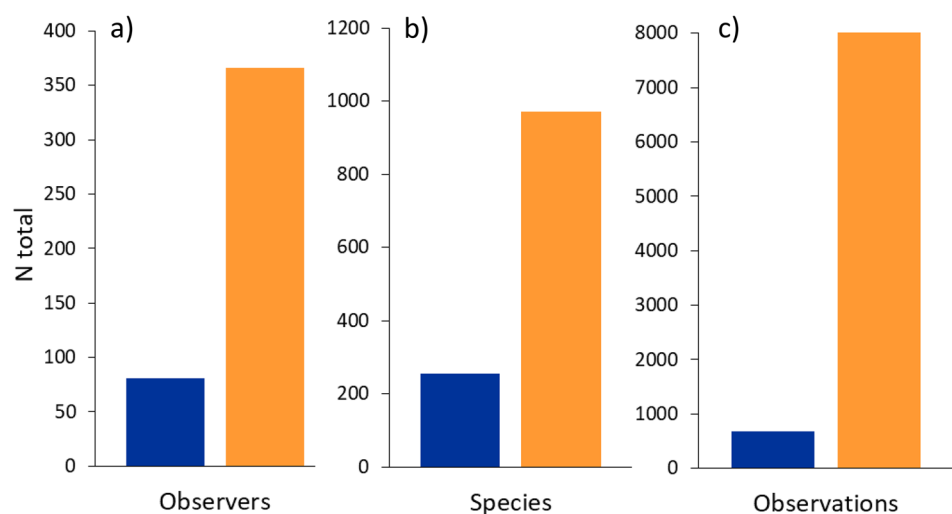
Figure 3 shows a summary of the number of species registered for the most iconic taxon. All the groups show an increase, but for Arachnida, Fungi, Insecta, Mammalia, Mollusca, and Plantae, the number of species recorded more than doubled. Moreover, during the project, two species of fish, a taxon not registered previously, were recorded in the area.

Figure 4 shows clearly the growth of biodiversity observations with the beginning of the project in September 2020. Promotional activities, such as classic biodiversity sampling surveys (from April to June 2021), BioBlitzes (e.g., October 2020 and May 2021), and data collection by students during classes (March 2022), showed a positive effect in the number of observations. Classic biodiversity surveys had a great impact on the number of birds, mammals and lichens observed. This is particularly noticed for birds in April 2021, with 273 birds registered, a value of only 17 for the same month of the following year, when no sampling was done. For mammals it is even more evident since this group was mostly observed during sampling directed to bats with 43 observations in July 2021 and only one in the same month of the following year. Lichens were more registered during July 2021, when two experts did the sampling. However, it is also noticed for this group the effect of BioBlitzes, particularly in October 2021 with 53 observations, as compared to none in October 2022. BioBlitzes also had a positive effect in the number of insect observations contributing to the highest number in May 2023 and the second highest number in October 2022. As compared to the same months of different year it is evident that BioBlitz were the main contributor to this data, in October of 2022 only two species were observed and in 2020 only 5. As for the month of May we can still see a high number of insect observations (91), however in this month classical sampling was done increasing the number of observations.

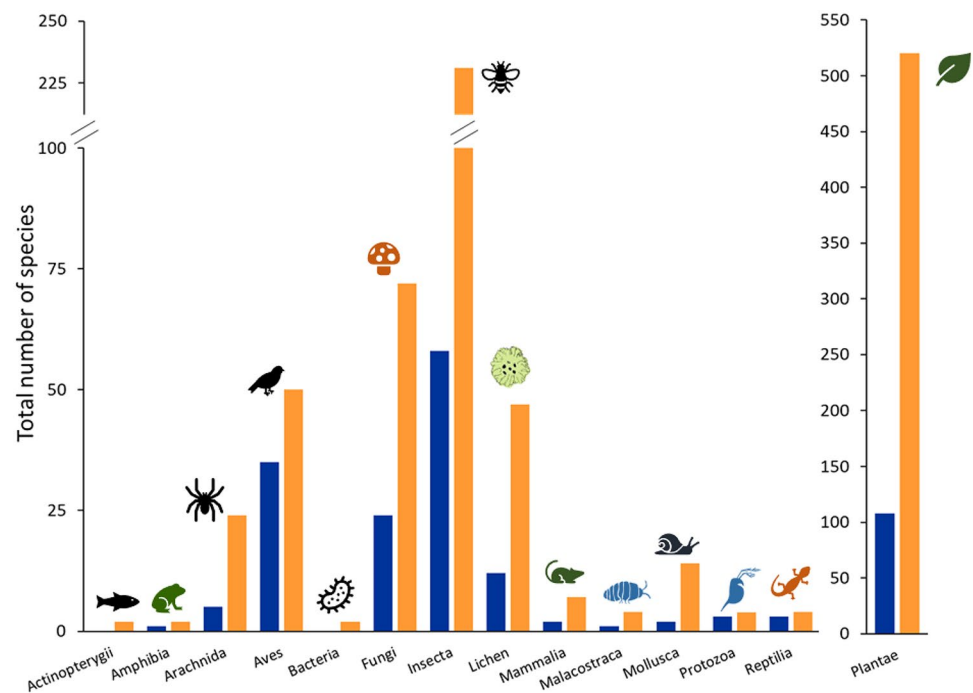
Dissemination activities were directed to fungi in November 2020 resulting in the highest number of observations for this taxon.

With almost 1600 observations made in March 2022, the impact of classes on plants was prominent, resulting from the activities organised within the Ecology subject. Plants also benefited from BioBlitzes in October 2021 (among

**Fig. 2** Total number of observers (a), species (b) and observations (c) registered in BioDiversity4All/iNaturalist platform in the studied area. Different colours indicate data from before (in blue) and after (in orange) the beginning of the project + Biodiversity@CIÊNCIAS. Data from 1st of September 2018 to 31st of December 2022



**Fig. 3** Total number of species of the 14 identified iconic groups registered in BioDiversity4All/iNaturalist platform in the studied area. Different colours indicate number of species registered, before (in blue) and after (in orange) the beginning of the project + Biodiversity@ CIÊNCIAS. Data from 1st of September 2018 to 31st of December 2022



others) and from particular campaigns direct to some species such as orchids.

Summer months are the period of the year with fewer observations since the university is closed part of the time and activities were not promoted. In Supplement 3, it is possible to see the top species for each of the iconic groups registered in the BioDiversity4All/iNaturalist platform for the project.

The 20 most observed species in the project (with over 50 records each) accounted for 373 observations. Comparing the observations gathered by specialists and by naturalists/students/others, the first observation of four of these 20 species was made by naturalists (2 species), students (1 species), and others (1 species). Regarding the 20 top observers of the project, nine were naturalists / students / others and were responsible for 3411 observations out of 5194, which corresponds to 65.7% of the contribution from the top 20 observers and to 33.89% of the total project observations.

### Observers profile

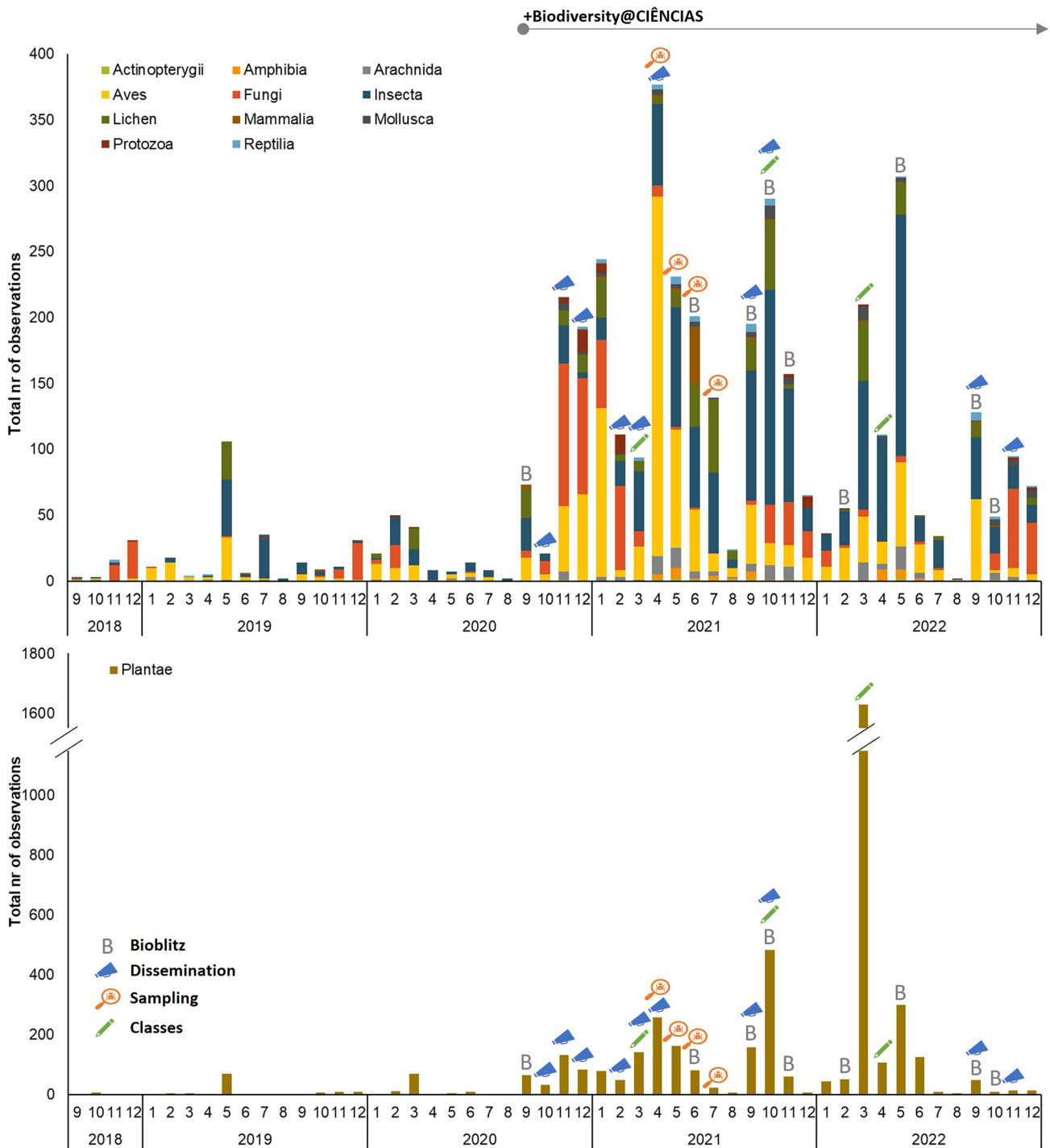
The three indices used, the iNaturalist Fidelity Index (Fig. 5), the Daily Observation Index (Fig. 6) and the Retention Rate showed that the four defined categories of observers—Naturalists, Researchers, Students, and Others—engaged differently with the project.

Regarding the iNaturalist Fidelity Index, values for Naturalists were mostly over 92%, indicating they used the platform mostly outside of the campus; Researchers and

Others responded similarly (with no significant differences according to the Wilcoxon test performed) and the iNaturalist Fidelity Index values ranging between 40% and 90% (median: 84.4% and 88.3%, respectively). Finally, Students showed the lowest iNaturalist Fidelity Index value of all categories (median: 3.24%, even though the upper quartile was above 84%), meaning they mostly made their observation in the context of the project. Overall, iNaturalist Fidelity Index values show that the project had a low effect on Naturalists, Researchers and Others, but a high impact on Students.

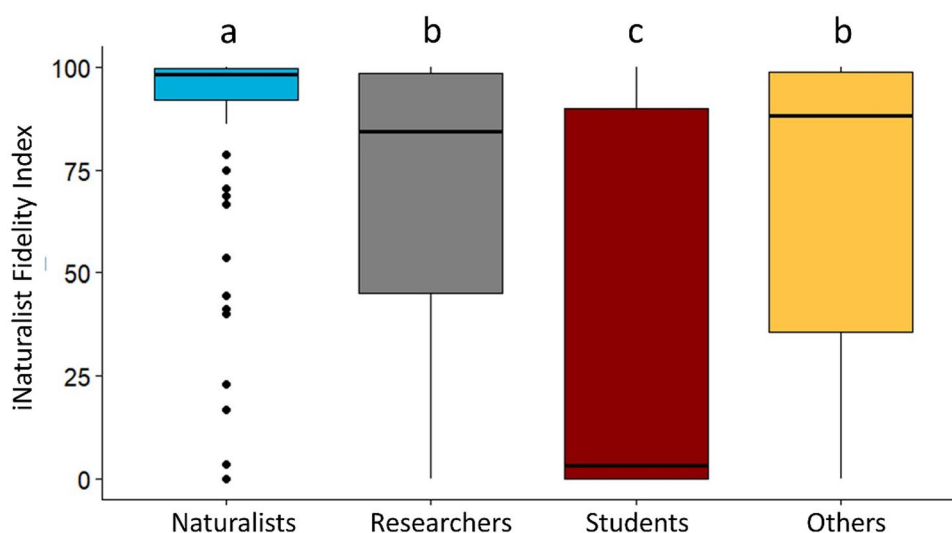
According to the Daily Observation Index, Wilcoxon tests indicated that the average number of daily observations on campus significantly increased ( $p < 0.001$ ) for the four categories (Fig. 6a and b): Naturalists (from 0.5 to 6.25 daily observations), Researchers (from 3.3 to 11.7 daily observations), Students (from 0.2 to 12.3 daily observations), and Others (from 0.3 to 2.4 daily observations), with Students and Researchers having significantly more observations than Naturalists and Others. Overall, Researchers were the group doing more daily observations before the project, while Students were the category with significantly fewer daily observations. On the other hand, they were the group with the higher rise in daily observations with significantly higher Daily Observation Index than Naturalists and Others.

Finally, the Retention Rate pointed to Researchers as the group that engaged in the project for longer periods (average = 5.89 months), followed by Naturalists (average = 3.38 months), Students (average = 1.76 months), and Others (average = 0.71 months).



**Fig. 4** Total number of observations registered in the BioDiversity-4All/iNaturalist platform in the studied area from 1st of September 2018 to 31st of December 2022, separated by iconic groups. All the events organized during the project are marked with a symbol and

separated into four categories: BioBlitzes, Dissemination activities, Sampling events, and Classes. The project +Biodiversity@CIÊNCIAS started in September 2020



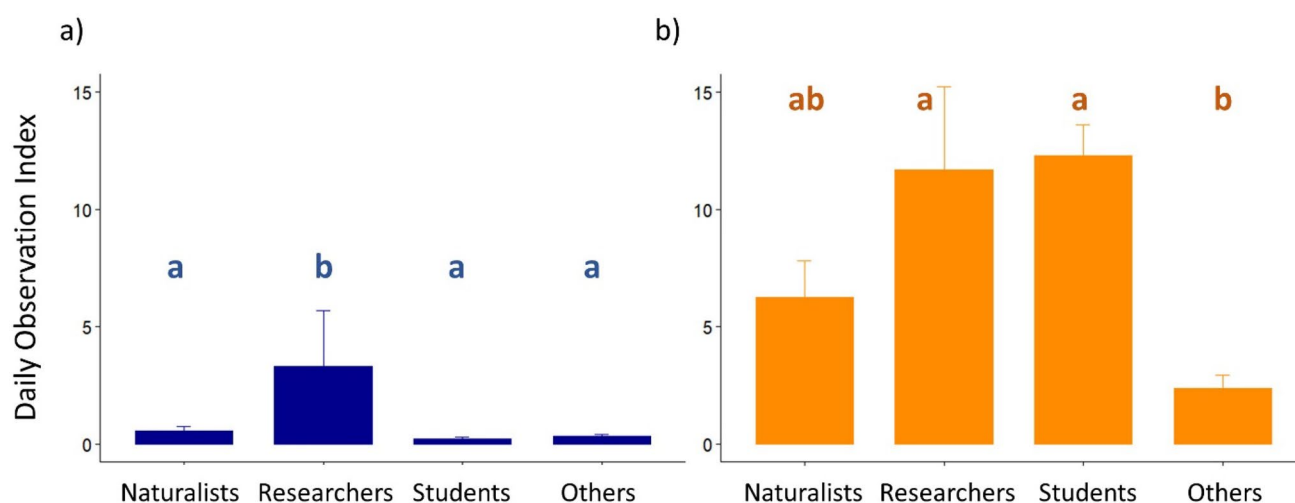
**Fig. 5** Boxplots showing iNaturalist Fidelity Index values calculated for the four categories of observers created: Naturalists ( $n=93$ ), Researchers ( $n=38$ ), Students ( $n=150$ ) and Others ( $n=32$ ). Central lines represent median values, box limits indicate the upper and lower quartiles, whiskers correspond to  $1.5\times$  the interquartile range above

and below the upper and lower quartiles, and points are the outliers. Different letters indicate statistically significant differences among user categories based on multiple pairwise comparisons using Wilcoxon tests with Bonferroni adjustment

## Discussion

The + Biodiversity@CIÊNCIAS project started under the scope of the sustainability policies of the Faculty of Sciences of the University of Lisbon (<https://ciencias.ulisboa.pt/pt/laboratorio-vivo-para-a-sustentabilidade>) which foster the promotion of knowledge and innovation in the field of sustainability and the raising of awareness and sharing of this same knowledge with both the science and

the external community. This work showed that a citizen science project like this can greatly contribute to monitoring urban biodiversity in a university campus. Overall, our findings show a high increase in the number of biodiversity registers and that through different activities to promote the observation and register of species it is possible to involve different groups of citizens and contribute to the knowledge of a greater diversity of taxonomic groups. Consequently, our diverse engagement strategies, such as



**Fig. 6** Daily Observation Index values (mean  $\pm$  se) calculated for the four categories of observers: Naturalists ( $n=93$ ), Researchers ( $n=38$ ), Students ( $n=150$ ) and Others ( $n=32$ ) and registered **a**) before the start of the project (blue) and **b**) during the project

(orange). Different letters indicate statistically significant differences in Daily Observation Index calculated among user categories based on multiple pairwise comparisons with Bonferroni adjustment

BioBlitz events for citizens or classes for university students, allow overcoming three relevant biases associated with citizen science, namely taxonomic, aesthetic, and temporal biases.

Citizen science has a great potential for increasing interest in biodiversity among the university community and the general public, which makes it an ideal tool for addressing societal engagement in biodiversity monitoring and conservation in the face of an unprecedented biodiversity crisis.

### Monitoring urban biodiversity in a university campus

The combination of green spaces, citizen science projects using species identification Apps and community-building involving citizen groups, makes university campuses areas with significant potential for monitoring urban biodiversity. Moreover, this integrated approach allows for a comprehensive study of the local ecosystem, fostering a deeper understanding of the interactions between urban environments and wildlife and how they are affected by different threats. It also promotes engagement and awareness among the university community and the broader public, encouraging active participation in biodiversity conservation efforts.

Some other studies have also analysed this potential. For example, the work of Guthula et al. (2022) shows how a campus can serve as living repositories and evolutionary labs for plant and small animal species that remain isolated due to fragmentation. In fact, adequate attention to campuses and other fragmented green spaces with a global conservation perspective could prove hugely beneficial in securing a wide variety of species in relatively small land areas. Liu et al (2021) review paper covered the history, diversity, and distribution patterns of living biodiversity on university campuses globally. They found over 300 university campuses that conducted biodiversity surveys, mostly on plants and birds, with China and India as research hotspots. Orenstein et al. (2019) work present a case study of how ecological considerations (biodiversity conservation, habitat preservation, and ecosystem integrity) can be integrated into campus strategic and statutory spatial planning. However, their work showed that ecological considerations play a relatively minor role in sustainability planning on university campuses and that the concepts of connectivity and compactness are applied broadly but generally only refer to social and educational considerations.

In our specific study, the presence of many citizens in this city area, as well as the interest of the scientific community in understanding the biodiversity of the campus and the potential use of this theme as a support tool for education, makes this urban area very interesting as a biodiversity monitoring location.

### Recognition of species occurring in urban environments

In the present work, the involvement in biodiversity monitoring by different categories of observers revealed the presence of species whose observation on the campus had not been documented before, mainly due to the absence of systematic work for some taxonomic groups. The relative heterogeneity of the area and the diversity of habitats, coupled with the presence of students and support from researchers, allowed this project to conduct a temporal analysis of the species richness (including native, exotic, and invasive species). Through this research, the project gained valuable insights into changing biodiversity over time, including the potential impacts of invasive species and the importance of preserving native biodiversity.

The university campuses analysed by Liu et al. (2021) harboured high biodiversity values, with an average of 199 plant species and 66 bird species on each campus, including many endemic and endangered species. On CIÊNCIAS campus, located in the centre of the Lisbon urban area, we detected more than 1000 species (716 were detected for the first time in the area), including 231 insects, 52 birds, and 530 plant species. The combination of continued data collection (more than two years) and the involvement of students and researchers has extraordinarily enriched our understanding of the campus ecosystem, aiding in its conservation and management efforts.

### Overcoming the taxonomic, aesthetic, and temporal bias

Tiago et al. (2017a) showed that efforts are required to increase the spatial evenness of sampling effort in citizen science projects, which could be addressed with the use of additional incentive mechanisms or gamification baselines to increase sampling effort in some regions or for some taxonomic groups. + Biodiversity@CIÊNCIAS results are in line with these, since the launch of challenges for recording specific groups, such as fungi, was essential in increasing the number of observations for certain taxonomic groups that were traditionally less observed. Due to a mushroom recording challenge launched on social media platforms during the autumn season, 82 species were identified. Less studied taxonomic groups tend to be deficient analysed in urban environments, as research efforts tend to concentrate in more natural areas. For these groups, citizen science constitutes a great help in collecting information (Krabbenhoft & Kashian 2020). Moreover, this project benefited from the presence of researchers on the campus who, highly committed to the project (see the Retention Rate values), collaborated in data collection and identification of taxonomic groups less appealing to the general public (Munzi et al. 2023). In addition to these challenges, the organization of

BioBlitzes and the inclusion of species recording in practical classes of the bachelor's degrees in Biology and Geography reduced the impact of temporal variations and led to greater homogeneity among the taxa sampled. (Chozas et al. 2023).

### **Biodiversity recording platforms as tools for university classes**

Ensuring that students connect with their environment, including the biodiversity it holds, is crucial, especially given the ongoing climate and biodiversity crises. Citizen science offers an effective way to promote engagement and support conservation efforts (Chandler et al. 2017a). However, it is essential for these citizen science projects to prioritize educational and personal objectives and encourage active involvement rather than mere information dissemination (Jordan et al. 2011).

The integration of platforms like iNaturalist, HerpMapper, and eBird in formal education is on the rise. By assisting with image and sound recognition mechanisms or providing freely accessible data, they allow students to explore and conduct their own analyses or create projects within platforms and social networks. However, it is important to determine whether these platforms foster meaningful learning experiences. Consequently, future research should focus on evaluating learning outcomes, biodiversity appreciation, and on the potential impact of citizen science-based platforms to student's involvement in conservation efforts. Moving beyond anecdotal endorsements, this evaluation will provide a more comprehensive understanding of the platform's effectiveness. In fact, in + Biodiversity@CIÊNCIAS there was a significant group of students who started recording biodiversity during classes and then became enthusiastic contributors to the platform (Supplement 4).

When considering the benefits for mental health of more permanent contact with nature, results from Ha & Kim (2021) showed that, individually, both the visual factor (the level of biodiversity) and auditory factor (the presence of natural sound) did not have statistical significance on the mental restoration of students. However, a significant interaction effect was found between the visual and auditory settings, indicating that high biodiversity and the presence of natural sound contributed to restorative benefits for students. By considering the result of this study, campus designers and administrators can create better campus environments to enhance the mental wellbeing of students Ha & Kim (2021).

### **COVID-19: a reinvention of the way of teaching**

Due to the Covid-19 pandemic, numerous activities originally scheduled for + Biodiversity@CIÊNCIAS were unable to proceed, particularly those requiring the assembly of large groups. On the other hand, the confinement led many

professors to attempt innovations in the way they conducted their online classes. Two activities were developed in the context of the Ecology classes of the bachelor's degree in Biology (CIÊNCIAS) where BioDiversity4All/iNaturalist platform was used to identify and georeferenced species observed by students in different parts of Portugal while attending classes remotely (see Chozas et al. 2023 for details). Later, once they returned to the campus, some of the students continued recording, leading to an increase in information within the project's study area. In fact, when analysing observers' profiles data for the iNaturalist Fidelity Index, it was noticed that, despite students generally low engagement with the platform, a significant number of them had a high iNaturalist Fidelity Index, which mainly corresponded to those students who had previously participated in the activities carried out during the COVID-19 epidemic (17.3%), indicating a clear enthusiasm for the platform during the period of confinement.

On the heels of a global pandemic that forced many students into isolation, innovative strategies to promote positive experiences were imperative for fostering connection with nature. Through these experiences, a commitment to biodiversity conservation can be fostered among observers. Niemiller et al. (2021) work argue that the iNaturalist platform can provide an additional tool to promote engagement with nature, particularly amongst digital natives. From their perspective, the goal was to spotlight the use of iNaturalist as an educational tool, address some of the concerns about its formal use in an educational capacity and begin the process of establishing best practices for using iNaturalist in an academic setting.

### **Creating links between academia and broader campus community, local residents and employees**

The organization of BioBlitzes in the study area was the most significant contribution to strengthening the relationship between the scientific community working in this field and the rest of the academic community, as well as the workers and residents in the surrounding areas of the university campus. The interaction between researchers and citizens through citizen science projects allows for a stronger connection between these two groups of society, with an increasing sharing of interests, concerns, and ideas. This connection can lead citizen science projects to evolve from being merely contributory or collaborative to co-creation projects, with all the advantages and closeness that this typology entails. The benefits of a society with greater scientific literacy are the most effective way to combat major issues such as climate change and biodiversity loss (Bennett et al. 2019). Moreover, iNaturalist as a platform provides substantial value as a place for community building and connecting with other naturalists as well (Di Cecco et al. 2021). Colding & Barthel (2017)

explore the potential for integrating university campuses into a global sustainability agenda, aiming to reestablish a closer connection between urban residents and the biosphere. This necessitates a socio-cultural transition that empowers universities and colleges to embrace their role as active stewards of the Earth System. With a keen awareness of their pivotal influence on shaping future generations, university campuses offer a distinctive socio-cultural environment to promote sustainable development in practical ways.

More attention must also be paid to restoring human connections with the natural world by affording the possibility of meaningful interaction with nature in close proximity to the places where people live and work (Pyle 1978). To do this, conservation scientists will need to participate in broad-based partnerships with planners, architects, health professionals, natural resource managers, and local citizens. We need to explore ways to convey conservation principles in a manner that draws people together rather than fostering an attitude of confrontation. There must be opportunities for the public, young and old, to explore and apply these principles in a variety of contexts, both formal and informal. The potential benefits for humans and wild species alike are too great to continue to ignore (Miller 2005; Niemiller et al. 2021).

Finally, the results from Tiago et al. (2017b) demonstrated that working deeply on people's involvement is fundamental to increase and maintain their participation in citizen science projects. If, for initial recruitment and in countries with low participation culture, mechanisms of external motivation may be necessary to guarantee higher levels of long-term participation, citizen science projects should foster intrinsic motivations. This can be done by incorporating in project design experiences of relatedness, capacity building, positive feedback, and adapted participation modes.

It is relevant to mention that both the BioBlitzes developed throughout the project and the social media campaigns contributed to an increase in the number of observers and observations in the area, improving the interaction between citizens and scientists. It is noteworthy that future studies should confirm the effectiveness of these actions in retaining citizens in citizen science projects.

## Concluding remarks

In this study, we investigated the potential of a university campus as a case study to comprehend and monitor urban biodiversity using citizen science. The results highlighted the significant capacity of citizen science to cultivate interest in biodiversity among both the university community and the general public. This establishes it as a valuable tool for promoting societal engagement in biodiversity conservation during an unprecedented biodiversity crisis. Additionally,

our findings emphasise the importance of different strategies, such as BioBlitzes, social media campaigns, and formal education initiatives, in reducing the impact of relevant limitations associated with citizen science, such as taxonomic, aesthetic, and temporal biases.

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**Data availability** Data is provided within the manuscript or supplementary information files.

## Declarations

**Ethical approval** The devices used to collect data (camera trapping and acoustic recorders) were properly marked and disclosed, and the work carried out received approval from the Ethics Committee of the Faculty of Sciences of Lisbon University.

**Competing interests** The authors declare no competing interests.

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