PROCEEDINGS OF SCIENCE

Counting lights for Sustainability – Insights from the Citizen Science Project Nachtlicht-BüHNE

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The Nachtlichter project (part of "Nachtlicht-BüHNE", funded during 2018 to 2022 by the Helmholtz Association of German Research Centres) aimed to collect information on artificial light sources at night. This was done as a cooperation between researchers and citizen scientists, who worked together at all stages of the project, including development of an app, data collection and analysis. The active participation in all stages is to be highlighted as a special feature of the project. During the data-collection-campaigns, more than 200 people worldwide counted over 250,000 lights, covering an area of around 22 km^2. Furthermore, the project strengthened public awareness on the topic of light pollution, and a deeper understanding of the problem was developed by the participants.

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1. Introduction

Light pollution is a growing problem worldwide. According to the new world atlas of artificial night sky brightness [1] which was created using satellite images, more than 80% of the world's population live under a light-polluted night-sky, and for about 30% the milky way is no longer visible from their home. Artificial light emissions and night sky brightness have been estimated to increase at a rate of about 3-6% annually [2]. Recently, Sánchez de Miguel et al. [3] reported an increase of 49% in the radiation density measured by satellites between 1992 and 2017, and the illuminated area worldwide was estimated to increase by 2.2% per year [4]. This light affects the environment, and numerous studies have documented its impact on insects [5], fish [6], bats [7] and other species including human beings [8].

Statements about the development of light pollution are frequently based on interpretation of satellite images (e.g. [9] and [10]). However, these images are taken from a great distance, and hence they do not give a full picture of the lighting situation on site. This complicates estimating the effects on humans, animals and plants using satellite based light pollution measurements. Comprehensive data on the local lighting situation, which would enable the analysis of impacts and the evaluation of consequential effects on the environment and human beeings, are currently lacking. For this reason, we developed the Nachtlichter app in order to collect and classify artificial light sources in public spaces. Within the project, we decided that light sources should be documented in terms of their type, quantity, and characteristics. At the same time, the citizen science approach was expected to strengthen awareness for light pollution and sustainable lighting. The project was led by the Deutsches GeoForschungsZentrum (GFZ) in cooperation with the Deutsches Zentrum für Luft- und Raumfahrt (DLR).

2. Project

2.1 App Development

As a citizen science project with a co-design approach, citizens were involved in the entire research process. Researchers, citizen scientists, and software developers worked on the app from November 2019 to August 2021. This included in particular the structure of the app, the data collection process, the input screen and the lighting categories, and this work was conducted in several phases. The process started with a Kickoff-Workshop in Jena in September where people were asked to go out and count lights using their own classification using this form: https://docs.google.com/forms/d/e/1FAIpQLScmi-No1ycVan1O19I9asl2SdcL-fGUhzqmgJS4ioAfkzkb5A/viewform. At the workshop, a group of people was invited specifically to take part in Nachtlichter. This group brainstormed questions like for example how to estimate the size of light sources. By December, a paper form had been worked out that was starting to look like the final classification system: http://lossofthenight.blogspot.com/2019/12/second-action-of-nachtlicht-buhne.html. Since the group met every month on Zoom to discuss the further development of the app.

The final version is based on a map interface, for which light sources per road section (transects) can be counted and described. The playful character of the app was intended to

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encourage participants to contribute to the data set. For example, measurement transects (typically segments from one street corner to another) change colour from blue to yellow on the map when they have been completed. After a survey is completed, the list of all light sources on the transect as well as their brightness (bright, normal, dim), light colour (white, orange, other) and beam angle (unshielded, partly shielded, fully shielded) or size (small, medium, large, extreme) is accessible as open data. In addition, data on traffic density and the use of motion detectors are collected for the transect as a whole. Fig. 1 shows the screen sequence when adding a light source to a transect.

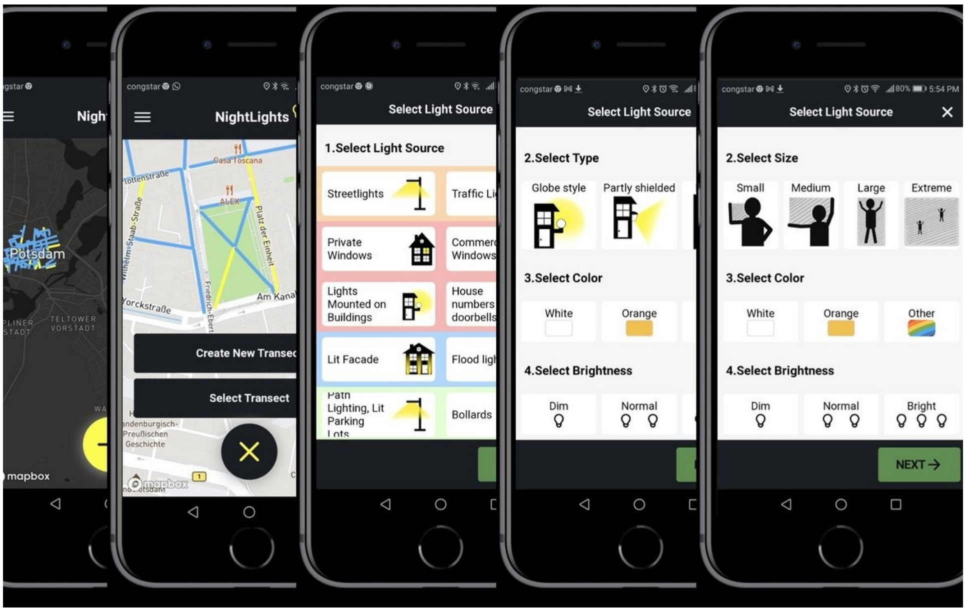

Fig. 1: Screen navigation in the app (two screens left: map screen with predefined transects, middle: selection of light category, two screens right: selection of light characteristics depending on chosen light category)

2.2 Organisation of the data collection

In each participating city (e.g. Potsdam, Dresden, Fulda, Bochum, Erlangen, Cologne, and Bolzano), local actors coordinated data collection campaigns. Together with the GFZ researchers, they determined areas of interest and checked them for accessibility. They promoted the campaigns, coordinated common counting events, designed and maintained a local campaign website, and provided regular newsletters on the progress of the project. The local teams met every two weeks via zoom with the researchers from GFZ and participants from the other cities. In addition to the larger campaigns with broad measurement areas, other initiatives with fewer participants (sometimes just one person) and smaller areas were started in several cities including Berlin, Erfurt, Leverkusen, Trier, Wittenberg, and Zorge, as well as in Belgium, Canada, France, Ireland, Italy, Serbia, Spain, Turkey and the USA.

2.3 Data collection campaigns

The data collection campaigns took place during September to November 2021, and started in each city with a kick-off event organised by the local coordinators. Afterwards, participants were free to decide whether to engage in coordinated counting events or collect data independently. A survey among 59 of the participants througout Germany showed that participants were drawn from a wide age range, although the 50-64 age group was the most involved. The majority of the citizen scientists reported having a university degree, but pupils and school classes were also involved in the project. Among the reasons given for participating in the project, a commitment to nature conservation predominated, followed by interest in citizen science or astronomy.

The campaign process in each city as well as the counting participation of the participants varied greatly. The authors supervised the local campaigns in Potsdam and Dresden and thus gained insight into the different processes of these two campaigns described in Fig. 2. In Dresden a total of 35 people participated actively in the counting process, while in Potsdam 24 participants collected data regularly. The Dresden campaign was shorter than the Potsdam campaign. The Dresden group established a fixed counting day on Tuesdays with changing meeting locations, and brought together between three and ten participants each week. The joint dates offered in Potsdam were less well received. There, participants preferred counting in small teams regularly via self-organization. As a result, in Potsdam counting took place on 53 out of 75 days, while in Dresden people collected data on only 41 days. The Dresden team walked a total of 66 km and counted 50,897 lights. Although the Potsdam team covered a similar distance with 54 km, about half as many lights were counted there (26,019).

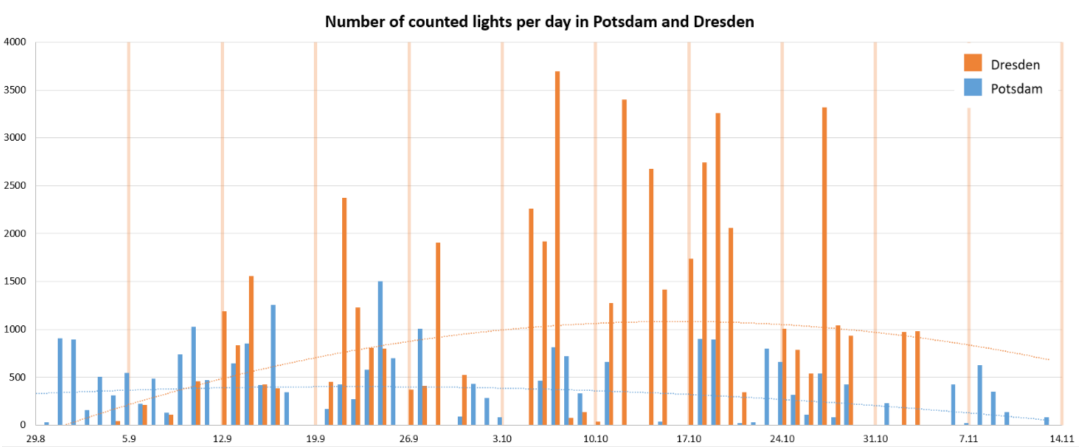

Fig. 2: Counted light sources (absolute numbers) per date in Dresden (orange) and Potsdam (blue) in 2021 (average value as dotted lines).

During the campaigns, 200 participants worldwide classified and recorded a quarter of a million lights along a total distance of 645 km. Some segments were also measured several times at different times of day or days of the week to determine changes in the amount of lights during night and month. Also there are transects that were counted by different participants to check consistency of the data.

2.4 Analysis and interpretation of collected data

Collected data is openly available on the website https://lichter.nachtlicht-buehne.de/. The data are anonymized, and the project was structured in a way that no conclusions about the

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lighting behaviour of individual households could be determined. The aim is to make the data available to a broad public, research institutions, planners, environmentalists and political actors in order to promote knowledge and serve as a basis for further research on light pollution.

Following the data collection, analysis and interpretation have been carried out since November 2021. The group contains participants of the early stages of the project as well as people that joined later on and consists of about 10 to 20 citizen scientists accompanied by the researchers. The process includes examining and correcting the data (e.g. removing duplicate records) as well as determining possible correlations with satellite data, writing papers and presenting the (intermediate) results at conferences, such as the Austrian Citizen Science Conference 2022. The direction of the data analysis is guided by the participants interests, and work steps as well as responsibilities are distributed based on their knowledge. The current state of the project is discussed in weekly zoom meetings within the group.

First results show that in Dresden, for example, street lighting accounts for 7% of the counted light sources while it is at 11% in Potsdam.

3. Conclusion and Outlook

The citizen science project "Nachtlicht-BüHNE" conducted lighting inventories on the ground in different locations in Germany and around the world. Involving the participants in each step of the project introduced them to the process of scientific research, and also created a community that is committed to night protection beyond the project. For example, stakeholders are planning follow-up campaigns to monitor changes in light over time in response to the current energy crisis. The data analysis is in progress. The project and its results are presented at various conferences, such as the Austrian Citizen Science Conference 2022, and should be published in scientific journals in the future.

The app is still available, and continues to be improved. The access to the collected data will remain open, which will enable further research questions to be addressed and more precise statements to be made about lighting and possible consequences for the environment.

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