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Come to the dark side – citizen science in nighttime ecology

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Abstract

Nocturnal ecology has hitherto led a shadowy existence in ecology, which traditionally focuses on diurnal species and functional relationships in the bright light of day. Yet nighttime hides exciting research insights and urgent conservation issues to be addressed. Citizen science is a promising approach to support this urgently needed exploration.

Keywords Artificial light at night, ALAN, Citizen science, Nocturnal ecology

Citizen science has become a valuable method to scientists and practitioners in environmental and ecological sciences [1] as it can help to address a variety of ecological issues. One of these issues is the ecology of the nocturnal niche and of the creatures it harbours. Despite the fact that half of the Earth's surface is experiencing darkness at any given time, nighttime is still an underexplored area in ecological research [2]. This is illustrated by the limited knowledge of the ecology of, and threats to nocturnal species: Out of all mammals on the IUCN red list, that are classified as data deficient to assess their population status and/or threat level, 81% are nocturnal [3]. Also, the by far most studied insect groups such as bees, butterflies and dragonflies are diurnal although nocturnal insect activity exceeds diel activity by almost a third [4]. Neglecting nocturnal pollinators in ecological pollinator networks (including insects, rodents and bats) may result in a distorted view of the structure of plant-pollinator networks with relevant implications for conservation assessments [5]. In recent decades, a new major driver of global environmental change—light pollution (caused by artificial light at night, ALAN)—has highlighted this lack of knowledge as a blind spot in ecological research [6]. ALAN has numerous effects on the individual level such as impacts on mortality, reproduction, foraging, migratory behaviour, diel activity, physiology and gene expression. Those may further lead to cascading effects on communities across ecosystem boundaries and hence impair ecosystem functioning (e.g. through food webs, predator–prey interactions and shifted phenologies) [7]. These cascading effects can even affect diurnal communities [8].

The underrepresentation of nighttime ecology in ecological research may be due to the fact that humans themselves are diurnal organisms, creating biases regarding the temporal dimension within research, but also in common knowledge within the society (e.g. species recognition) [9].

CS can support the developing field of nighttime ecology that has been understudied for too long. Many "unknowns" remain to be addressed to better understand the ecology of the dark, the relevance of its species and the detrimental impacts on its biodiversity so we can design effective mitigation measures. Ultimately, we may even need to fundamentally rethink our common projection of knowledge of ecosystem functioning, which has mainly been gathered in diurnal environments, onto nocturnal systems [10]. There is further a serious deficit of transferring scientific evidence into policy and public perception [6]. In this context, citizen or community

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science holds the potential to enhance data collection, but also to bridge the information gap between science and society: For example, the monitoring of nocturnal species can be improved by recruiting people who are active at night (like people returning from leisure activities or shift workers) who could observe nocturnal or crepuscular animals on their way home. As human behaviour is crucial in nature conservation, knowledge exchange can also be one important pillar of nocturnal CS e.g. by informing people about the detrimental effects of light pollution and training them on how to minimize ALAN wherever possible. CS may provide the interface of scientific research with the required cultural and regional context, like the simple knowledge of the existence of a certain nocturnal species in one's own backyard. This increases the ability of science to address complex ecological aspects for which empirical evidence is needed alongside public and policy engagement [11].

CS is a promising tool for nighttime ecology but also entails specific challenges. For instance, involving people who happen to be out at night but have no particular prior interest in the subject, has the potential of reaching out to new target groups, it may, however, also be challenging to motivate them in the first place. Another aspect is -depending on the project- the requirement of special safety and engagement considerations: In some areas or at certain times of the night, people need specific gear (e.g. red lights) or safety precautions are required to protect vulnerable groups [12]. Participation of children can be limited due to sleeping times or legal limits. The relatively low knowledge in nocturnal species taxonomy together with their richness (for example the number of moths species compared to butterflies) may be an obstacle, when involving citizen scientists in research that requires species identification. For some projects this is negligible, as the data reporting does not require identification on the species level. However, targeted nocturnal data contributions are mandatory.

Despite of the challenges involved, CS already contributes to nighttime ecological research and could do so even further in the future. Due to its broadband character (ranging from low level engagement to co-creation) and often interdisciplinarity, it can strengthen the field of nighttime ecology in many ways (Fig. 1): It can support monitoring efforts targeting numerous nocturnal species and help to assess the multi-dimensional impacts of ALAN on species and ecosystems (see Table S1). For example, CS informed AI can assist taxonomic identification of nocturnal insects [13] and even enable the detection of new night-active species like semi-slugs, that have recently been discovered by citizen scientists in Brunei (Table S1, line 29). CS may uncover overlooked nocturnality like in the case of the common grass snake *Natrix natrix*, a widespread European snake that is traditionally

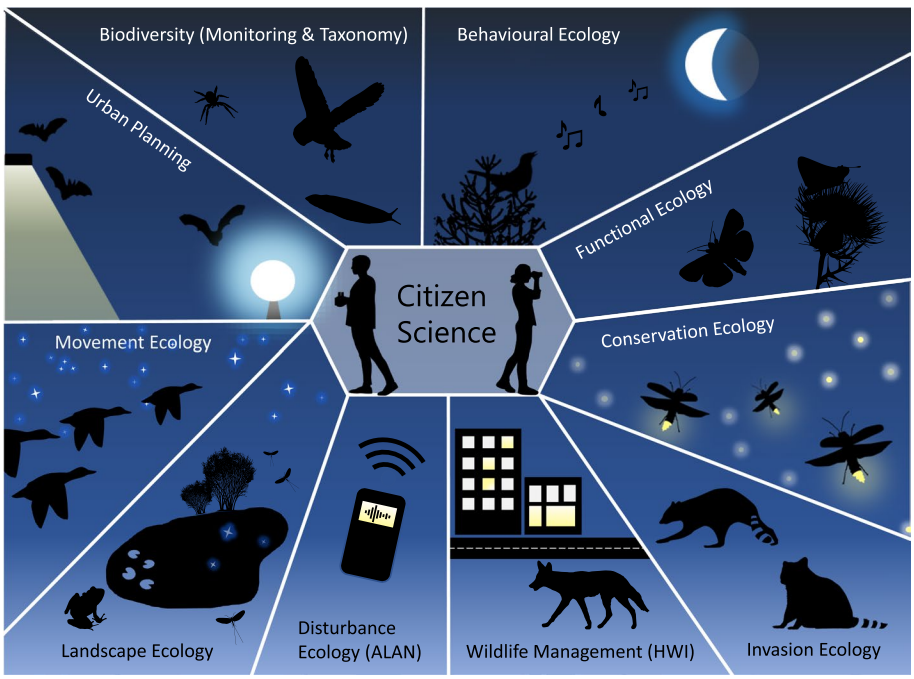

Fig. 1 The growing field of nighttime ecology overarches several ecological research disciplines and concerns various areas of applied ecology. Citizen science is already making an important contribution to these today, but has the potential to further enhance the development of nighttime ecology

considered diurnal (Table S1, line 31) and it can foster the detection of unknown behaviours such as the cryptic migration of the Common *Potoo Nyctibius griseus* in Brazil (Table S1, line 6). The use of CS can help to study the evolution of behaviour, such as the evolution of song in nightingales (Table S1, line 15) and it can further reveal surprising behavioural adaptations of nocturnal animals, such as the unexpectedly common arboreal habitat use of amphibians in Great Britain (Table S1, line 24). CS has been used to investigate the fitness of diurnal species in response to a disturbed nocturnal resting period, for example by using a Neighborhood Nestwatch Program to study the variation in annual survival rates of avian species in urban areas (Table S1, line 25). In urban areas, CS can ultimately inform city planning, for example, by using citizen-recorded bat vocalizations along different habitat structures to evaluate the potential of urban areas for bat conservation and to develop evidence-based recommendations on how to improve urban spaces for bat protection (Table S1, line 17). Where humans live close to wildlife, the employment of CS can also pacify human wildlife conflict and inform wildlife management, like in the case of coyotes roaming at night (Table S1, line 8) or help to investigate the ecological impacts of invasive species such as nocturnal urban invasions and agricultural damages of birds in South Korea (Table S1, line 36).

CS can make use and be combined with a variety of different methods, from long established (e.g. camera trapping, standardized surveys, transects, bioacoustic monitoring) to more recent ones (e.g. webGIS mapping, eDNA, machine learning, other AI tools). It thus holds the potential to enrich the developing field of nighttime ecology along different engagement levels (see also Table S1).

Here we want to state that the field of nocturnal ecology not only deserves much more attention by the research community—but also by society, nature conservationists and politics—and that CS could be an essential component of this attention.

The more we uncover, the more we realize how hidden the dark side of all life is, and how important it is to protect it. Even for diurnal creatures, the alternation of day and (dark) night, which is deeply rooted in evolutionary history, is essential (e.g. for sleep cycles and circadian rhythms). We thus want to make a strong plea for more nighttime ecological research. CS provides a necessary tool here, because it can generate data of often overseen fauna, flora and their interactions. It can further empower citizens to engage in their right for dark nights as a source of quietness and recovery and raise awareness about nocturnal ecology among multiple actors. By connecting different actors/stakeholders and combining disciplines and methods, CS can therefore be crucial in increasing the capacity of science to address nocturnal ecological problems and to find solutions to the rapidly vanishing natural darkness of the night.

Abbreviations

ALAN Artificial light at night
CS Citizen Science

Supplementary Information

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Additional file 1: Scope of nighttime ecological research built on citizen science based approaches. Selected examples from the last 5 years.

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F.H., S.E.K., S.K., S.S. had the idea of this comment, A.K. collected literature on CS in nighttime ecology, S.E.K., S.K. reviewed the literature and wrote the manuscript, A.K., S.S. and F.H. edited the manuscript thoroughly. S.E.K. prepared the figure.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

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