Effects of light pollution on insects

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Introduction

The United Nations and the European Union recognise Artificial Lights At Night (ALAN) as a sensory polluting agent that has increased worldwide in recent decades. ALAN has a major effect on intra and interspecific interactions, resulting in a cascade of effects on biodiversity and ecosystem services. This reveals its contribution as an environmental stressor capable of reshaping entire ecosystems. Due to this issue, varied organism groups (including microorganisms and plants) experience a wider range of alterations causing wavelength-dependent responses. Nevertheless, the effects of ALAN are not limited only to nocturnal or crepuscular species but also to diurnal communities (**Figure 1**).

Insects play a key role in all terrestrial ecosystems and are considered the most successful animals on Earth. However, they are uncommonly included in extinction risk assessments, conservation projects and biodiversity datasets. Insects consist of the primary food source for several species and provide habitat maintenance and pollination as the main ecosystem services. A great number of studies confirm that there is an accentuated global decline in insects mainly due to anthropogenic activities such as modification and/or loss of habitat, climate change, invasive species, and the use of agrochemicals. Considering insects and their specific threats to be fairly unknown, nocturnal or crepuscular insects and their specific threats (i.e. light pollution) have remained further neglected.

Lepidoptera is a megadiverse order of insects and constitutes the second-largest order in terms of diversity. Nocturnal Lepidoptera (or moths) comprise 88-91% of all described Lepidoptera and are more ecologically and taxonomically diverse than butterflies. **Moths** are the **major nocturnal pollinators** of flowers, therefore pollination services may be significantly disrupted by the loss of the moth community. Adding this fact to the disproportionately low level of research compared with diurnal Lepidoptera, makes it fundamental to support this cause by broadening knowledge for nightlife conservation.

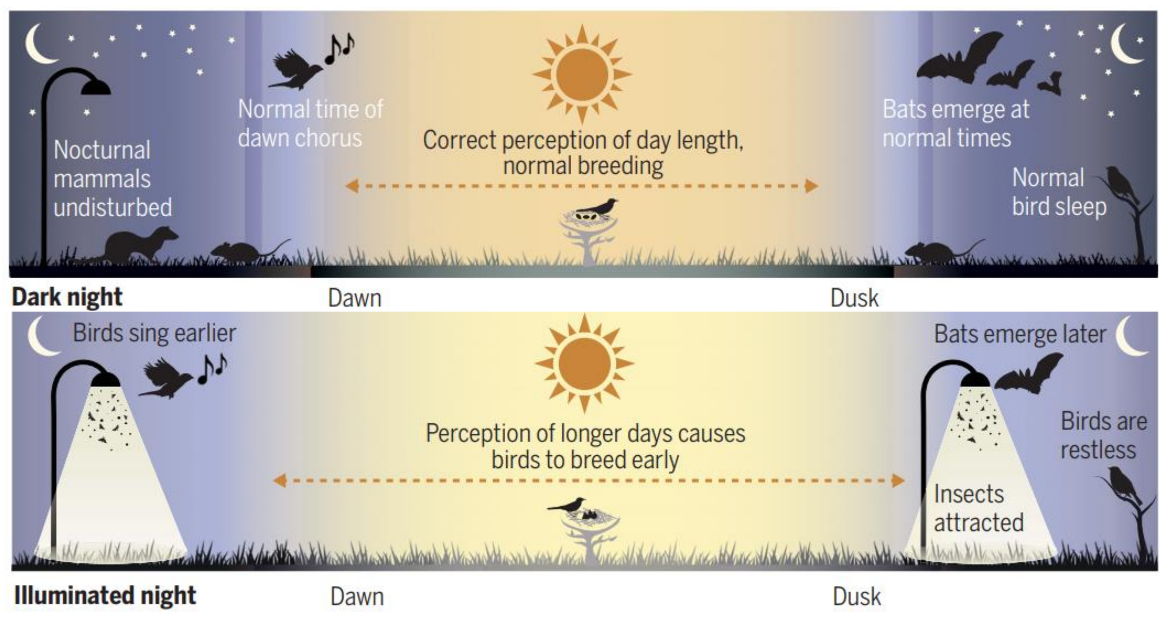

Figure 1 | Above: Standard situation of natural events on a dark night. **Below:** Same situation with a series of effects produced by an illuminated night, leading to ecological mismatches. Extracted from Desouhant *et al.*, (2019).

- **Main goal:** This study aimed to gather information about the effects of ALAN in insects with a special focus on Lepidoptera to inform conservation and/or management strategies for the protection of this highly diverse group towards light pollution.

Material and Methods

The information collected is a result of a literature review that was developed during the first year of the LIFE Natura@night project, the scientific papers where selected with the following search term: "*moth*" + "*Light pollution*" and subsequently screened by the following criteria: *studies located in Europe, with preference for Macaronesia* (no papers were found), *only peer-reviewed papers, fairly recent papers and written in English*. The main aim was to update existing information on how light pollution affects insects. This bibliographic review was composed of three chapters where the basic information on insect abundance and distribution, with a focus on Lepidoptera in Macaronesia (Chapter I) and their effects on ALAN (Chapter II) in addition to proposed mitigation measures (Chapter III) was displayed. A total number of 88 scientific papers were consulted, from which, 37 articles were selected for further analysis as an attempt at systematic analysis. To systematise the information a database was created to classify the papers regarding the main topic addressed, a set of ALAN-related questions answered and the target group-related questions. The answers were given on a *yes/no basis* to have a general idea about the current knowledge in this subject.

Results

- The analysed studies indicate that in general, **light pollution** seems to **reduce the total biomass and change the composition of insect communities, contributing to global insect declines**. However, responses are very taxon-specific and therefore, may not affect all species and/or genera in the same way.
- **The response of insects to ALAN is significantly influenced by their visual systems.** Vision has taxonomic features, each species perceives the intensity and wavelength of light differently, depending on the possessed number and types of photoreceptor outputs (**Figure 2**). Insects are trichromats and dispose of UV-, blue-, and green-sensitive photoreceptors, therefore are commonly attracted to short wavelengths. **Attractiveness to light (phototaxis) is also taxon-specific,** and dependent on the spectral sensitivity of the studied species or genera (i. e, Noctuids are more attracted to short-wavelength lights than other genera of moths).
- Outlining some of the effects of ALAN on insects (**Figure 3**), ALAN can produce **changes in behavioral responses**, that alter normal activities such as **local movements** (compromising orientation and navigation during flight, altered detection of; shelter, food and oviposition substrate), **disrupt ecological interactions** as **intra and interspecific interactions** (by shifting species into temporal niches, food web interactions and as altered predator and competition rates), **changes in reproductive behaviour, affecting reproductive success** by altered sexual communication and courtship signals (disruption of mating, breeding and the reduction of its duration), **alteration of life cycles.** ALAN also influences **physiological processes** by altering the hormonal balance of individuals, influencing their fitness (changes in colour and camouflage), **reduction of habitat quality, changes in geographic distribution, reduction of species diversity, habitat fragmentation** (affecting biotope connectivity, leading to less resilient insect populations), **impact on pollination,** influencing **migratory flows** as changes in geographic distribution occur, which can result in the **reduction of fitness** (individually and as populations), **decreased survival and reproduction success** affecting community composition and population dynamics.
- Nocturnal animals, typically present visual systems adapted to low natural night-time light such as the moon and stars. There is growing concern about the disruption of vital behaviours of nocturnally active insects. The chances of survival for many species of nocturnal insects have decreased significantly as a result to ALAN.
- **Regarding Lepidoptera,** vision plays an important role. There is a higher number of photoreceptors in diurnal species than in nocturnal species (**Figure 4**). **Nocturnal Lepidoptera** present colour vision at a low light intensity and sacrifice resolution characteristics to gain more sensitivity. In general, **moths are particularly sensitive to light spectrum between 300 and 400 nm of wavelength,** as a result to these characteristics, they are known to be highly attracted to ALAN.

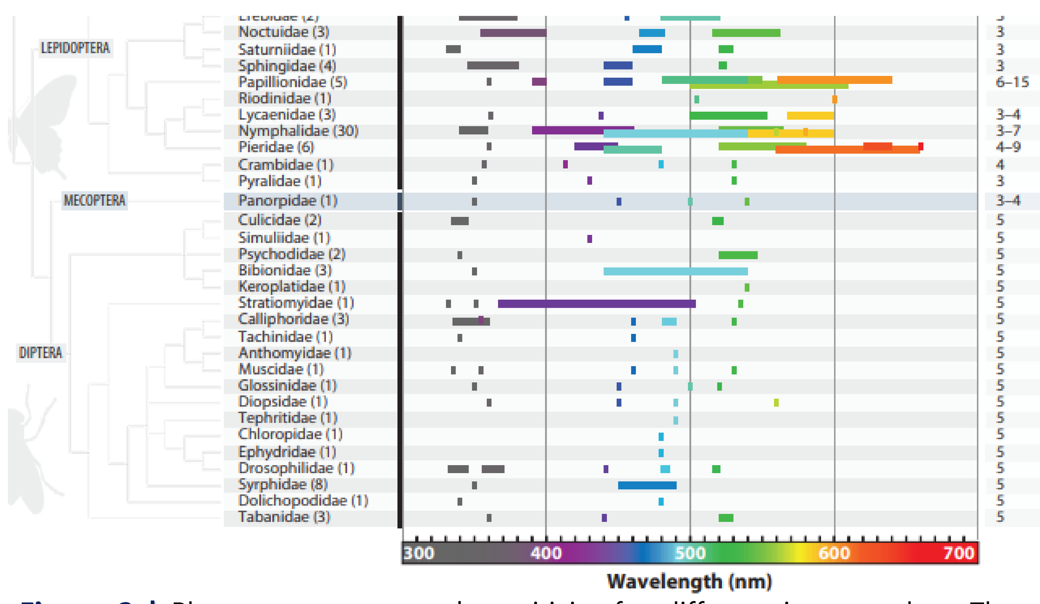

Figure 2 | Photoreceptor spectral sensitivity for different insect orders. The number of photoreceptor types is shown on the right column. Extracted from Van Der Kooi *et al.*, (2021).

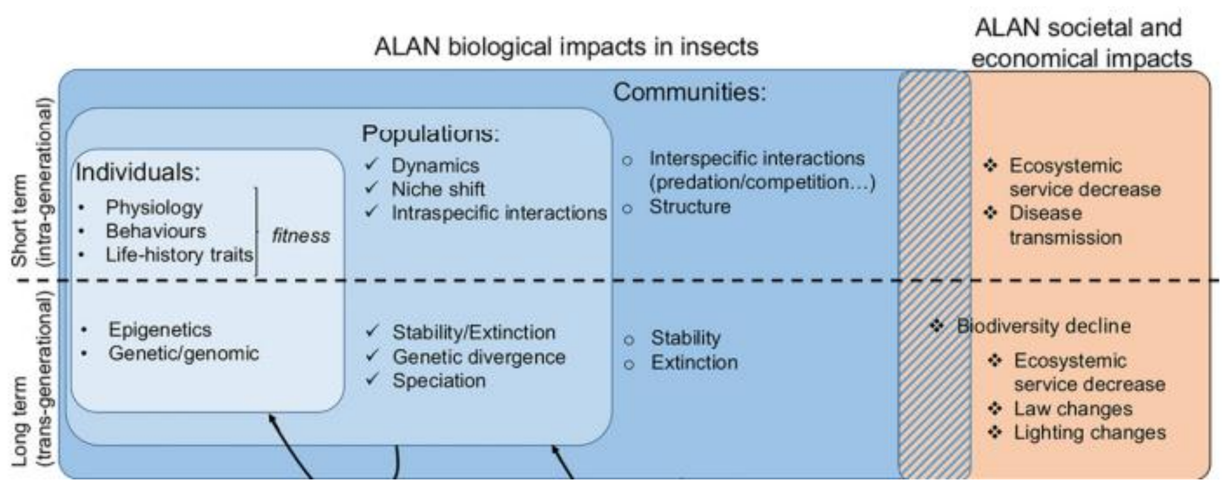

Figure 3 | Summary of ALAN effects at various levels of biological organization in insects. Extracted from Desouhant *et al.*, (2019).

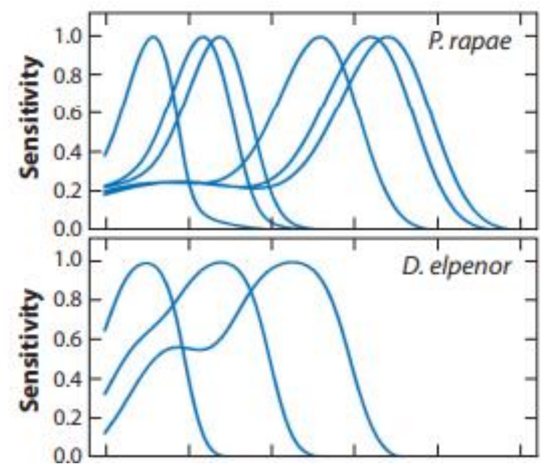

Figure 4 | Schematic representation of photoreceptor anatomy for diurnal Lepidoptera *P. rapae* and nocturnal Lepidoptera *D. elpenor* giving clear differences in their sensitivity according to their vital activity. Extracted from Van Der Kooi *et al.*, (2021).

Discussion

- In the past decades the development in lighting technology has led to major increases in the distribution and intensity of artificial light and its growth is continuing largely unchecked. **Light pollution fragments populations and diminishes biodiversity which is vital to ecosystems**. Artificial light has the potential to significantly disrupt ecosystems, mismatching the natural light/dark patterns and has several negative impacts.
- Understanding how different study groups perceive light is crucial for implementing actions to reduce light pollution. Since there is no artificial light without ecological impact, each type of light can impact differently diverse species. **Understanding the sensitivity of wildlife to different light wavelengths is essential for assessing the potential impact of artificial light on animal behaviour and physiology**.
- **Actions to reduce artificial light impacts are necessary and justified, although further research is required to fully understand the impacts of ALAN.** The effects of ALAN are theoretically admitted to be well known. However, further specific studies are needed to explain more about the technical aspects of light pollution (such as *wavelength, radiance, luminescence, number and type of light used in each experiment*) and how it affects nature in a taxon-specific way, more studies are needed on the effects of light pollution on different insects and study in detail if light pollution can be considered as a driver of insect decline.
- **The literature about this theme is patchy** and there is little scientific data on the actual effects of emitted light on other groups of study. The disappearance of certain insects can trigger a cascade of effects on the functioning of ecosystems. Insects most affected by excessive light are those with nocturnal habits. **Correlative studies established direct links between ALAN and population declines in moths.** A decline in such specialist pollinators will produce low pollination rates of flowers, producing a reduction in plant density in many species which can also extrapolate the negative effect on agricultural production.

Acknowledgements

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References

Anderson, M., Rotheray, E. L., & Mathews, F. (2023). Marvellous moths! pollen deposition rate of bramble (Rubus futicosus L. agg.) is greater at night than day. *Plos one, 18*(3), e0281810.

Bruce-White, C., & Shardlow, M. (2011). *A review of the impact of artificial light on invertebrates.* Buglife-The Invertebrate Conservation Trust. ISBN: 978-1-904878-99-5.

Desouhant, E., Gomes, E., Mondy, N., & Amat, I. (2019). Mechanistic, ecological, and evolutionary consequences of artificial light at night for insects: review and prospective. Entomologia Experimentalis et Applicata, 167(1), 37-58.

Grubisic, M., & van Grunsven, R. H. (2021). Artificial light at night disrupts species interactions and changes insect communities. Current Opinion in Insect Science, 47, 136-141.

Van Langevelde, F., Van Grunsven, R. H. A., Veenendaal, E. M., & Fijen, T. P. M. (2017). Artificial night lighting inhibits feeding in moths. *Biology Letters, 13*(3), [20160874].

Macgregor, C. J., Pocock, M. J., Fox, R., & Evans, D. M. (2015). Pollination by nocturnal Lepidoptera, and the effects of light pollution: a review. Ecological entomology, 40(3), 187-198.

Owens, A. C., & Lewis, S. M. (2018). The impact of artificial light at night on nocturnal insects: a review and synthesis. Ecology and evolution, 8(22), 11337-11358.

Van Der Kooi, C. J., Stavenga, D. G., Arikawa, K., Belušič, G., & Kelber, A. (2021). Evolution of insect colour vision: from spectral sensitivity to visual ecology. Annual Review of Entomology, 66, 435-461.