ALAN

ARTIFICIAL LIGHT AT NIGHT CONFERENCE

2025 WESTPORT IRELAND

presented by

DARK SKY IRELAND

Mayo Dark Skies

main sponsor

Comhairle Contae Mhaigh Eo
Mayo County Council

Programme Abstracts Booklet

Welcome from the Local Organising Committee

Welcome to Westport!

On behalf of Dark Sky Ireland, Mayo Dark Skies, the Local Organising Committee and our sponsors we'd like to welcome you to the largest-yet ALAN conference and promises to be an enjoyable occasion. Our venue lies close to the Mayo Dark Sky Park which won Dark Sky Place of the Year in 2024 and, as the northern hemisphere's only Gold Tier DS Park we hope that you'll get to visit and see our world-standard night skies, or simply to enjoy the natural night-time environment.

ALAN 2025 has been in preparation for the past two years and wouldn't have succeeded without the assistance of many people although we'd like to single out our thanks to our skilled conference organiser, Lisa Hallinan, who went above and beyond in terms of commitment – thank you Lisa! Also a big thank you to all our volunteers who you'll meet around the venue, and to Albert White for wrangling the abstracts into some sort of order.

Our jam-packed schedule addresses the diversity of light at night research and includes side events with researchers, environmentalists, professional lighting designers & engineers and local authorities – all indicative of the broad scope of the issue and the need to work as a diverse community in order to resolve the problems. We hope that you will enjoy some of these events and, perhaps, also get to see the lighting changes made in the nearby town of Newport which lies on the edge of the Dark Sky Park. Additionally, the timing of the meeting was deliberately chosen to precede the Mayo Dark Sky Festival, which will commence at the end of the week. This is the ninth year of the Festival and promises the usual wide range of events and speakers: check out the programme at: https://www.mayodarkskyfestival.ie/

Finally, we'd like to express our thanks to all our sponsors, particularly our main sponsor Mayo County Council who have worked closely with us over the years and supported our efforts to both protect the night-time environment and improve our towns. We thank the Council for their continued support and generous sponsorship of ALAN.

The abstract book is ordered in terms of invited speaker contributions first, then contributed talks and posters, both organised alphabetically by first author within their respective sections.

We look forward to hearing about the latest research over a wide range of fields, catching up with old friends, and making new ones either at the meeting or an after-hours social setting.

Enjoy the conference!

Brian & Georgia

Welcome from the Science organisers

Welcome to the 9th Scientific Conference on Artificial Light at Night, ALAN2025 in Westport, Ireland. It’s going to be a full and diverse conference!

With 144 submissions and almost 200 attendees, we have a new ALAN record. As the interest in ALAN increases, the emphasis of the ALAN conference is slowly changing. This conference is a valuable place for researchers to discuss their projects with peers from their own and from other disciplines. It is a place where researchers from nature science and technology meet colleagues from social sciences and humanities. It’s a scientific conference.

But it’s always great for researchers to have their results recognised and used for science-based practice. This year, we have a small but highly welcome group of lighting designers who show how the need to reduce ALAN influences their projects. We also will hear how science communicators increase awareness for the value of darkness. And we will hear about the growing number of regulations and legislation on light emissions.

We are also lowering borders. For a long time, it seemed that there are two factions within the ALAN community: the “industry” who wants light for its beauty and for safety, and the “dark sky defenders” who want to keep the skies dark to see the stars and protect nature. Reality gives us another picture. As our nights get brighter, we value subtle lighting designs. We understand the real consequences of ALAN and question the long-preached benefits of artificial light. Does more light really makes us safer? Do we lose the beauty of our cities if we don’t illuminate them brightly?

In the coming days we will hear arguments for a more careful use of ALAN. We will have time for exchanges between researchers, communicators, practitioners, and activists. We will have lots of scientific talks about the newest ALAN results, but we will also have workshops…. and there will hopefully still be enough time to just talk over a cup of tea or coffee (or a good pint). Together, with our different ways of thinking and acting, we will bring chance to the world around us.

My thanks go to the local organising team from Dark Sky Ireland and Mayo Dark Skies who worked hard over the last two years to make this conference happen. And thank you all for being part of ALAN2025!

Best wishes

Annette Krop-Benesch
co-chair steering committee

Invited Talks

Darkness and Artificial Light at Night: Towards Better Coexistences

Theme: Society

Nick Dunn

Lancaster University, Lancaster, United Kingdom
nick.dunn@lancaster.ac.uk

Biography

Nick Dunn is Professor of Urban Design and Director of Imagination, the design-led research centre at Lancaster University, UK. He is also a Director of DarkSky UK, developing more sustainable relationships between the built environment and the night, as well as exploring ways to promote wider and inclusive participation with dark skies. Nick is the author of *Dark Matters* (2016) and *Dark Futures* (2025) and co-editor of *Rethinking Darkness* (2020) and *Dark Skies* (2023).

Enchantment with the night sky is woven into the story of what it means to be human. The history of our connection with dark skies is rich and diverse. It has shaped and been shaped by culture, religion, science, and society. In addition to the scientific knowledge that astronomy provides, artists, poets, and philosophers have been inspired by the stars, moon, planets, and universe. Throughout history, dark skies have provided an important domain in which we look for meaning in our lives. Yet many of us can no longer access the wonder of a starry sky, if indeed we have ever had the opportunity to experience one. In an era of climate emergency, we need to fundamentally rethink what we do, how we do it, and why.

Fig. 1: The nocturnal city as a stage, Hulme Park, Manchester, 10 March 2025. © Nick Dunn.

Embracing darkness is about so much more than tackling light pollution. In this talk, I will explain how it is connected to everything. Our ideas and ingenuity, our relationships and responsibilities to others, our innovations and their implementation. Together, these represent our capability to flourish or perish. However, for as long as we have been around as a species, we have struggled with darkness. From our primeval origins to the present day, the dark is widely comprehended as unsettling. To reclaim the dark as a source of positive, progressive conceptual thinking is no small task. It compels us to look deep into ourselves, our histories, our cultures, and our values. It may be uncomfortable for us to question the structures and fabric of our beliefs and

our societies. Yet I propose it is a vital key to unlocking a rebalanced relationship with each other, our countless nonhuman neighbours, and the planet.
Rather than more and more where artificial light at night is concerned, are we capable of having a different relationship with darkness? In the context of many cities in the West, and increasingly in urban centres elsewhere, darkness is unwanted, connected as it is to negative cultural and historical associations alongside contemporary attitudes towards fear and crime. Certain values of light and its implications of clarity, cleanliness, and coherency have since been transferred across the global experience of culture more widely. This has resulted in a decline of how we perceive and understand darkness, to its detriment. Recent technological developments have been quick to set out their benefits, often with an emphasis on economic savings, without worrying too much about the other costs that artificial light can have. We have astonishing levels of light in numerous aspects of our lives, yet the growth and change of source of this artificial luminosity have largely gone unnoticed by most people, while for some it has serious detrimental effects.

What does this mean for us and our cities in the twenty-first century? Light still invokes notions of disclosure, surveillance, and security. Positioning darkness as a positive agent for architecture and urban design brings forth an urgent need to better understand the value of different coexistences of light, shade, and dark to the public. This will enable us to provide a socially equitable and environmentally desirable future that promotes civic life differently from business-as-usual approaches. Recent shifts in understandings about darkness suggest an opportunity for designers, policy makers, and communities to shape the nocturnal world anew.

To achieve this requires a major rethink in how we perceive the built environment and darkness. Before that, we need to question what we value and desire. Responsible lighting and careful choreography of darkness in urban places can provide important conditions for creativity, culture, socialising, and health and well-being. Rather than flooding the urban fabric with bright artificial light, curating illumination so that it enhances the qualities of place and supports the collective life within it—human and nonhuman—must form a central tenet of how we design for nocturnal citizenry. We need fresh approaches to change the prevailing mindset and encourage us all to reimagine and reconfigure cities between dusk and dawn.

We already speak of green and blue elements in our cities, spaces and infrastructures that can enhance biodiversity, mitigate climate change, and improve human health and well-being. If we consider dark skies as a type of natural infrastructure, with comparable benefits, then we can understand how reimaging urban nature as one of daytime and nocturnal rhythms is a gateway to an entirely new conception of nightlife in cities.

Restoring dark skies in cities would enable a more cohesive relationship between built environments and natural ones rather than the sharp distinctions that currently influence our thoughts and actions. Beyond the important preservation and conservation of existing dark sky places, forging new ways to darken urban environments would make a significant contribution as part of a holistic approach towards better coexistences between light and dark, human and nonhuman, built and natural environments.

Assessing Large Regions Using Light Pollution Models: Strategies and Limitations

Theme: Measurement and modeling

Hector Linares Arroyo,[1,*] Eduard Masana[1] , Manuel García-Gil[2], Martin Aubé[3]

[1] Institut de Ciència dels Cosmos (ICC-UB-IEEC), Barcelona, Spain
[2] Departament de Territori, Habitatge i Transició Ecològica, Generalitat de Catalunya, Spain
[3] Département de Géomatique Appliquée, Université de Sherbrooke, Canada

hectorlinares.lightpollution@gmail.com
[*] presenting author

Assessing light pollution levels over large regions (>5,000 km2) is a complex task. The high variability of sky brightness due to atmospheric variations, distance and orography, requires a dense grid of assessment locations. Using ground-based instruments would necessitate a network of hundreds, if not thousands, of devices. Satellite data provide information of the light emitted upwards but not the light pollution level experienced from the ground. Numerical light pollution models offer the best approach to address this challenge [1].

In recent years, we have developed a methodology for assessing large areas [2] with the Illumina model [3] serving as the basis for computations, using satellite imagery [4] to estimate light source characteristics. We applied this methodology to Catalonia (30,000 km^2), generating a zenith sky brightness map with a 5×5 km sampling grid, and to the province of Tarragona (6,000 km^2), refining the resolution to 1×1 km [2].

In 2024, an extensive campaign was conducted to gather detailed information on street lighting systems across all municipalities in Catalonia. Here, we present two new zenith sky brightness maps of Catalonia, now at an improved spatial resolution (1×1 km grid): one based on the detailed street lighting inventory and another derived from satellite imagery.

Comparison with ground-based measurements indicates that the street lighting inventory provides a more realistic representation than satellite-derived estimates. Being the most probable reasons poor spatial and spectral resolution of satellite images. These results further highlight the need for improved nighttime satellite missions tailored to light pollution studies.

Building on these findings, we refined our methodology by integrating both datasets based on land use, considering street-lighting regulation strategies and domestic lighting to generate a third zenith sky brightness map of the region. Additionally, we explored optimal approaches for assessing night-sky quality over large areas beyond the zenith direction.

References

[1] Fabio Falchi *et al.*, The new world atlas of artificial night sky brightness. *Sci. Adv.* **2**, e1600377(2016). DOI:10.1126/sciadv.1600377

[2] Hector Linares, Eduard Masana, Salvador J. Ribas, Manuel García-Gil, Martin Aubé, Alejandro Sánchez de Miguel, Alexandre Simoneau, Assessing light pollution in vast areas: Zenith sky brightness maps of Catalonia, Journal of Quantitative Spectroscopy and Radiative Transfer, Volume 309, 2023, 108678, ISSN 0022-4073, https://doi.org/10.1016/j.jqsrt.2023.108678.

[3] M. Aubé, A. Simoneau, New features to the night sky radiance model illumina: Hyperspectral support, improved obstacles and cloud reflection, Journal of Quantitative Spectroscopy and Radiative Transfer, Volume 211, 2018, Pages 25-34, ISSN 0022-4073, https://doi.org/10.1016/j.jqsrt.2018.02.033.

[4] Alejandro Sánchez de Miguel, Christopher C.M. Kyba, Martin Aubé, Jaime Zamorano, Nicolas Cardiel, Carlos Tapia, Jon Bennie, Kevin J. Gaston, Colour remote sensing of the impact of artificial light at night (I): The potential of the International Space Station and other DSLR-based platforms, Remote Sensing of Environment, Volume 224, 2019, Pages 92-103, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2019.01.035. 03

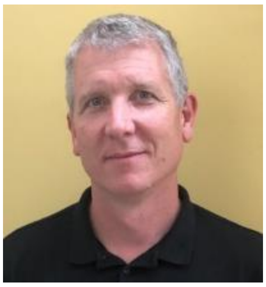
Updating light metrics as a tool to better align light to biological need

Theme: Society

Robert J Lucas

Division of Neuroscience and Centre for Biological Timing, Faculty of Biology Medicine and Health, University of Manchester, Manchester M13 9PT, UK

Robert.lucas@manchester.ac.uk



Biography

Rob Lucas is the GSK Professor of Neuroscience at the University of Manchester. He runs a research lab (https://lucasgroup.lab.manchester.ac.uk) studying mechanisms of light detection in animals and the multiple ways in which light influences their behaviour and physiology. He has a long-standing interest in updating methods of light measurement to improve their relevance for biological responses beyond human vision.

Artificial light sources vary not only in their total power output but also in how that power is distributed across wavelength. It follows that meaningful quantification must account for such differences in spectral quality. Because biological photosensors are never equally sensitive to all wavelengths, predicting effective biological dose requires a wavelength weighting function that describes the spectral sensitivity of the biological process under consideration. Accordingly, the SI metrology for light, which provides measures of illuminance (units=lx), luminance (units=Cd/m^2) and luminous flux (units=lumens), employs a wavelength weighting function called $V(\lambda)$ that assumes peak sensitivity to light at 555 nm (green). Now 100 years old, $V(\lambda)$ is an idealized efficacy curve for visual brightness in a 'standard' human adult observer in bright light. However, $V(\lambda)$ does not provide a good approximation of the wavelength sensitivity of other important biological responses to light. The capacity of light to suppress sleep and shift the circadian clock in humans is shifted to shorter (bluer) wavelengths. Meanwhile, non-human species show great variation in wavelength sensitivity depending on both the species and the type of light response under consideration. It follows that, while matching the luminance of diverse lights can make them appear equivalently bright for humans, they may have very different ability to disrupt our sleep and impact the biology of wild life. I will describe initiatives to update light metrics to address this problem and how these better align lighting design to biological need.

Coastal light pollution: a multi-stressor perspective

Theme: Biology and Ecology

Elena Maggi[1,*]

[1] *Dipartimento di Biologia, University of Pisa, Pisa, Italy*
elena.maggi@unipi.it
[*] *presenting author*

More than 22% of the world's coastline is currently exposed to light pollution, mostly from permanent light sources such as streetlamps used in towns and ports for recreational or safety purposes (Davies et al. 2014; Ferretti et al. 2025). This results in Artificial Light At Night (ALAN) intensities ranging from 0.1 to 22 lx at the sea surface (Gaston et al. 2013). The impact of ALAN remains detectable at depths of up to 10 m and can even extend to 20 m under clear-water conditions (Smyth et al. 2022).

Light pollution, however, represents just one of a growing suite of threats to coastal ecosystems; in fact, coastal habitats are increasingly affected by urban sprawl and disproportionately exposed to multiple anthropogenic stressors, as well as to the effects of climate change (Krishna et al. 2025). This highlights the urgent need to frame studies on the ecological impacts of light pollution within a multi-stressor framework, grounded in robust experimental protocols. Such an approach enables a better understanding of whether the effects of light pollution act additively, synergistically, or antagonistically with respect to those of other stressors (Crain et al. 2008).

Since the ultimate goal of an ecological approach to such topic is to preserve ecosystem functioning and health, it becomes imperative to focus on species of ecological relevance, such as habitat-forming species. In coastal environments, these notably include key primary producers such as macroalgae and seagrasses.

In the Mediterranean, *Posidonia oceanica* forms extensive meadows in coastal areas, where it is exposed, among other stressors, to night-time light pollution (Dalle Carbonare et al. 2022) and anthropogenic noise (Solè et al 2021). The effects of these pressures may cascade through the biodiversity associated with the meadows and the biological interactions they sustain. Again, along the marine coasts, several brown macroalgal species are also capable of forming extensive beds, modifying environmental conditions and creating habitats for a wide range of organisms. Among these, the invertebrate communities associated with the algal canopy remain relatively poorly studied, as do the potential cascading effects of ALAN on them. Furthermore, little attention has so far been given to how ALAN—and any other additional coastal stressor—may, over relatively short timescales, affect the microbial communities associated with these habitat-forming species, generating additional indirect effects that could interact with the direct impacts of light pollution. Examples of such approaches are currently carried out within the AquaPLAN project and other international collaborations.

References

Crain CM, Kroeker K, Halpern BS (2008*) Interactive and cumulative effects of multiple human stressors in marine systems.* Ecol Lett 11: 1304–1315

Dalle Carbonare L, Basile A, Rindi L, Bulleri F, Hamedeh H, Iacopino S, Shukla V, Weits DA, Lombardi L, Sbrana A, Benedetti-Cecchi L, Giuntoli B, Licausi F, Maggi E (2023) *Dim artificial light at night alters gene expression rhythms and growth in a key seagrass species (Posidonia oceanica).* Sci Rep 13:10620

Davies TW, Duffy JP, Bennie J, Gaston KJ (2014) *The nature, extent, and ecological implications of marine light pollution*. Front Ecol Environ 12: 347–355

Ferretti M, Rossi F, Benedetti-Cecchi L, Maggi E. (2025) *Ecological consequences of artificial light at night on coastal species in natural and artificial habitats: a review*. Mar Biol 172:5

Gaston KJ, Duffy JP, Gaston S, Bennie J, Davies TW (2013) *Human alteration of natural light cycles: causes and ecological consequences*. Oecologia 173: 1007–1019

Krishna S, Rahman S, Ananthasubramaniam B, Dawson TP, Mace GM (2025) *Cumulative impacts of multiple stressors on coastal ecosystems: pathways to resilience*. Front Mar Sci 11: 1481734.

Smyth TJ, Wright AE, Edwards-Jones A, McKee D, Queirós A, Rendon O, Tidau S, Davies TW (2022) *Disruption of marine habitats by artificial light at night from global coastal megacities*. Elementa: Science of the Anthropocene 10:00042

Solé M, Lenoir M, Durfort M. *et al.* (2021) *Seagrass* Posidonia *is impaired by human-generated noise.* Commun Biol 4, 743

Protecting the Night: Towards Coherent Legal Frameworks for Light Pollution Mitigation

Theme: Governance & Regulation

Yana Yakushina[1,*]

[1] Ghent University, Ghent, Belgium
Yana.Yakushina@UGent.be (ya.yakushina@gmail.com)
[*] presenting author

In recent years, light pollution has emerged as an increasingly important issue on legal and policy agendas worldwide. It poses a growing concern due to its wide-ranging impacts, from obstructing astronomical research to contributing to environmental degradation and adverse health effects on humans and wildlife. In response, several countries across Europe and beyond have begun introducing regulatory measures aimed at mitigating light pollution and promoting more responsible lighting practices [1].
Despite this positive momentum, regulatory approaches remain highly fragmented. Legal frameworks differ widely between jurisdictions, and many still lack comprehensive or enforceable provisions [2]. These inconsistencies create significant regulatory gaps, which undermine both the enforceability and the overall effectiveness of efforts to combat light pollution. Moreover, a lack of coordination between local, national, and international actors further limits progress. Given these challenges, there is an urgent need for more coherent and harmonised action. A unified approach could significantly strengthen the impact of regulatory efforts while still allowing for flexibility to accommodate local contexts.
The presentation provides an overview of current regulatory developments, highlighting prevailing trends and key obstacles. It draws on a developed classification of regulatory approaches to night-time protection and includes visually presented maps illustrating which countries have adopted such regulations [2]. The presentation also explores practical questions regarding the legal framing of light pollution: whether it can be considered a form of pollution, whether the night may be regarded as part of nature, and what regulatory approaches could most effectively support night-time preservation [3]. Finally, it concludes with practical recommendations for improving regulatory effectiveness without requiring major legislative amendments, which might otherwise face resistance from governments at various levels.

References

[1] Yakushina, Y., Valdivia-Lefort, M., Martin, C., et al. (2024). National approaches to the protection of dark and quiet skies. https://doi.org/10.5281/zenodo.14566125

[2] Yakushina, Y. (2024). Light pollution regulations and where to find them. Journal of Environmental Management, 373, 123757. https://doi.org/10.1016/j.jenvman.2024.123757

[3] Yakushina, Y. (2025). The endangered night: The challenge of light pollution within the international environmental legal context. Journal of Environmental Law. Advance online publication. https://doi.org/10.1093/jel/eqaf025

Contributed Talks & Posters

(Note that the abstracts are ordered alphabetically by first author who is not necessarily the presenter)

Studying bird response to light in multiple spectral bands using weather surveillance radar and remotely-sensed ALAN

Theme: Biology & Biology and Ecology

Carrie Ann Adams[1,2,*] and Kyle Horton[1]

[1] Purdue University, West Lafayette, United States
[2] Carleton University, Department of Biology, Ottawa, Canada
Ca.adams.ecology@gmail.com
[*] presenting author

Introduction

The rapid conversion of outdoor lighting to light emitting diodes (LEDs) is contributing to increased ALAN emissions, especially in the shorter (bluer) wavelengths (Figure 1a; Sánchez de Miguel et al. 2021). Many species have higher visual sensitivity to shorter wavelengths, and blue light may attract more nocturnally migrating birds and increase collision mortalities (Figure 1b; Longcore 2023). However, our primary means to measure ALAN at a national and global scale — observations based on the Suomi VIIRS Day-Night Band — lack of sensitivity to blue light (Figure 1a). Our project objectives are: **(1) create a multi-spectral nighttime light product** for ALAN research and monitoring in the new age of LEDs by integrating DNB observations with newer data sources; **(2) leverage this enhanced nighttime light product, in combination with continental-scale data about bird migration, to create guidelines for tuning the spectra of LED lights** and prioritizing efforts to reduce light pollution across urban, rural, and remote contexts.

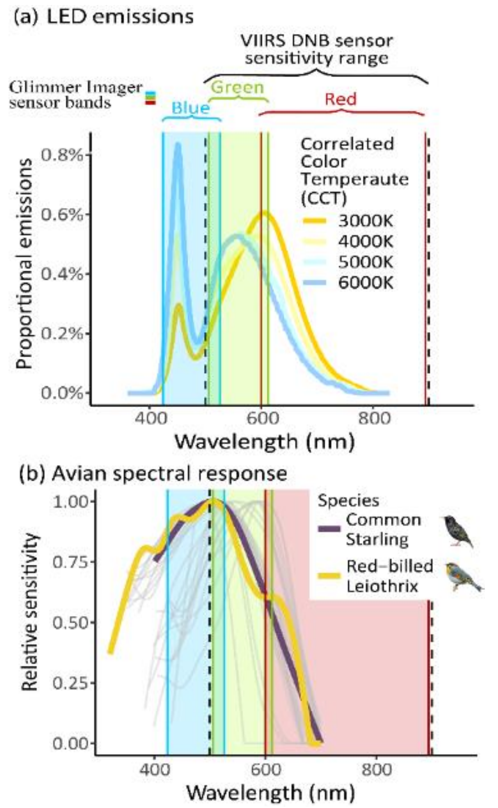


Figure 1. Spectral comparison of light emissions by LEDs, sensitivities of avian species, and sensitivities of VIIRS DNB and GI sensors (a) Spectral power distributions for LEDs of varying correlated color temperatures. Note the prominent spike in proportional emissions in the blue wavelengths. Vertical lines represent the sensitivity range of the VIIRS DNB and GI sensors (b) Visual spectral response curves for two passerine (colored lines) and 24 non-passerine (grey lines) avian species (Longcore et al. 2023).

Methods

For the first objective, we are using radiance measurements from the red, green, and blue spectral bands of the Sustainable Development Science Satellite 1 (SDGSAT-1)'s Glimmer Imager (GI) sensor (Figure 1b), where it is available, to train a neural network to create a multi-band predictive map of ALAN (MBP-ALAN map) across the continental US and southern Canada. The neural network will make ALAN predictions in the blue, green, and red bands by combining BM data with hyperspectral imagery from other NASA missions (PACE, EMIT, and DESIS) and remotely sensed metrics of other human dimensions known to be associated with band-specific emissions.

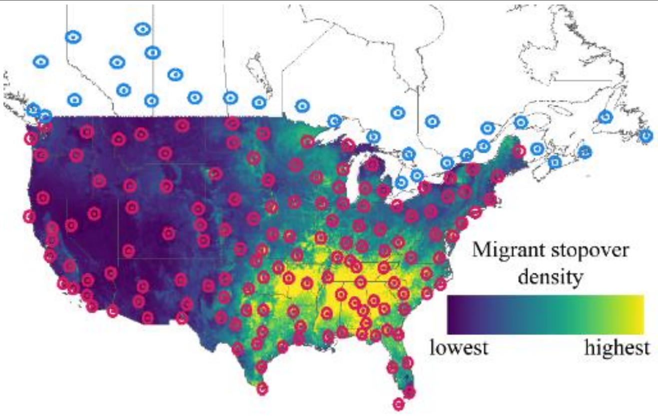


Figure 2. Locations of the US's 143 (red) and Canada's 33 (blue) weather surveillance radars with radar-based predictions of migratory bird stopover density in the US. Colors represent Horton et al.'s WSR-based predictions of stopover density (2023). We are extending stopover density and aerial migration traffic maps into Canada and studying how red, green, and blue ALAN affects stopover densities.

For the second objective, we are using measures from weather surveillance radar (WSR) to quantify the effects of ALAN total radiance and radiance in each spectral band on stopover density and airspace use by avian migrants across the continental US, and we are expanding these radar-based maps of bird migration into Canada. We are testing whether (a) more migrants are attracted to stopover in areas with shorter wavelength (bluer) light; (b) the effect of incremental increases in ALAN diminishes as total radiance increases; and (c) light sources in rural areas attract more birds, per unit ALAN, because of higher contrast with surrounding darkness. We are using the SDGSAT-1 GI product to study response to light in multiple spectral bands, and we will also use the MBP-ALAN map upon its successful completion.

Conclusions

Many recent studies have leveraged the combination of the VIIRS DNB sensor and more than two decades of bird migration data from weather surveillance radar to substantially advancing our understanding of the temporal and spatial dynamics of bird migration in a changing world (McLaren et al. 2018; Horton et al. 2023). By integrating multiple remote-sensing products to measure ALAN in multiple spectral band and expanding radar-based migration maps into Canada, we will fundamentally advance our understanding of how the global conversion to LEDs is changing the spatial dynamics of bird migration

References

Horton KG, Buler JJ, Anderson SJ, et al (2023) Artificial light at night is a top predictor of bird migration stopover density. Nat Commun 14:7446. https://doi.org/10.1038/s41467-023-43046-z

Longcore T (2023) A compendium of photopigment peak sensitivities and visual spectral response curves of terrestrial wildlife to guide design of outdoor nighttime lighting. Basic and Applied Ecology 73:40–50. https://doi.org/10.1016/j.baae.2023.09.002

McLaren JD, Buler JJ, Schreckengost T, et al (2018) Artificial light at night confounds broad-scale habitat use by migrating birds. Ecology Letters 21:356–364. https://doi.org/10.1111/ele.12902

Sánchez de Miguel A, Bennie J, Rosenfeld E, et al (2021) First Estimation of Global Trends in Nocturnal Power Emissions Reveals Acceleration of Light Pollution. Remote Sensing 13:3311. https://doi.org/10.3390/rs13163311

Impact of non-uniform lighting on gaze behavior and pupil size: A gender specific study of pedestrians at night-time.

Theme: Social Sciences & Humanities

Minu Agarwal,[1,*] Pritha Dev,[2] Mayur Jartarkar[2] and Nayansi Singh[1]

[1] CEPT University, Ahmedabad, India
[2] Indian Institute of Management, Ahmedabad, India
minu.agarwal@cept.ac.in
[*] presenting author

Introduction

Street lighting is viewed as a key supporter of night time "feeling of safety" for pedestrians. Key lighting parameters such as light level (brightness), uniformity and color temperature are known to influence pedestrian's feeling of safety. Physical characteristics of the streets (e.g., prospect or visibility, evenness of walkway) also contribute to feeling of safety.

Lighting uniformity in particular is an important factor in street lighting design as it often dictates fixture selection and pole-spacing. Directives for uniform lighting and cost constraints often imply that fixtures with low shielding angles are used and/or pole-spacing may be reduced.

This study investigates how lighting uniformity affects pedestrians' perceived safety in leisure environments—settings where environmental threats are minimal and pedestrians are not engaged in goal-directed movement. In such contexts, social cues, particularly the visibility of other pedestrians, become more salient.

In this study, we compare the "feeling of safety" of pedestrians on two seperate liesure walkways with uniform and non-uniform lighting based on gaze behavior. Unsettled gaze patterns, frequently switching between distant and near passer-by indicate anxeity – where absence of anxiety would suggest "feeling of safety".

(a) Walkway A, clear prospect, uniform lighting

(b) Walkway B, clear prospect, non-uniform lighting

Fig. 1: Two leisure sites being used for the study (location, Ahmedabad, India). *(Image for Walkway A from Gujrat tourism website)*

In addition to gaze behavior, variability in pupil size would suggest if uniform lighting offers any significant adapation and visual acuity related benefits given the gaze patterns being exhibited by the pedestrians.

Methods

This field study is being conducted in two leisure areas in Ahmedabad, India, which are similar in physical layout and social context. Both offer unobstructed views and smooth walkways, minimizing non-lighting-related sources of anxiety. However, they differ significantly in lighting uniformity: Walkway A (E_min/E_max = 0.67) and Walkway B (E_min/E_max = 0.18).

Participants' gaze behavior and pupil size are being recorded using Tobii Pro Glasses 3 eye-tracking devices, along with GPS trackers to monitor movement speed and location. The study design draws on the triad framework for urban lighting (Jedon, Haans, and de Kort 2023) which posits that lighting can influence pedestrian attention directly (via visual contrast) and indirectly (through changes in arousal, alertness, or anxiety). By holding environmental factors constant, we aim to isolate the effects of lighting uniformity.

Conclusions

Data collection is currently underway. Due to weather-related delays, only Walkway B has been studied so far. Eight participants (4 women, 4 men) have completed the protocol, and data analysis is ongoing.

References

Fotios, S, and M Johansson. 2019. "Appraising the Intention of Other People: Ecological Validity and Procedures for Investigating Effects of Lighting for Pedestrians." Lighting Research & Technology 51 (1): 111–30.

Fotios, S, A Liachenko Monteiro, and J Uttley. 2019. "Evaluation of Pedestrian Reassurance Gained by Higher Illuminances in Residential Streets Using the Day–Dark Approach." Lighting Research & Technology 51 (4): 557–75.

Fotios, S, J Uttley, C Cheal, and N Hara. 2015. "Using Eye-Tracking to Identify Pedestrians' Critical Visual Tasks, Part 1. Dual Task Approach." *Lighting Research & Technology* 47 (2): 133–48. https://doi.org/10.1177/1477153514522472.

Jedon, R, A Haans, and Y de Kort. 2023. "Proposing a Research Framework for Urban Lighting: The Alertness, Arousal and Anxiety Triad." *Lighting Research & Technology* 55 (7–8): 658–68.

Jedon, Richard, Antal Haans, and Yvonne de Kort. 2024. "Pedestrians' Alertness and Perceived Environmental Safety Under Non-Uniform Urban Lighting." Global Environmental Psychology, March. https://psycharchives.org/en/item/537e4e7d-4d49-4f3c-b316-ed1976d40ec4

Portnov, Boris A., Rami Saad, Tamar Trop, Doron Kliger, and Alina Svechkina. 2020. "Linking Nighttime Outdoor Lighting Attributes to Pedestrians' Feeling of Safety: An Interactive Survey Approach." Edited by Quan Yuan. *PLOS ONE* 15 (11): e0242172.

Sacred Darkness: Design approach on lighting strategies for Adam's Peak, Sri Lanka

Theme: Technology and Design

Dinuka Amarakoon,[1,*] Prof. Michael F.Rohde[2]

[1] Wismar University of Applied Sciences, Wismar, Germany
[2] Wismar University of Applied Sciences, Wismar, Germany
corresponding.author@institution.de
[*] presenting author

The night sky has been a human experience throughout human history, but true darkness and starry skies are very rare due to light pollution. Also making it unlikely for most people to experience; Dark sky areas are often remote and inaccessible. This raises the question; Could public, accessible dark sky experiences create awareness about the issue?

This Project focuses on Adam's peak, Sri Lanka. A pilgrimage site for many religions and a global attraction. Mountain peak with socio cultural significance, situated in a "UNESCO world heritage" listed wildlife sanctuary. Pilgrims and travelers from around the world travel these trails during dark hours, to experience the sunrise from the summit. Close to 20000 visitors on a single evening at weekends or holidays. Light pollution is one of many anthropogenic effects that disrupt the ecologically very sensitive environment. **(UNESCO World Heritage Center, 2017) (Ministry of Wildlife and Forest Resources Conservation, n.d.)** But one that could be and should be mitigated. The project is an exploration and design attempt for the question "How to accommodate night-time hiking in natural environments with responsible use of light?"

The project is practice-based research where the outcome is a design proposal aimed at solving an issue with a holistic approach. The research synthesizes existing knowledge to build a framework for the design proposal. Theoretical research is mainly on human / other species vision and light pollution mitigation strategies. Conducted surveys and mapping allowed real world data to inform about the human presence, their needs and topographical nature of the context and trails. The process of developing a design proposal as a pilot for dark sky friendly environments align with a solution-oriented approach.

The design proposal presents a holistic perspective on the issue. Allowing anthropogenic light to minimize its impact on ecology, and to create a unique experience for the travelers. Throughout the proposal, utilizing varied scenarios allows lighting to be functional throughout the night, while minimizing its impact. Another key element is the attention to responsible outdoor lighting guidelines from several resources. **(Department of Climate Change,Energy,the Environment and Water, 2023) (Dick, 2016)** Taking advantage of the human scotopic vision; the use of red light to minimize impact on the ecosystem and to create a spiritual dark sky experience for the travelers is also intriguing. **(Cao, 2013)**

Fig. 1: Top Left: During daytime from a distance (Source: Author), Bottom Left: During nighttime; current level of light pollution. *Entire view is with in the wilderness sanctuary. (Source: Pasindu Sandaruwan; used with permission), On the right: a trail sections above Upper Montane Rain Forest, closer to the Summit. During daytime and with proposed linear luminaires, along the handrail; utilizing red light. Mitigating impact of ALAN (Source: Author)

In conclusion, the proposal should be tested in real-life conditions for further development. However, it also sets a precedence on possible approaches to a complex context. Conservation through utilization and hence creating awareness is the key consideration.

Acknowledgement

The work is a result of a Master Thesis, in Architectural Lighting Design MA, Hochschule Wismar. Completed by Dinuka Amarakoon, in July 2024. Under the supervision of Prof. Michael F. Rohde (1) and Mr. Michael Bamberger (2).

References

Cao, D. (2013). Color Vision and Night Vision. *Retina (fifth edition).*

Department of Climate Change,Energy,the Environment and Water. (2023). *National Light Pollution Guidelines for Wildlife.* Commonwealth of Australia.

Dick, R. (2016). *Guidelines for Outdoor Lighting for Low-Impact Lighting.*

Ministry of Wildlife and Forest Resources Conservation. (n.d.). *Adams Peak Wilderness Reserve*. Retrieved from Ministry of Wildlife and Forest Resources Conservation: https://www.mwfc.gov.lk/2022/03/18/episode-11-adams-peak-wilderness-reserve/

UNESCO World Heritage Center. (2017). *Central Highlands of Sri Lanka.*

Smart Luminance Solutions: Machine Learning and Computer Vision-Driven Strategies for Combating Indoor and Outdoor Artificial Light Pollution

Theme: Technology and Design

Aryush Aravind

FLiP, Irvine, USA
aryusharavind@gmail.com
* *Aryush Aravind*

Introduction

Light pollution is defined as excessive or misdirected artificial lighting. With prolonged exposure it poses serious environmental, ecological, and health challenges. Artificial light pollution disrupts natural ecosystems by altering animal behaviors such as navigation and feeding cycles, predator-prey interactions, pollination patterns [1]. In addition, it impacts human circadian rhythms, leading to health issues like sleep disorders triggered mainly by melatonin suppression and diminishes the visibility of celestial objects [1][2]. Bará and Castro-Torres (2024), documented that light pollution is increasing at an alarming rate. Data shows that urban artificial light pollution is growing rapidly at an annual rate of 9.6% [3]. This growing trend warrants the urgent need for better technology-based solutions tailored to reduce excess indoor and outdoor lighting. Current approaches, such as replacing traditional lighting with LEDs fail to address the issues documented above [2][4] and adaptive solutions that minimize energy use and environmental impact are underexplored.

Existing lighting solutions focus on using energy-efficient lightings and enforce regulations to limit over-illumination and light trespass. However, these strategies remain insufficient because of the following reasons.

Limited Customization: Current solutions often lack context-specific adjustments, such as adapting light intensity to suit activity in progress or environmental feedback [3][4].
Partial Mitigation: Technologies addressing skyglow and glare remain underdeveloped [4].
Lack of Adherence to Standards: Current solutions lack feedback mechanisms that can adjust lighting using activity based recommended settings from standards organizations like the Illuminating Engineering Society (IES) or other international standards.

Design

The proposed design is for an innovative smart luminance management system that integrates a Raspberry Pi controlled central controller with a touch enabled display and multiple edge units with a luminance measurement sensor along with the camera and a sophisticated software module to dynamically regulate lighting based on activity in progress and ambient conditions. Core features of the solution include:
Real-Time Luminance Adjustment Based on Standards: The solution has the functionality to set luminance levels based on standards for different indoor and outdoor spaces.
Energy Conservation: By adapting to activity levels, the system prevents over-illumination and minimizes energy wastage.
Modular Reference Design: The proposed design is modular that can be extended and customized based on the requirements of different use cases (residential, commercial, office & outdoor) and scaling needs.

Central Control Unit: The central control unit, powered by a Raspberry Pi controller and a touch-enabled display, will serve as the system's brain, coordinating the operation of edge devices and functions as a configuration and status display module. This unit will communicate with edge devices using Wi-Fi, allowing for centralized management of luminance settings. Users can configure area-specific luminance levels or opt for the auto mode, which adjusts lighting based on applicable standards for area type, activity, and ambient lighting. The central control unit will also serve as a status display module that displays all edge devices' states. The system will also store and analyze historical data, enabling advanced optimizations, such as forecasting usage patterns and providing suggestions for luminance levels if the device is configured in manual mode.

Edge Device (Switch): The edge device, installed as a smart switch, will be equipped with a Raspberry Pi processor unit, an integrated camera, and a luminance sensor to manage lighting in each area locally. Each edge device will operate semi-autonomously, with localized decision-making capabilities for immediate responsiveness to motion or activity. The luminance sensor on each edge device will provide feedback on actual lighting levels, ensuring that lighting meets the centralized settings or adapts to changes in environmental conditions. The camera in the edge device will capture video frames, and the software module running on the device will parse the video frames individually and process them using OpenCV [7] computer vision models to extract the silhouette of the actions in progress. These silhouette images will be processed using advanced machine learning algorithms to identify ongoing activities, enabling activity-based luminance adjustments. For example, the system can dim lights when detecting passive activity like sitting or napping and increase brightness during active tasks like reading or exercising. This capability extends outdoors, where motion sensing and activity detection can optimize security or other outdoor lighting to minimize glare and skyglow. The decentralized approach used in the design ensures scalability and reduces the processing load, creating a robust, adaptive lighting system suitable for all applications. Since security and user privacy are essential, the system is designed such that only the silhouettes are extracted from the videos and the raw videos are not stored anywhere and will be discarded after real-time processing.

References

1. Hirt, M. R., Evans, D. M., Miller, C. R., & Ryser, R. (2023). *Light pollution in complex ecological systems*. *Philosophical Transactions of the Royal SocietyB*, 378(20220351).
2. Dr. Rasna Rajkhowa. (2014). *Light Pollution and Impact of Light Pollution*. International Journal of Science and Research (IJSR), Volume 3, Issue 10.
3. Bará, S., & Castro-Torres, J. J. (2024). *Diverging evolution of light pollution indicators: can the Globe at Night and VIIRS-DNB measurements be reconciled?*
4. International Dark-Sky Association (IDA). (2024). *Guidelines and Standards for Reducing Light Pollution.*
5. Novoselov, A. (2024, December 19). *How to dim the consequences of global light pollution. UCLA.* https://newsroom.ucla.edu/releases/new-report-global-light-pollution-consequences-solutions
6. Lighting Standards | Energy | U.S. Agency for International Development. (n.d.). U.S. Agency For International Development. https://www.usaid.gov/energy/powering-health/technical-standards/lighting
7. OpenCV. (2024, December 24). *OpenCV - Open Computer Vision Library*. https://opencv.org/.

Bat behavior according to public lighting modalities

Theme: Biology and Ecology

R. Colombo,[1] M. Arnaud,[1,*] A. Grand[2], A. Grange[2], T. Malatrasi[3]

[1] Asellia, Sisteron, France
[2] Université Savoie Mont-Blanc UFR Sciences et Montagne, Le Bourget-du-Lac, France
[3] Métropole Nice Côte d'Azur, Nice France
marnaud@asellia-ecologie.fr
Mathilde ARNAUD

Light pollution affects bat populations, especially of the short-range echolocators (SRE) which include the *Myotis*, *Rhinolophus* and *Plecotus*. Light can affect their hunting behavior in two ways: it can have a positive impact with insect-attracting streetlights and creating areas of higher prey densities; or it can have a negative impact with bright areas being avoided by bats. This avoidance behavior can be very problematic by modifying their flight routes and requiring sometimes significant detours in order to reach dark areas. Here we investigated the reaction towards three lighting modalities of European bats.

The study takes place on 7 municipalities within the Natura2000 site "Vallons Obscurs". 86 recorders are placed, 43 under streetlight and 43 in unlit non-artificialized areas. These plots form Impact-Control pairs. We applied for each Impact site one of the three modalities: no extinction, partial extinction (between 23 p.m and 5 a.m) or total extinction (all night). Each bat contact was recorded with a SM4bat with one night of recording by site between 15th June and 15th August 2024. The records are analyzed by Tadarida R and pre-identified. Then, they are manually analyzed if the doubts were too important, to be assigned to a species. Then the data is analyzed with the version of R 4.4.2., using GLMM and by studying the bat species grouped into guilds:

- Long-range echolocators (LRE): emit long, loud low-frequency calls, allowing long-distance perception. They can fly at high altitude in an open environment.
- Medium-range echolocators (MRE): include intermediate species. They are often adapted to anthropization.
- Short-range echolocators (SRE): emit short, faint, high-frequency sounds. They fly in closed environments and are sensitive to habitat connectivity.

The results show contrasted behavior between the three guilds. For the MRE, there is no significant difference between the three modalities of lighting. It is an expected result because they are ubiquitous species, adapted to urban environments and they are known for their hunting behavior near street lamps. There are more contacts with the "no extinction" modality (Fig. …). The lighting modalities don't influence strongly the behavior of LRE, except for "partial extinction" where there are less contacts. The most telling results are these concerning the SRE. The contacts with "total extinction" are significantly higher than these with the two other modalities: "partial and no extinction". The artificial lights influence the SRE behavior even when there are only three hours of lighting, leading for an abandonment of the site for the entire night.

Light can be used advantageously by some bats. The concentration of insects at the level of the street lamps are indeed an easily exploitable resource, which will attract the species of non-lucifugous bats. It can then be observed that individuals are concentrated at the points and a virtual desertion in the dark areas. This impact on the distribution of is not negligible, which can lead to an increase in intra- or inter-competition flight routes and a reduction in the presence of insects in the dark areas. In addition, under the light, studies suggest that insects will tire more quickly and die, thus reducing biomass available for bats. Conversely, for lucifugous species, bright areas will be avoided. This can lead to the use of more energy-intensive flight routes, and therefore less good reproductive success, or even the abandonment of hunting areas and therefore the isolation of populations. For these species, the illuminated areas represent sectors of too high exposure to the risk of predation. As for the lodgings, several studies have shown that lighting can lead to the abandonment of the lodging. To conclude, total summer extinctions, and even if they are not implemented all year round, seem to be the most beneficial measure and appear to be very effective in their implementation time. They even seem to completely cancel out the effect of street lamps. Indeed, our results show no significant differences in activity between the Control plots and Impact for the total extinction modality.

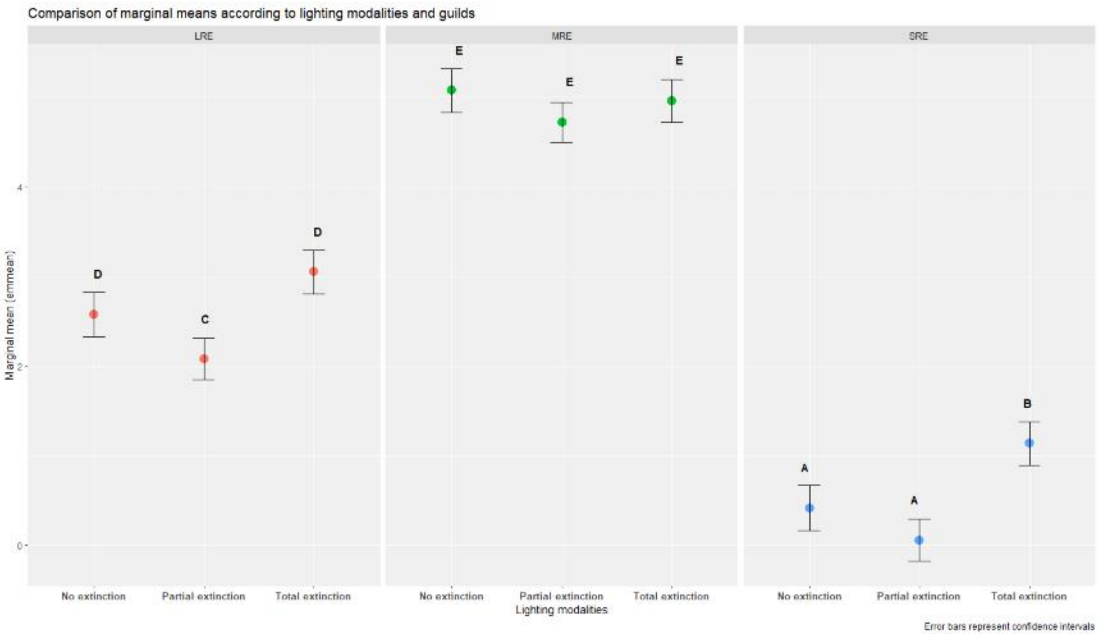


Fig. 1: Marginal means of bats contacts per modality and guild. Two different letters mean a significant difference.

References

Falcón, J., Torriglia, A., Attia, D., Viénot, F., Gronfier, C., Behar-Cohen, F., ... & Hicks, D. (2020). Exposure to artificial light at night and the consequences for flora, fauna, and ecosystems. *Frontiers in Neuroscience*, *14*, 602796.

Kerbiriou, C., Barré, K., Mariton, L., Pauwels, J., Zissis, G., Robert, A., & Le Viol, I. (2020). Switching LPS to LED streetlight may dramatically reduce activity and foraging of bats. *Diversity*, *12*(4), 165.

Mariton, L., Kerbiriou, C., Bas, Y., Zanda, B., & Le Viol, I. (2022). Even low light pollution levels affect the spatial distribution and timing of activity of a "light tolerant" bat species. *Environmental Pollution*, *305*, 119267.

Mariton, L., Le Viol, I., Bas, Y., & Kerbiriou, C. (2023). Characterising diel activity patterns to design conservation measures: Case study of European bat species. *Biological Conservation*, *277*, 109852.

Voigt, C. C., Dekker, J., Fritze, M., Gazaryan, S., Hölker, F., Jones, G., ... & Zagmajster, M. (2021). The impact of light pollution on bats varies according to foraging guild and habitat context. *BioScience*, *71*(10), 1103-1109.

Illumina v3: Modeling sky brightness up to the third order of scattering

Theme: Measurements and modeling

Martin Aubé,[1,2,3,*] Linares H. A.[1]

[1] Cégep de Sherbrooke, Sherbrooke, Canada
[2] Université de Sherbrooke, Sherbrooke, Canada
[3] Bishop's University, Sherbrooke, Canada
aubema@gmail.com
[*] presenting author

Physically based modeling of artificial sky brightness has improved significantly over the four past four decades. The first models were limited to the first order of scattering. But in the early 2000s, Aubé et al. demonstrated that the addition of the second order of scattering was essential. Its contribution can be even greater than the first order of scattering under certain conditions. Recently, Kocifaj et al. showed that for an observer located far from the sources, or for a turbid atmosphere or for short wavelengths, second order of scattering is not sufficient to properly model the sky brightness.

In light of this new information, we decided to include the third order of scattering in the Illumina model. Modeling the second order of scattering by ray tracing was already computationally demanding. Adding the third order of scattering is even more cumbersome. To limit the computation time to reasonable values, we optimized part of the Illumina kernel. More specifically, for both the second and the third order of scattering, we are extrapolating high resolution radiance contributions by using a set of six low resolution computations. We also implemented a dynamic activation of the second and third order. There contributions are only calculated when they are significant. These model enhancements are released as Illumina v3.

In this paper, we performed a first numerical experiment by sequentially activating the first, second, and third order of scattering to infer their relative contribution to the sky brightness. We carried out the calculation for a specific case corresponding to a real situation. The observer was located at Mont-Mégantic observatory in Quebec, Canada. This particular geographic context is characterized by a small amount of lighting fixtures within a 10 km radius, then a small city called Lac Mégantic (pop. ~6k) 25 km away and finally a larger town called Sherbrooke (pop. ~170k) 60 km away. Most lighting systems have amber spectrum and are full cutoff in a radius of 28km and Sherbrooke is lit by a mix of High Pressure Sodium (HPS) and amber LEDs. The rest of the territory is assumed to be lit with HPS and 4000K LEDs. We tested the relative contribution of the three orders of scattering towards zenith and at 10 degrees above horizon towards each city as well as southward. South is among the darkest direction. The preliminary results of this numerical experiment will be discussed.

References

Aubé, M., Simoneau, A., Munoz-Tunon, C., Diaz-Castro, J., & Serra-Ricart, M. (2020). Restoring the night sky darkness at Observatorio del Teide: First application of the model Illumina version 2, Monthly Notices of the Royal Astronomical Society, 497(3), pp.2501-2516.

Aubé, M., Simoneau, A., (2018) New Features to the Night Sky Radiance Model Illumina: Hyperspectral Support, Improved Obstacles and Cloud Reflexion, Journal of Quantitative Spectroscopy and Radiative Transfer, Vol. 211, pp. 25-34.

Aubé, M. (2015) Physical Behaviour of Anthropogenic Light Propagation into the Nocturnal Environment, Philosophical Transactions of the Royal Society - B, Vol. 370, Issue 1667.

Assessing the potential health impact of urban lighting: A citizen science initiative

Theme: Health

Martin Aubé,[1,2,3] Sébastien Poulin[1,*]

[1] Cégep de Sherbrooke, Sherbrooke, Canada
[2] Université de Sherbrooke, Sherbrooke, Canada
[3] Bishop's University, Sherbrooke, Canada

aubema@gmail.com
[*] presenting author

Light pollution occurs when artificial light at night (ALAN) is emitted into the environment at levels and/or times that disrupt it. It is directly responsible for obscuring the starry sky but also disrupts wildlife and plant life. Light pollution also interferes with the human circadian cycle, which can lead to health problems such as an increased risk of certain cancers. Around 70% of ALAN could be eliminated simply by adopting better lighting practices. Municipalities are generally ill-equipped to address these issues. As part of the Québec Research Funds a new citizen science program was created. Sébastien Poulin, a citizen of the city of Québec, submitted a question related to light pollution to the new program, and it was selected. The question was then proposed to researchers willing to carry out a citizen science project over a period of 2 years to answer the question. Martin Aubé, a researcher and professor of physics at the Cégep de Sherbrooke, volunteered for this research project. The research team comprise Martin Aubé, the scientific lead, Sébastien Poulin, the citizen-researcher and Prof. Aubé's graduate students. The team is assessing the potential impact on human health of the lighting systems in the cities of Québec and Trois-Rivières (Canada). To do this, a LANcube v2 radiometer was assembled by the citizen researcher with the help of Prof. Aubé and his students. The LANcube was then used to map ALAN and identify the properties of the lighting systems in the city's streets. This data helps identify high-health risk areas while allowing the identification of mitigation solutions to the city's stakeholders.

Fig. 1: M. Aubé and S. Poulin installing the LANcube on car roof (left) and an example of melatonin suppression impact map for a Quebec City district (right). Red circles identify high melatonin suppression impact regions while the green circles highlight low impact.

In this paper, we summarize the method used to map ALAN, especially its associated melatonin suppression impact which we define as the product of the melatonin suppression index (MSI) the sideward averaged vertical illuminance. We also show how the lighting system inventory can be extracted from the recorded database to identify the problematic lighting systems that should be replaced to mitigate their potential health impact.

References

Aubé, M., & Houle, J. P. (2023). Estimating lighting device inventories with the LANcube v2 multiangular radiometer: Estimating lighting device inventories. *International Journal of Sustainable Lighting*, *25*(1), 10-23.

Aubé, M., Marseille, C., Farkouh, A., Dufour, A., Simoneau, A., Zamorano, J., Roby, J. & Tapia, C. (2020). Mapping the Melatonin Suppression, Star Light and Induced Photosynthesis Indices with the LANcube. *Remote Sensing*, *12*(23), 3954.

Aubé M, Roby J, Kocifaj M (2013) Evaluating Potential Spectral Impacts of Various Artificial Lights on Melatonin Suppression, Photosynthesis, and Star Visibility. PLoS ONE 8(7): e67798.

Garcia-Saenz A., Sánchez de Miguel A., Espinosa A., Valentin A., Costas L., Castaño-Vinyals G., Moreno V., Pollan M., **Aubé M.**, and Kogevinas M. (2019) Artificial light at night (ALAN), blue light spectrum exposure and colorectal cancer risk in Spain (MCC-Spain study)." *Environmental Epidemiology* 3, 212.

Garcia-Saenz, A., Sánchez de Miguel, A., Espinosa, A., Valentin, A., Aragonés, N., Llorca, J., Amiano, P., Martín Sánchez, V., Guevara, M., Capelo, R., Tardón, A., Peiró-Perez, R., Jiménez-Moleón, J. J., Roca-Barceló, A., Pérez-Gómez, B., Dierssen-Sotos, T., Fernández-Villa, T., Moreno-Iribas, C., Moreno, V., García-Pérez, J., Castaño-Vinyals, G., Pollán, M., **Aubé, M.**, Kogevinas, M. (2018) Evaluating the association between artificial light-at-night exposure and breast and prostate cancer risk in Spain (MCC-Spain study), Environmental Health Perspectives, *126*(4), 047011.

DARKERSKY4CE: a strategic transnational approach to reduce light pollution in Central Europe

Theme: Governance & Regulation

Remy Baltieri,[1,*] Dario Barghini,[2] Donata Bonino,[2] Balázs Borkovits,[3] Manuel Breitenfelder,[4] Bartlomiej Dahm,[5] Daniel Dalton,[4] Daniele Gardiol,[2] Susanna Gardiol,[1] Eleonora Gasparotto Nascimben,[2] Zoltán Haász,[3] Andreas Hartl,[4] Roman Hillebrand,[6] Michael Jungmeier,[4] Anikó Kiss,[3] Kata Konstantin,[3] Franz-Philipp Kraushofer,[4] Greti Manfreda,[7] Chiara Lamberti,[2] Luciano Massetti,[2,8] Agata Mazurek,[5] Rafał Modrzewski,[5] Jasmina Nikić,[7] Susanne Nilsson,[1] Zlata Petrenko,[2] Marta Polizzi,[4] Silvana Rückert,[6] Lilia Schmalzl,[4] Mariia Shelest,[4] Vid Svara,[4] Timea Szilágyi,[3] Luca Versino[1]

[1] GAL Escartons e Valli Valdesi, Torre Pellice, Italy
[2] INAF - Osservatorio Astrofisico di Torino, Pino Torinese, Italy
[3] South Transdanubian Regional Innovation Agency Ltd., Pécs, Hungary
[4] Carinthia University of Applied Science, Villach, Austria
[5] Kujawsko-Pomorskie Voivodeship, Toruń, Poland
[6] Aufbauwerk Region Leipzig GmbH, Leipzig, Germany
[7] Regional Development Agency of Northern Primorska L.t.d., Nova Gorica, Slovenia
[8] CNR-IBE Istituto per la BioEconomia del Consiglio Nazionale delle Ricerche, Sesto Fiorentino, Italy
corresponding author: daniele.gardiol@inaf.it
[*] presenting author

Introduction

Light pollution is an escalating environmental challenge with profound impacts on human health, ecosystems, and astronomical observations (Hassan, 2024; Rich & Longcore, 2006; Falchi et al., 2020). Central Europe ranks among the most light-polluted regions globally, necessitating coordinated efforts to address this issue (European Topic Centre on Human Health and the Environment, 2022). The Interreg Central Europe project "DARKERSKY4CE" brings together stakeholders from Italy, Poland, Hungary, Germany, Austria, and Slovenia to shift the perception of artificial light at night (ALAN). By integrating scientific research, policy development, and public engagement, we aim to develop a comprehensive strategy to mitigate the adverse effects of ALAN and promote sustainable development.

Aims and Strategy

The project seeks to change how light pollution is perceived by policymakers, tourism operators, visitors and local communities. Instead of being seen as an inevitable by-product of modern life, dark skies should be recognized as valuable assets for biodiversity conservation and sustainable tourism. By raising awareness and providing practical solutions, we aim to develop a comprehensive strategy for mitigating ALAN in Central Europe while demonstrating the economic and environmental benefits of preserving dark night skies. The project aims to create a strategy to reduce light pollution and promote sustainable development through astro-tourism, form thematic working groups to protect nocturnal ecosystems, transform dark skies into a touristic asset and encourage local participation, developing a comprehensive strategy using strategic foresight.

Pilot Actions and Pilot Demonstration Sites

A key component of DARKERSKY4CE is the implementation of four pilot actions (PA) across five pilot demonstration sites (PDS). PDS serve as testing grounds for innovative approaches to reduce light pollution, with partners collaborating across borders to share expertise and ensure effective solutions. The initiative is structured to promote knowledge exchange, in order to adapt and apply the insights gained in each location elsewhere. The five PDS are located in: Leipzig Region, Germany; Toruń, Poland; Turin Western Valleys, Italy; Somogy County, Hungary; Carinthia, Austria. Each site will focus on different aspects of light pollution mitigation, from ecological impact assessments to policy development. In the Leipzig Region, PDS1 will demonstrate how reducing light pollution in public lighting systems can safeguard natural ecosystems. Two PDS — one in Hungary and one in Austria — will work closely together to compare how light pollution affects different landscapes and ecosystems, ensuring a wider understanding of its impacts and possible solutions. In Poland, PDS2 will focus on the development of a dark sky tourism offer through the elaboration of an educational tourism concept. In Italy, PDS3 will experiment with a participatory approach, enlarging and consolidating dialogues among potentially conflicting stakeholders on the topic of light pollution and attractiveness of dark skies when in presence of cultural heritage. The project will also include a travelling exhibition showcasing findings from the PAs. This exhibit will make research results accessible and transferable across Europe.

Towards a Dark Sky Macro-Region

Our approach encourages local authorities to recognize dark skies as both a biodiversity safeguard and an economic opportunity. By assessing the touristic and astronomical potential of various sites, we provide the foundation for a roadmap leading to the first Dark Skies macro-region in Central Europe. Through international collaboration and sharing of expertise, DARKERSKY4CE aspires to set a precedent for effective light pollution reduction, offering a scalable model for regions facing similar challenges worldwide.

References

European Topic Centre on Human Health and the Environment. (2022) Review and assessment of available information on light pollution in Europe. European Environment Agency. Retrieved from ETC HE Report 2022/8: Review and Assessment of Available Information on Light Pollution in Europe — Eionet Portal

Falchi F, Cinzano P, Elvidge CD, Keith DM, & Haim A (2011) Limiting the impact of light pollution on human health, environment and stellar visibility. https://doi.org/10.1016/j.jenvman.2011.06.029

Hassan NE (2024) Light pollution and its effects on human health and the environment: A review. Asian Journal of Environment & Ecology, 23(10), 96-108. DOI: 10.9734/ajee/2024/v23i10613

Rich C, Longcore T, editors (2006) Ecological consequences of artificial night lighting. Island Press.

Natural influences on night sky brightness and implications for site quality characterization

Theme: Measurement and Modeling

John C. Barentine,[1,*] Albert D. Grauer,[2] Hannes Gröller[2] and Emilio Falco[3]

[1] Dark Sky Consulting, Tucson, USA
[2] Catalina Sky Survey, Tucson, USA
[3] DarkSky Southern Arizona, Tucson, USA
john@darkskyconsulting.com
** presenting author*

Introduction

The loss of nighttime darkness around the world is well-documented, and it poses challenges for the scientific productivity of astronomical observatories and the management of ecologically protected places. The natural components of night-sky brightness (NSB) vary considerably over the course of the 11-year solar magnetic activity cycle (Benn and Ellison 1998; Krisciunas et al. 2007; Grauer et al. 2019) and even around solar minimum (Grauer and Grauer 2021). This complicates efforts to assign objective night-sky quality metrics to sites such as International Dark Sky Parks. A better understanding of natural sources of NSB and their behavior over periods from minutes to years is key to observatory site characterization and protection, as well as for conservation of protected areas. One particularly valuable outcome of such an increased understanding may be the ability to predict NSB values. By scheduling astronomical observations around anticipated changes in NSB, scientific facilities could be made more productive and cost-effective. In this work we aim to improve the interpretation of time-series NSB data from both light-polluted and unpolluted sites.

Method

We use data from three Unihedron Sky Quality Meter-Lens (SQM-L) devices at sites in the southwestern U.S. spanning a distance of 300 km: Kitt Peak National Observatory (31.9624, -111.6004), Mt. Lemmon, Arizona (32.4426, -110.7887) and Cosmic Campground, New Mexico (33.4795, -108.9225). Data were filtered to remove contamination from twilight, moonlight and clouds, then matched up with time series of two solar geomagnetic indicators: Bz GSM (the *z*-component of the interplanetary magnetic field near the Earth in Geocentric Solar Magnetospheric coordinates) and the kinetic energies of solar wind protons obtained from the NASA OMNIWeb Science Data Portal.

Results

The NSB measurements in Fig. 1 show the known seasonal variation often attributed to the Russell-McPherron (1973) effect. The temporal window of the data set brackets the time between the minimum of Solar Cycle 24 to the ongoing maximum of Cycle 25; over this time we see an average NSB increase of about 0.5 magnitudes per square arcsecond (mpsa). Near solar maximum there are many specific instances of high NSB values likely due to the impacts of solar coronal mass ejections on the Earth’s magnetosphere. However, there are also isolated peaks in the NSB measurements that correlate strongly with the apparent arrival of fast and energetic solar wind streams that reverse the polarity of Bz. We searched for, but did not find, strong evidence of a time delay between the onset of solar geomagnetic events and elevated NSB reported by, e.g., Krisciunas *et al*. 2007. We also note

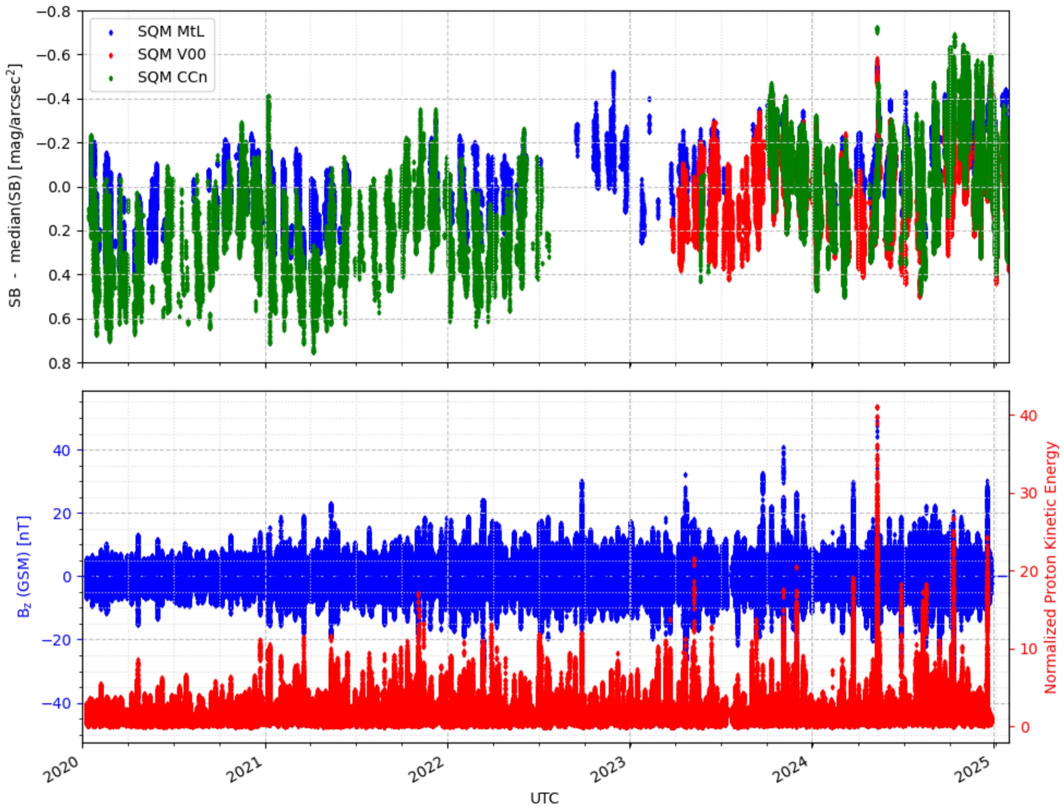


Fig. 1. NSB measurements and solar geomagnetic activity indicators during the rise of Solar Cycle 25 during 2020-2025. The upper panel shows individual measurements from SQM-Ls at three sites separated by up to 300 km: Kitt Peak National Observatory, Arizona ("V00", red points), Mount Lemmon, Arizona ("MtL", blue points) and Cosmic Campground, New Mexico ("CCn", green points). Each trace is the difference at each time between each individual measurement from that location and the median value for the full time series. The lower panel shows the z-component of the interplanetary magnetic field (blue trace) and the normalized energy of solar wind protons (red trace) at one-minute intervals from the NASA OMNIWeb Science Data Portal.

the dispersion of NSB measurements for all three monitors is roughly the same at solar minimum as at solar maximum, ranging up to ±0.3 mpsa.

References

Benn C & Ellison S (1998) Brightness of the night sky over La Palma. New Astron Rev 42(6–8): 503–507

Grauer A, Grauer P, Davies N & Davies G (2019) Impact of Space Weather on the Natural Night Sky. Pub Astron Soc Pac 131(1005): 114508

Grauer A & Grauer P (2021) Linking solar minimum, space weather, and night sky brightness. Sci Rep 11:1

Krisciunas K, Semler D, Richards J, Schwarz H, Suntzeff N, Vera S & Sanhueza P (2007) Publ. Astron. Soc. Pac. 119: 687–696

Russell C & McPherron R (1973) Semiannual variation of geomagnetic activity. J Geophys Res 78: 92–108

Lightshed Management: A Regional Approach To Light Pollution Control

Theme: Governance & Regulation

John C. Barentine,[1,*] Richard F. Green[2] and Aaron Lien[2]

[1] Dark Sky Consulting, Tucson, USA
[2] University of Arizona, Tucson, USA
john@darkskyconsulting.com
[*] presenting author

Regulatory models for controlling light pollution over large geographical areas have historically taken either top-down or bottom-up approaches implemented on (sub-) national or local levels, respectively. But these methods have failed to stem the rising and virtually unchecked global tide of outdoor artificial light at night (ALAN) emission.

We speculate that policy interventions at the middle level may be more effective in terms of measurably reducing light pollution. This involves a balance of local input and control through policies that act on large, multi-jurisdictional scales. We are inspired by the principles of regional watershed management. This method is informed by the concept of network governance where stakeholders form partnerships with the goal of establishing a common vision for the management of a resource that is simultaneously viewed as an economic good and a social good.

As the watershed is the land area that channels all surface and subsurface water toward common outflow points, we conceive of a “lightshed” as the geographic territory over which the outdoor ALAN emissions of cities and other sources are distributed. In this we build on radiative transfer modeling efforts demonstrating the spatial transmission of light pollution between different territorial areas. These results demonstrate the inadequacy of a municipality-by-municipality light pollution control framework given that ALAN readily drifts across multiple political boundaries from source to sink. The watershed analogy demonstrates the need for concerted and coordinated efforts in both the vertical and horizontal directions of the jurisdictional hierarchy.

In our model, groups of governments in a territory first agree to seek a solution to light pollution. They commit to a quantitative goal of reducing light pollution by some measurable amount in a defined period of time. That goal can be set relative to metrics such as light emissions per capita within the territory. The simplest goal is to hold that figure steady over time with population growth, but this still allows for net positive growth in light emissions. A more ambitious goal is to gradually draw down light emissions by actively cutting waste. Given the extreme inefficiency of typical outdoor lighting installations, we believe there is significant, untapped potential to achieve meaningful emissions reductions through better design and operation of outdoor lighting, including making better use of lighting controls.

Like watershed systems, lightshed systems have multiple, conflicting uses that tend to spread both benefits and costs unevenly among users. To encourage cooperation leading to achievement of regional light emissions reductions goals, we envision something like a cap-and-trade system in which increasing light emissions in one part of the territory must be compensated for by reduced emissions in another. The right to emit light at night becomes a tradable commodity. Such a system could help offset the costs of lighting design and retrofits required to reach emission reduction targets.

As an example, we consider the lightshed of southern Arizona, USA, centered on the Tucson metropolitan statistical area, which has a population of about 1 million inhabitants. A suggested boundary of this lightshed is shown in Figure 1. The boundary is drawn as the contour for which the zenith night-sky brightness is 50% higher than the presumed natural background level. Barentine *et al*. (2018) found that light emissions within the boundaries of the incorporated City of Tucson totaled 5.5×10^{8} lumens, or about 1015 lumens per capita, in 2017. The population rate of change in the last decade averaged about +0.5% year^{-1}, while satellite-indicated light emissions rose about 16% since 2017. We estimate the light consumption in 2025 to be about 1165 lumens per capita, which represents an increase of at least 15% in eight years.

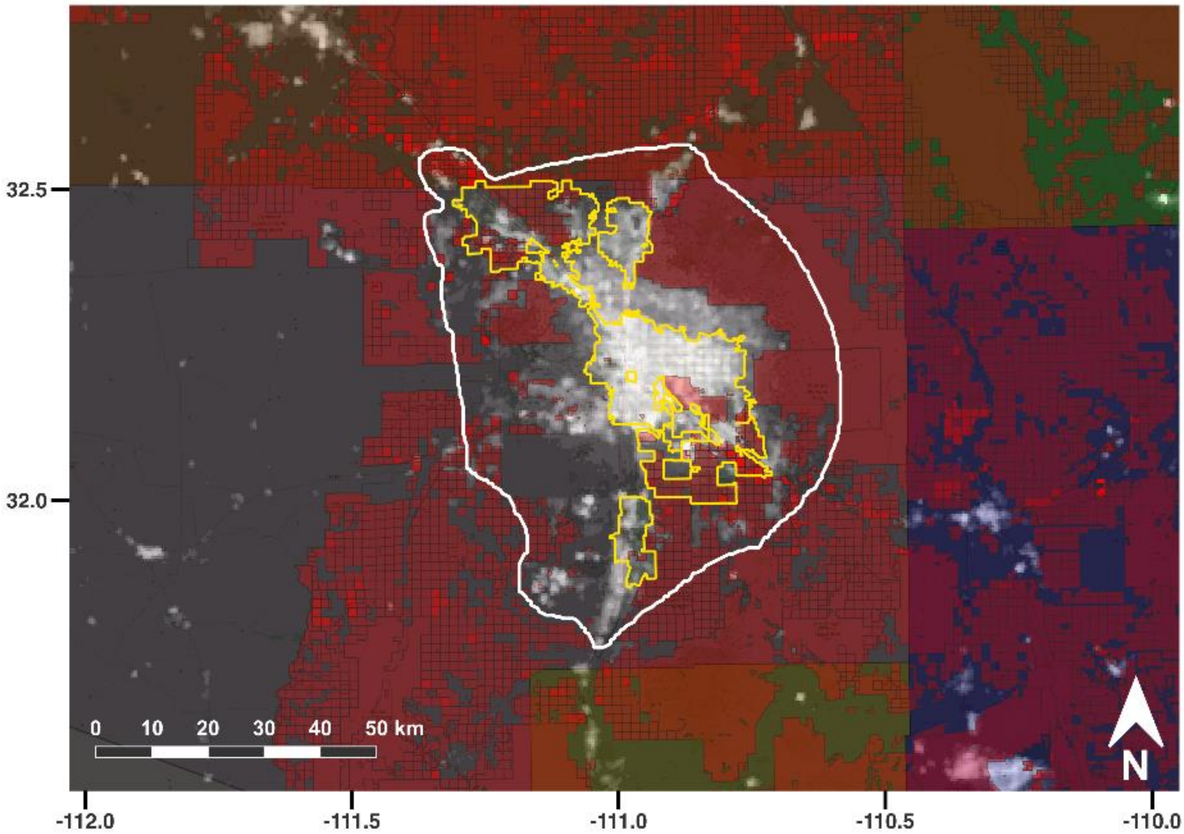


Fig. 1: A suggested lightshed boundary (white line) surrounding the greater Tucson, U.S., metropolitan area. Various colored, large polygons in the background represent county boundaries in the U.S. state of Arizona. Boundaries of incorporated municipalities are shown as yellow lines. Shaded red polygons represent lands owned by the State of Arizona or the U.S. federal government. The grayscale overlay is the VIIRS-DNB Nighttime Lights Monthly Cloud-Free Composite for February 2024. The base map is from OpenStreetMaps, licensed under the Open Database License.

References

Barentine JC, et al (2018) Skyglow changes over Tucson, Arizona, resulting from a municipal LED street lighting conversion. J of Quant Spectr and Rad Trans, 212, 10-23

All-Sky Measurements of the Night Sky Brightness by the Italian PRISMA Fireball Network

Theme: Measurement and Modeling

Dario Barghini,[1,*] Daniele Gardiol,[2] and Chiara Lamberti[1]

[1] INAF – Istituto Nazionale di Astrofisica, Osservatorio Astrofisico di Torino, 10025 Pino Torinese (TO), Italia
dario.barghini@inaf.it
[*] presenting author

PRISMA (Prima Rete Italiana per la Sorveglianza sistematica di Meteore ed Atmosfera) is a fireball network mainly dedicated to the observation of bright meteors and to the recovery of freshly-fallen meteorites on the Italian territory. The project is coordinated by INAF, the Italian National Institute for Astrophysics, and counts more than 60 collaborating institutes. PRISMA is also a partner of the FRIPON international consortium. To date, the network consists of more than 70 stations, each employing a monochromatic all-sky camera module operating continuously at 30 frames per seconds to capture and properly sample the atmospheric path of bright meteors, i.e. fireballs and bolides. Since 2016, the PRISMA network has observed approximately 3000 meteors and allowed for the recovery of two freshly-fallen meteorites, namely Cavezzo (01/01/2020, L5-an, 55.3 g) and Matera (14/02/2023, H5, 117.5 g).

In order to perform the astrometric and photometric calibration, every 10 minutes during nighttime, the system acquires a series of 5 seconds exposure images where stars brighter than -4.5^V magnitude can be observed. The PRISMA network has been collecting these data since 2016, thus allowing a systematic monitoring of the night sky brightness over the Italian territory in the wavelength bandpass between 300 and 900 nm.

Fig. 1: The all-sky camera of the PRISMA network installed on the rooftop of the Astrophysical Observatory of Turin, in Pino Torinese, Piedmont, Italy (http://www.prisma.inaf.it/)

In this contribution, we will present the methods, data analysis, and first results of the PRISMA network regarding light pollution monitoring in Italy during the last ten years.

References

Barghini et al. (2019) Astrometric calibration for all-sky cameras revisited, Astron Astrophys 626:A105

Barghini et al. (2024) The recovery of the Matera H5 ordinary chondrite thanks to the observations of the PRISMA fireball network, Europlanet Science Congress 2024, held 8-13 September, 2024 at Freie Universität, Berlin, Germany, EPSC2024-449

Colas et al. (2020) FRIPON: a worldwide network to track incoming meteoroids, Astron Astrophys 644:A53

Gardiol et al. (2019) News from the Italian PRISMA fireball network. Proceedings of the 37th International Meteor Conference held 30 August - 2 September 2018 in Pezinok, Slovakia, 81-86

Gardiol et al. (2021) Cavezzo, the first Italian meteorite recovered by the PRISMA fireball network. Orbit, trajectory, and strewn-field, Mon Not R Astron Soc 501:1215-1227

Life-long ALAN exposure affects avian brain plasticity in sex- and region-dependent patterns

Theme: Biology and Ecology

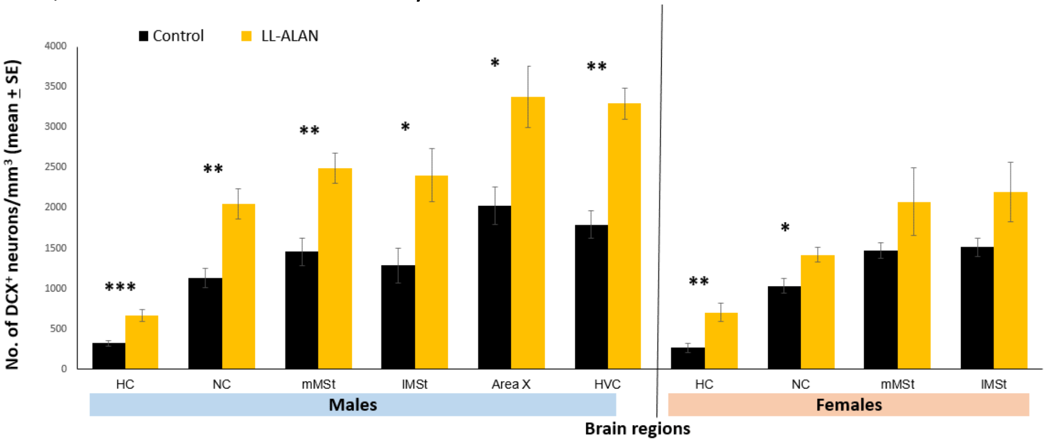
Anat Barnea,[1,*] Stan Moaraf,[1,2] Rachel Heiblum,[1] Nofar Klein, [1] and Shahaf Shenfarber [1]

[1] *Department of Natural Sciences, The Open University of Israel, Raanana, Israel*
[2] *School of Zoology, Tel Aviv University, Tel-Aviv, Israel*
anatba@openu.ac.il
[*] *presenting author*

Previously, we explored the effects of ALAN, melatonin, brain plasticity and behavior in zebra finches (ZF; *Taeniopygia guttata*). ALAN increased proliferation and recruitment of new neurons in various brain regions in both sexes. In addition, ALAN differentially affected neuronal densities in these regions, suggesting that some regions are more resilient to ALAN than others, and that males are more resilient than females [Moaraf et al., 2020 a & b, 2021]. We hypothesized that these changes might compensate for ALAN-induced neuronal death in these regions, and/or are due to increased night-time locomotor activity caused by sleep disruption. However, these studies involved only short-term ALAN exposure. The current study aims to investigate the effect of Life-Long ALAN exposure (LL-ALAN) on brain plasticity in birds, reflecting more ecologically relevant conditions for wild birds. We hypothesized that the negative effects observed in the brain under shorter exposure will persist or increase in a region- and sex- dependent manner, ultimately affecting behavior.

Parents (P) ZF were housed in two indoor breeding aviaries to produce experimental F1 birds. Both aviaries had the same daytime illumination, but the Control aviary was dark at night, while the LL-ALAN aviary was exposed to 5 lux of light at night. When F1s reached adulthood (around 90 days), they were moved to cages in another room, under their respective light conditions from hatching (LL-ALAN or Control), and housed a male and a female per cage. F1s remained in these cages for 10 weeks, during which we periodically recorded their body mass, daytime and night-time plasma melatonin levels and locomotor activity (not shown here). F1s were then euthanized and brains were assayed for cell proliferation, recruitment of new neurons, neuronal densities, and apoptosis. As previously, we focused on neuronal recruitment, in the hippocampus (HC), nidopallium caudale (NC), and medial striatum sub regions (mMSt and lMSt). These regions serve various functions, processing, respectively, spatial, auditory, homeostatic and reflexive pathways, and somatosensory and motor function. In males, we also examined HVC and Area X, which are male-specific regions of the song system. Neuronal recruitment was detected in brain sections by staining doublecortin (DCX) for recently born neurons [Balthazart et al. 2008], and Hu, a neuronal marker [Barami et al., 1995].

Overall, our findings indicate that LL-ALAN increases new neuronal recruitment in both sexes and in most regions (see figure). This supports our hypothesis that the deleterious effects that we previously observed in the brain under shorter ALAN exposures persist under the more ecological scenario of life-long exposure. A detailed comparison between the two types of ALAN exposures is limited due to methodological differences between our studies. Previously we used BRDU (5'-bromo-2'-deoxyuridine) as a specific cell birth-date marker for new neurons, while here we used DCX, a more general marker for brain plasticity (which also labels new axons and dendrites). Despite this, a comparison indicates that in males, LL-ALAN increased neuronal recruitment in all the tested brain regions compared with Control (this study), whereas shorter ALAN exposure had no effect in the HC and NC in males (Moaraf et al., 2021). In females, LL-ALAN increased neuronal recruitment significantly only the in HC and NC, whereas under shorter ALAN exposure a significant increase was found also in mMSt and lMSt (Moaraf et al., 2020b). These sex differences suggest that, under ecological-like conditions, females are more adaptive to ALAN than males. Furthermore, the sex- and region-dependent differential effects of LL-ALAN compared with shorter ALAN exposure emphasize the importance of studying the effects of ALAN in both sexes and under relevant ecological conditions, or at least under laboratory simulation of such conditions.



Effects of LL-ALAN on number of DCX$^+$ neurons / mm^3 (mean ± SEM) in the brain regions HC, NC, mMSt, lMSt (both sexes); and Area X and HVC (only males). *, **, *** indicate significant differences between groups ($p<0.05$, $p<0.01$, $p<0.001$ respectively); N = 8 females and 8 males in Control; 8 females and 5 males in LL-ALAN.

Another intriguing question is how ALAN-induced changes in brain plasticity affect behavior. For example, we observed changes in neuronal recruitment in HVC and Area X, the male-specific regions involved in the song system, under both LL-ALAN and shorter ALAN exposure, indicating that ALAN may alter song behavior and result in impaired/mistimed singing. Such behavioral shifts could negatively affect male fitness and survival by reducing their ability to attract mates and defend territories. Future studies will explore such questions and further our understanding of the ecological implications of ALAN and its potential impact on the misalignment of internal rhythms with external cues in animals exposed to light pollution.

References

Balthazart J, Boseret G, Konkle AT, Hurley LL, Ball G (2008) Doublecortin as a marker of adult neuroplasticity in the canary song control nucleus HVC. Eur J Neurosci 27:801–817

Barami K, Iversen K, Furneaux H, Goldman SA (1995) Hu protein as an early marker of neuronal phenotypic differentiation by subependymal zone cells of the adult songbird forebrain. J Neurobiol 28(1):82-101

Moaraf S, Vistoropsky Y, Pozner T, Heiblum R, Okuliarová M, Zeman M, Barnea A (2020a) Artificial light at night affects brain plasticity and melatonin in birds. Neurosci Lett 716: 134639

Moaraf S, Heiblum R, Vistoropsky Y, Okuliarová M, Zeman M, Barnea, A. (2020b) Artificial Light at Night increases recruitment of new neurons and differentially affects various brain regions in female zebra finches. Int J Mol Sci 21(17): 6140

Moaraf S, Heiblum R, Okuliarová M, Hefetz A, Scharf I, Zeman M, Barnea A (2021) Evidence That Artificial Light at Night induces structure-specific changes in brain plasticity in a diurnal bird. Biomolecules 11(8): 1069

Envirolight - Self-responsible sustainability in Lighting Design

Theme: Technology & Design

Jonas Bönner[1,*], Dr. Annette Krop-Benesch[2] , Prof. Dr. Cornelia Moosmann[1]

[1] HAWK, Hildesheim, Germany
[2] Krop-Benesch Lichtwissen, Seeheim-Jugenheim, Germany
jonas.boenner@stud.hawk.de
[*] presenting author

Introduction

Conservation in lighting design is not an option, but a necessity. The last years have been characterized by a social rethink. Circular economy and energy efficiency are terms that almost every renowned lighting manufacturer uses to advertise their products. However, sustainability is not an advertising strategy, but should be an obligation for all industrial sectors. While night-time lighting is crucial for maintaining the standard of living in modern societies, it disrupts ecosystems. The lighting industry faces the challenge of balancing environmental responsibility with professional practice. Those who are uncompromisingly Eco-friendly in their lighting will leave the night alone and preserve the darkness. Nevertheless, there are ways of expressing illumination and a fascination for light while at the same time showing consideration for nature.

Fig 1: Minimal inverse light for the Sedanallee footpath and cycle path

“Envirolight” shows what this integration of sustainability into the concept work can look like. This - currently still theoretical - lighting design outlines a lighting concept for the *Sedanallee*, a former boulevard in the city of Hildesheim in Lower Saxony. The concept is characterized in particular by the fact that a great deal of research work preceded the design process.

Methods

In addition to an analysis of the ecological and traffic conditions, a survey of residents and passers-by was carried out in order to integrate their perceptions and needs into the concept.

Conclusions

The lighting concept based on these findings has been given the name Envirolight to indicate the link between light and nature. The lighting concept for the *Sedanallee* is based on a number of premises.

1. Reason-based action: All lighting is an intervention in nature. Laws and standards currently pay too little attention to environmental protection. It is therefore necessary to find responsible ways to avoid light pollution.

2. Adaptive lighting management: Lighting should flexibly adjust to usage with variable intensity and timing, using sensors where possible.

3. Avoid light spill: The lighting fixtures are designed and positioned in such a way that they do not emit unnecessary light into the sky or onto neighboring green spaces and buildings.

4. Reduction of brightness: Attention is paid to a level of brightness that meets the need for safety and visibility without being excessively bright.

5. Color spectrum with minimal blue content: To minimize the impact on wildlife and the human sleep-wake rhythm, the light used has a low blue content.

Outcome

The lighting concept for *Sedanallee* aims to make pedestrian and cycle traffic safer and more visible through environmentally friendly lighting, while at the same time staging the space as an attractive outdoor area. The use of discreet, inhomogeneous light with warm colors at 1800 Kelvin creates an inviting atmosphere and reduces the impact on wildlife thanks to the low blue component. The alignment of the luminaires prevents unnecessary illumination of the non-pedestrian areas and direct upward light emission. The light levels are deliberately kept low, with a maximum of 10-15 lux directly underneath the luminaires, which quickly drop to less than one lux towards the outside, in order to meet both the users' desire for atmospheric light and environmental protection.

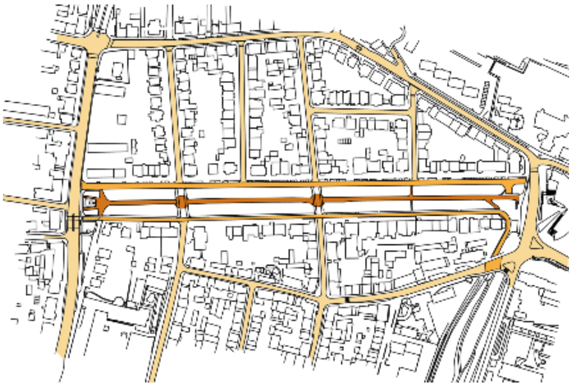


Fig 2: Contrast between warm white light colors provides orientation

To achieve this lighting effect, cable luminaires are installed on sturdy, tall trees on the avenue and supplemented by masts on the opposite side, which enable a zigzag pattern of cable installation. This installation method protects the roots of the 130-year-old trees by laying cables mainly above ground. Where no suitable trees are available, bollard luminaires are used, which have the same light color and intensity to ensure a constant comfortable atmosphere and to maintain the open chain of the avenue. Motion detectors on poles and bollard luminaires in key areas ensure that the lighted sections are illuminated as required and then switched off again for a calming lighting mood. This adaptive lighting management reduces pedestrian exposure and saves energy.

Prospects

The responsibility for sustainability lies with all lighting designers. Technical innovations help to master the balancing act between environmental justice and creative freedom. Intelligent control systems and adaptable lighting ensure that different needs can be met and that environmentally friendly lighting creates places where people and animals enjoy spending time.

Measuring ALAN in the 3D space using the Dronegoniophotometer

Theme: Measurement and Modeling

Constantinos A. Bouroussis[1, *], Fabio Rinderer[1], Florian Stuker[1], and Alex Trabucchi[1]

[1] *Swiss Federal Institute of Metrology METAS, Bern, Switzerland*
constantinos.bouroussis@metas.ch
[*]*presenting author*

Introduction

Artificial light at night, known as light pollution, has been a significant subject of scientific and environmental research for many years. Its negative impacts affect humans, animals, plants, biodiversity, ecological functions, and even astronomical observations. Since light disperses and reflects in all directions, it is crucial to apply measurement and assessment techniques to accurately quantify light pollution. Currently, there are no widely accepted and applicable measurement instruments or techniques that serve the diverse needs of various scientific disciplines and stakeholders. Most existing instruments have drawbacks such as the lack of traceable SI calibration, poor long-term stability, and inadequate relative spectral responsivity. Additionally, most light pollution measurement techniques are ground-based.


Fig. 1: Field test measurements by flying the UAS over known light sources

This research aims to establish the first standardized metrology system for measuring and assessing light pollution using Unmanned Aerial Systems (UAS). The proposed solution involves aerial platforms equipped with specially designed measuring devices for light pollution assessment, including irradiance and illuminance sensors, spectrometers, and multi-camera clusters with standardized colorimetric responsivity.

Methods

The proposed platform currently features two types of sensors under development. The first type employs a low illuminance level measuring system capable of detecting illumination levels from 1E-5lx to 1E5lx. This setup quantifies upward light from various heights as the drone flies over a predefined grid, creating an upward light heatmap and estimating wasted upward energy. The second setup includes an imaging system that captures photometrically corrected spatial information of outdoor lighting installations, resulting in a 3D point cloud of photometric data and identifying major contributors of spill light.

The measurement procedure is divided into flight planning and execution, and the measurement task. The drone carries and positions the measurement equipment at predefined points in 3D space, rotating it as needed. Normal UAS fly over predefined locations (waypoints) outlining an area or path to be covered during the flight. However, this approach is limited due to the need for a dense grid of measurement points. A special algorithm was developed to create custom flight paths for measuring light in different shaped grids. The flight path is uploaded to the UAS, and the mission is executed automatically.

The first working prototype instrument developed is a high dynamic range illuminance meter, designed to document upward light from outdoor lighting installations. The device includes a photometer head with a large silicon diode, a multi-gain amplifier, a control unit, a communication module, and a battery pack. The photometer was calibrated using a reference lab facility and can measure illuminance from a few hundred µlx to hundreds of klx. A microcontroller gathers measurement data, controls the gain setting on the amplifier, stores the data, and transfers it back to the control center of the flight. The measurement procedure is controlled and monitored by custom software offering flight data, live measurement values, and visualization of key results.

In-Lab and Field Tests

The UAS measurement platform was tested both indoors and in the field. Indoor tests verified system connectivity, using a moving carriage with the system mounted on it and various light sources placed on the floor. Real flights verified the flight and measurement capabilities of the system, using special outdoor setups with known light sources. Various flight missions tested the sensitivity of the measurement instrument, the drone's flyability, and appropriate settings for the measurement procedure. Verification tests demonstrated that the platform can measure at least five decades of upward illuminance and perform automated flight grids over predefined areas. Further development includes integrating a 3-axis gimbal for aiming the measurement cluster and testing of the multi-camera cluster.

Acknowledgments

This work is part of the research project SPOTLIGHT, funded by the Swiss National Science Foundation (SNSF) (https://www.wsl.ch/de/projekte/spotlight/).

Assessing the impact of public lighting extinction on road safety using satellite observation

Theme: Governance & Regulation

Emma Bousquet Borrut[1,*], Sébastien Castets[1], Aurélien Mure[1], Vincent Ledoux[1], Paul Verny[1], Romain Borrod[1], Florian Greffier[1], Vincent Boucher[1], Stéphanie Bordel[1], Guillaume Saint-Pierre[1], Alain Somat[2], Carine-Daniella Niyomwungere[2], and Helga Mondésir[3]

[1] Cerema, Toulouse, Lyon, Aix-en-Provence, Angers, and Saint-Brieuc, France
[2] Université de Rennes 2, Rennes, France
[3] Délégation à la sécurité routière, Ministère de l'Intérieur, Paris, France
emma.bousquet@cerema.fr
[*] presenting author

Introduction

As part of efforts to reduce environmental impact and energy expenses, many European municipalities are implementing policies to reduce or even partially or completely turn off public lighting. The extinction of public lighting can affect the visibility of road infrastructure, users' visual perception, their behavior, and their sense of safety. In this context, the French project SéRENOS (Road Safety : Night time lighting and earth observation) aims to explore the consequences of nighttime lighting extinction on road safety. The main goal is to provide quantitative elements regarding the impact of nighttime lighting extinction on accident rates. The project is financed by the French Road Safety Directorate (DSR) from the Ministry of Interior.

Various local studies tried to assess the impact of road lighting on traffic accidents, but led to different conclusions (Elvik, 1995 ; Rea et al., 2009). The majority of studies agree that the presence of public lighting is associated with a 20% to 30% reduction in the risk of nighttime accidents. Nevertheless, numerous limitations and potential biases could affect these results, and other studies conclude that public lighting reduction or extinction are not correlated with an increase of nighttime accidents (Perkins et al., 2015). The SéRENOS project aims to quantify this impact for French mainland territory, by considering satellite observations of nighttime radiance, and a large amount of data from (i) the national traffic accident database from 2012 to 2024 and (ii) one year of floating car data (FCD) at the national scale.

Methods

In France, public lighting extinction is a common practice for many municipalities since the energy crisis (2022), but this information is not reported at the national scale. To tackle this lack of knowledge, public lighting extinctions were first detected with NASA’s Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting Partnership Program (S-NPP) satellite. Daily VNP46A2 products of the Day/Night Band were considered and aggregated at the monthly scale from January 2012 to December 2024, over France. Monthly time series were computed over each French municipality, considering only the brightest spots using the 90th quantile, leading to almost 20.000 municipalities in the analysis. A method was then developed to detect changes in radiance time series, considering a binary segmentation algorithm. Strong decreases (i), light decreases (ii), and increases (iii) were detected, respectively associated with (i) public lighting extinction ; (ii) partial public lighting extinction or renovation ; and (iii) urban or commercial development. These detections were reported in a map on continental France, ggrepresenting the 2012-2024 period (Fig. 1). Almost 12.000 municipalities were found to have set up a public lighting extinction policy, mostly in winter 2022.

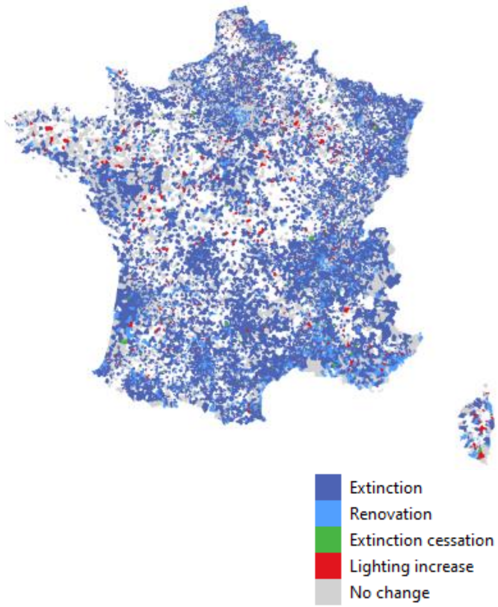


Fig. 1: National map of public lighting evolution from 2012 to 2024 over French municipalities, Cerema.

These results were then confronted with the national traffic accidents database, which registers all physical accidents leading to medical care. Each accident is well documented, with exact location, date and time, road type, public lighting presence, weather conditions, drug or alcohol use, etc. The dataset was firstly filtered from potential bias. Over the municipalities practicing public lighting extinction detected beforehand, the number of nighttime accidents were aggregated and compared before and after the extinction implementation. The preliminary results seem to indicate that the number of accidents decreases following the extinction event, then is back to normal within a few months. This conclusion could however be altered with the date of application of most extinctions (autumn 2022). A second analysis of the satellite radiance observed at the location and date of the accidents seems to show that severe and lethal accidents are generally linked with lower values of radiance than minor accidents. These results will be consolidated in the next few months, and will be complemented by an analysis of traffic speed database.

Conclusions

The analysis of long-term VIIRS/NPP satellite data enabled to detect changes in public policies of lighting over France since 2012. Total extinctions were distinguished from partial extinctions or renovations and from lighting development. A national map was produced and will be freely available in the next months. The impact of public lighting extinction on driver behavior and traffic accidents was then investigated, using a national traffic accidents database. The results are currently preliminary but tend to show that (i) the number of accidents decreases just after the extinction event, and then recovers its initial values; and (ii) dark conditions lead to more serious road accidents.

References

Elvik, R (1995) Meta-analysis of evaluations of public lighting as accident countermeasure. Transportation Research Record, 112-123

Rea, M S, Bullough, J D, Fay, C R, Brons, J A, Derlofske, J V, Donnell, E T (2009) Review of the safety benefits and other effects of roadway lighting. National Cooperative Highway Research Program Transportation Research Board of the National Academies, 61

Perkins, C, Steinbach, R, Tompson, L, Green, J, Johnson, S, Grundy, C, Wilkinson, P, Edwards, P (2015) The effect of reduced street lighting on crime and road traffic injuries at night in England and Wales : A controlled interrupted time series analysis. In What is the effect of reduced street lighting on crime and road traffic injuries at night ? A mixed-methods study. NIHR Journals Library.

A portable spectral measurement device for Skyglow

Theme: Measurement

Grace Bramer[1,2,*], Constantinos Bouroussis[1]

[1] Federal Institute of Metrology METAS, Bern, Switzerland
[2] University of Bern, Bern, Switzerland
grace.bramer@metas.ch
[*] presenting author

Skyglow is one of the most visible indicators of light pollution from artificial lighting at night. It has played a crucial role in the history of light pollution research, both in measurement techniques and in raising awareness of the issue. Astronomers were the first to recognize the impact of light pollution, as stray light interfered with their ability to observe and study the stars and the universe. This realization led to the development of the first measurement tools designed to quantify skyglow, such as the Sky Quality Meter (SQM) (Hänel et al., 2018; Cinzano, Falchi, & Elvidge, 2001; Sánchez de Miguel et al., 2017).

Fig. 1: Photo of the night sky showing the impact of skyglow.

The SQM, a portable and easy-to-use device, quickly gained popularity beyond the astronomical community. Night sky enthusiasts and citizen scientists embraced the technology, leading to a global effort to map skyglow and light pollution. These efforts helped highlight light pollution as a significant environmental concern and fueled modern initiatives aimed at reducing excessive artificial light, promoting the idea that everyone deserves a clear view of the night sky.

However, since the introduction of the SQM, the lighting landscape has undergone a dramatic transformation. The widespread adoption of LED lighting—driven by decreasing costs, increased brightness, and improved efficiency—has resulted in a more illuminated world (Kyba, Hänel, & Hölker, 2014). Traditional incandescent bulbs and sodium streetlights have largely been replaced by LEDs, which offer tailored light distributions. The range of spectrums these sources have mean that the spectral response of the device becomes a critical factor in obtaining accurate measurement results. As this often differs from device to device, a single channel measurement device can give an inaccurate value if not calibrated for the particular spectrum it is measuring. Moreover, a non-standardized spectral responsivity prohibits calibration to SI and thus traceability to the corresponding unit. Therefore, a calibrated grating based spectral measurement device provides a significant advantage, providing a more accurate intensity measurement as well as spectral information. Measuring the spectral radiance and irradiance of skyglow and thus, the raw information for the calculation of the derived quantities (e.g. photopic/scotopic luminance, melanopic radiance and so on) provides a critical advantage in understanding how different light sources influence the night environment. This has important implications for human health, social interactions, and ecological systems, including wildlife behavior and biodiversity (Kyba et al., 2017).

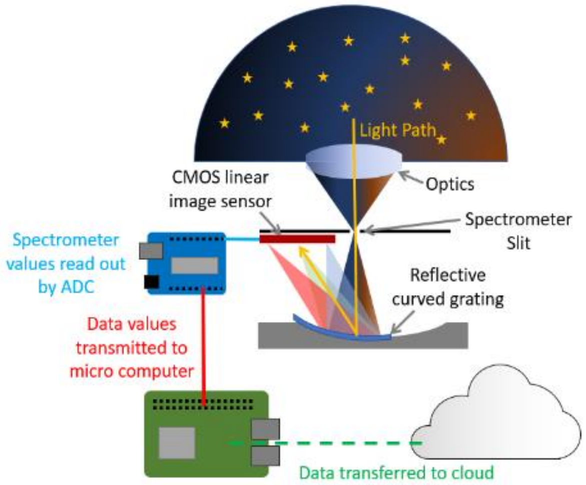


Fig. 2: Block diagram of proposed Skyglow measurement device.

To address this need, we propose a next-generation SQM, a sky irradiance/radiance measurement device capable of measuring both the spectral distribution and intensity of skyglow. This new device will retain the core advantages of the original SQM—portability and affordability—while integrating advances in sensor technology to enable spectral measurements. Developments in fluorescence and Raman spectroscopy have led to compact, highly sensitive spectrometers that are well-suited for this application. By combining a micro-spectrometer with widely available microcomputers, we are developing an IoT-enabled spectral measurement device for long-term skyglow monitoring.

We hope that the low cost and reproducibility of this device will make it ideal for establishing a network of skyglow measurement stations, enabling data collection across large and remote areas. Its portability also allows it to be co-located with other environmental monitoring equipment, such as air pollution sensors or biological research stations studying the effects of artificial light on insect populations. This would generate valuable new datasets, deepening our understanding of how light pollution interacts with and affects the world around us. This work is part of the SPOTLIGHT project, funded by the Swiss National Science Foundation (SNSF).

References

Cinzano, P., Falchi, F., & Elvidge, C. D. (2001). The first World Atlas of the artificial night sky brightness. Monthly Notices of the Royal Astronomical Society, 328(3), 689–707. https://doi.org/10.1046/j.1365-8711.2001.04882.x

Hänel, A., Posch, T., Ribas, S. J., Aubé, M., Duriscoe, D., Jechow, A., ... & Zotti, G. (2018). Measuring night sky brightness: methods and challenges. Journal of Quantitative Spectroscopy and Radiative Transfer, 205, 278–290. https://doi.org/10.1016/j.jqsrt.2017.09.008

Kyba, C. C. M., Hänel, A., & Hölker, F. (2014). Redefining efficiency for outdoor lighting. Energy & Environmental Science, 7(4), 1806–1809. https://doi.org/10.1039/C3EE43760J

Kyba, C. C. M., Kuester, T., de Miguel, A. S., Baugh, K., Jechow, A., Hölker, F., ... & Guanter, L. (2017). Artificially lit surface of Earth at night increasing in radiance and extent. Science Advances, 3(11), e1701528. https://doi.org/10.1126/sciadv.1701528

Sánchez de Miguel, A., Aubé, M., Zamorano, J., Kocifaj, M., Roby, J., & Tapia, C. (2017). Sky Quality Meter measurements in a colour changing world. Monthly Notices of the Royal Astronomical Society, 472(3), 3177–3188. https://doi.org/10.1093/mnras/stx145

SPOTLIGHT Project Partners

Swiss Federal Institute for Forest, Snow and Landscape Research - WSL (https://www.wsl.ch/en/)
Department of Geography – University of Zurich (https://www.geo.uzh.ch/en/department.html)
Elektrizitätswerke des Kantons Zürich – EKZ (https://www.ekz.ch/de/privatkunden.html)
Federal Institute of Metrology – METAS (https://www.metas.ch/metas/en/home.html)

Spotlight project website: https://www.wsl.ch/de/projekte/spotlight/

Light Pollution Alters Arthropod Behaviours

Theme: Biology and Ecology

Hannah D. Broeckx,[1,*] Anne N. Haringhuizen[1], Alanna L. Brown[1], Emily R. Burdfield-Steel,[1] and Astrid T. Groot[1]

[1] *Institute for Biodiversity and Ecosystem Dynamics, Amsterdam, Netherlands*
h.broeckx@uva.nl
[*] *presenting author*

With advancing technologies and expanding urbanization, anthropogenic light at night (ALAN) has become a significant environmental stressor, continuing to grow in both surface area and intensity (Kyba et al., 2017, 2023). ALAN is increasingly recognized as a driver of arthropod declines, through alterations in movement, foraging, reproduction, and predation. (Owens et al., 2020).

We investigated the effects of ALAN on the behavioural activities of jumping spiders and lepidopteran larvae, with a particular focus on shifts in activity patterns, including potential constriction or extensions into the night. Both groups are central players in the food web, as caterpillars are important herbivores and nutritious prey, while jumping spiders act both as predator and prey.

In a first study, we tested whether dim light pollution (1.5 lux, cold white LED 5500K) affects larval behaviour of three lepidopteran species that differ in both anti-predator colouration and adult activity period: the cryptic, nocturnal, species *Mamestra brassicae*, the cryptic, diurnal, species *Pieris napi* and the aposematic, diurnal, species *Pieris brassicae*. We found that the behaviour of all three species was affected by ALAN. However, the responses were species specific. When we focused on tracking feeding activities on differently orientated leaf disks, we found an overall increase in nocturnal feeding by all three species under dim light conditions. This study highlights that even low levels of light pollution can disrupt the behaviour of species, highlighting the need to preserve fully unpolluted areas.

In a second study, we investigated how different light intensities and spectra influence the behaviour of the diurnal jumping spider *Marpissa muscosa*, focusing on locomotor activity and sheltering behaviour. Using automated tracking with 30 second interval images, we monitored spider movement over a 24 hour period. Nocturnal movement and sheltering behaviour were recorded under three light intensities—1.5 lux, 10 lux, and 100 lux—representative of levels encountered by this highly mobile species. These tests were conducted under cold white light (5500K). Interestingly, we found that only the highest intensity treatment influenced spider behaviour, with significantly more movement and less sheltering by the spiders compared to the dark night control. When we examined whether these behavioural differences persisted under warmer LED light (2700K, 100 lux), we found no behavioural alterations. These results suggest that warmer or less bright lights can mitigate ecological light pollution for this species.

Together, these studies highlight the complexity of species-specific responses to ALAN and underscore its potential to disturb ecosystem interactions, particularly as taxa from different guilds within a food web exhibit different levels of sensitivities and responses. Effective mitigation strategies must prioritize minimizing these disruptions to preserve the integrity and stability of natural ecosystems.

References

Kyba, C. C. M., Kuester, T., De Miguel, A. S., Baugh, K., Jechow, A., Hölker, F., Bennie, J., Elvidge, C. D., Gaston, K. J., & Guanter, L. (2017). Artificially lit surface of Earth at night increasing in radiance and extent. *Science Advances*, *3*(11), 1–9.

Kyba, C. C. M., Wagner, J. M., Kuechly, H. U., Walker, C. E., Elvidge, C. D., Falchi, F., Ruhtz, T., Fischer, J., & Hölker, F. (2023). Citizen Science Provides Valuable Data for Monitoring Global Night Sky Luminance. *Scientific Reports*, *3*, 1835.

Owens, A. C. S., Cochard, P., Durrant, J., Farnworth, B., Perkin, E. K., & Seymoure, B. (2020). Light pollution is a driver of insect declines. *Biological Conservation*, *241*, 108259.

Dimming streetlights reduces insects' attraction but leaves bats in the dark

Theme: Biology & Biology and Ecology

Sander W.J. Buddendorf[1,2,*] & Hannah Broeckx[3], Emily R. Burdfield Steel[3], Astrid T. Groot[3], Marcel E. Visser,[1,2] and Kamiel Spoelstra[1]

[1]Department of Animal Ecology, Netherlands Institute of Ecology (NIOO-KNAW), Wageningen, the Netherlands
[2]Chronobiology Unit, Groningen Institute for Evolutionary Life Sciences (GELIFES), University of Groningen, Groningen, The Netherlands
[3]Institute of Biodiversity and Ecosystem Dynamics, University of Amsterdam, Amsterdam, The Netherlands

s.buddendorf@nioo.knaw.nl
[*] presenting author

Anthropogenic light disrupts rhythms and behaviours in nearly all organisms, but especially so in nocturnal animals such as bats and their prey. Bats are often repelled by light, but some fast-flying and agile species opportunistically forage on accumulated insects around light sources. The disruption of anthropogenic light can therefore be especially severe in strongly illuminated urban environments. Dimming streetlights is often suggested as a mitigation measure, but its effectiveness in reducing impacts on bats and insects—and how it affects their nightly and season timing—remains poorly understood.

To test this, we recorded bat activity for a full year across three light treatments in urban habitats: high-intensity, low-intensity (dimmed), and dark controls. To examine the effects of light dimming on predator-prey interactions in detail, we collected high-temporal-resolution insect data during a summer month using five-minute interval photography of insects arriving on a white sticky sheet.

Our results show that insects were most abundant near high-intensity lights, and dimming light moderately reduced attraction. However, insect numbers remained higher under dimmed lights compared to dark conditions. For pipistrelle bats – a synanthropic species known to exploit aggregated insects around lights sources – the effect of dimming light was however limited. Interestingly, this species did not forage more around streetlights than in nearby dark locations in our urban study sites, while it has been shown that rural-dwelling pipistrelles tend to forage more around anthropogenic light. In addition, the effect of dimming light on pipistrelle activity varied throughout the season.

Although the short-term impact on bat activity is relatively small, reduced insect attraction to light could have long-term benefits. By reducing insect mortality near light sources—where many become trapped and perish from exhaustion or collisions—it may help slow insect declines in urban areas. Additionally, with fewer insects drawn to illuminated areas, more prey remains available for bats hunting in the darkness.

While light dimming reduces insect attraction, its limited effect on bats underscores the need to preserve dark refuges in urban landscapes to support biodiversity.

Modelling light pollution reduction in France with Otus 3.0

Theme: Measurement and Modelling

Rolf Buhler[1,*], Philippe Deverchere[1], Sébastien Vauclair[1]

[1] *DarkSkyLab, Fontenilles, France*
rolf.buhler@darkskylab.com
[*] *presenting author*

Introduction

Introduction We present a new software package for the calculation of Artificial Light At Night (ALAN) (il)luminance levels called Otus 3.0. It incorporates state-of-the-art ALAN diffusion models with different atmospheric profiles, cloud cover and urban emission functions. In a first study, we apply our model to France, where significant efforts have been made to reduce light pollution over the last decade. We calibrate our models using a unique dataset of sky brightness measurements taken over 6 years at 136 different locations. We find good agreement between models and data. We show that the emission function is typically more tilted towards the zenith in urban centres. Including this dependence in the model significantly improves the fit to the measurements. We show that the average zenith luminosity in France decreases by approximately 30% between 2012 and 2024. The main drivers of this improvement are the switching off of public lighting in the middle of the night and the renewal of lighting parks.

Methods and Results

Otus 3.0 has been developed to improve the modelling accuracy of ALAN and to make it more flexible. The tool allows the calculation of artificial zenith luminosity and diffuse illuminance from satellite radiances. Arbitrary (generally asymmetric) kernels can be used to simulate the emission and scattering of ALAN in the atmosphere. The applied kernels can be varied in space and time. We derived several kernels using the SkyGlow software, e.g. for different atmospheric aerosol content and cloudiness (Kocifaj & Lamphar 2014, Wallner & Kocifaj 2023). We have also simulated different components of the urban emission function by varying the direct and reflected emission components. We will discuss the effect of these parameters on zenith luminance and diffuse illuminance.

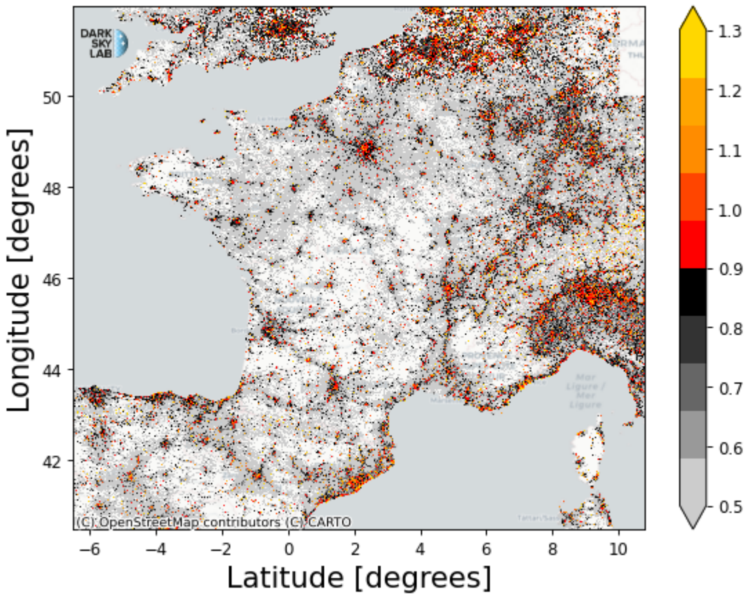


Fig 1: Radiance observed near nadir (0-20°) divided by the off nadir radiance (40-60°), as seen by NASA`s and NOAAs VIIRS-DNB instrument in 2023.

We applied Otus 3.0 to France between the years 2012 and 2024. As can be seen in Fig. 1, the urban emission typically peaks strongly towards the zenith. This is expected due to light blocking by buildings in the horizontal direction (Kyba et al. 2022). We therefore applied diffusion kernels corresponding to two different city emission functions for the areas shown in colour and grey in Fig. 1, respectively.

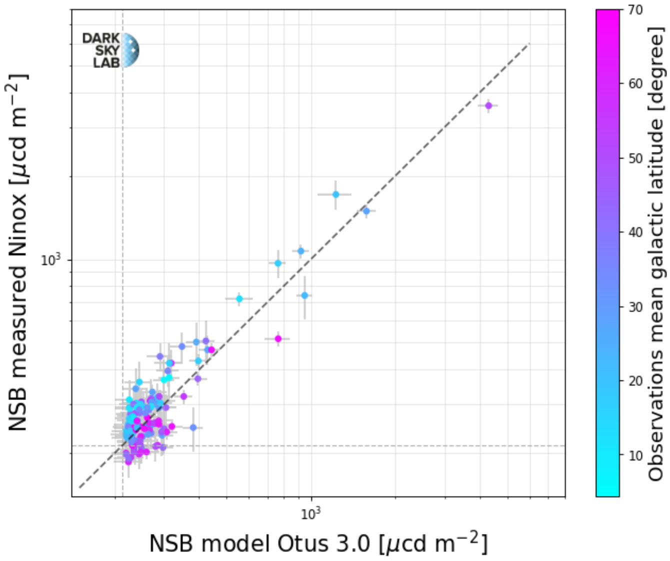


Fig 2: Comparison between simulated and measured Night Sky Background levels. The colour scale shows the mean galactic latitude in the region observed by the Ninox. For mode details see the text.

We calibrated our model using a set of sky brightness measurements performed by DarkSkyLab since 2018, using Ninox recorders at 136 different locations (Deverchère et al. 2022). The methods and results of this measurement campaign are presented in a companion contribution. We have fitted the kernel normalisations and the natural sky background to the Ninox measurements. As shown in Fig. 2, we find good agreement between the two.

In France, several policies have been implemented over the last decade to reduce light pollution. Many districts have switched off public lighting in the middle of the night and renovated lighting parks. The modelling results show that the average artificial luminance in the middle of the night decreased by approximatelly 30% between 2012 and 2024. This is in stark contrast to the increasing ALAN levels observed in most parts of the world and Europe (Falchi et al. 2023, Plotard 2024). We hope that these efforts set a positive example and will be further strengthened in the future.

References

Kocifaj, M., & Lamphar, H. A. S. (2014). Quantitative analysis of night skyglow amplification under cloudy conditions. Monthly Notices Of The Royal Astronomical Society, 443(4), 3665-3674.

Kyba, C. C. M., Aubé, M., Bará, S., Bertolo, A., Bouroussis, C. A., Cavazzani, S. et al. (2022). Multiple angle observations would benefit visible band remote sensing using night lights. Journal Of Geophysical Research Atmospheres, 127(12).

Deverchère, P., Vauclair, S., Bosch, G., Moulherat, S., & Cornuau, J. H. (2022). Towards an absolute light pollution indicator. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-022-21460-5

Wallner, S., & Kocifaj, M. (2023). Aerosol impact on light pollution in cities and their environment. Journal Of Environmental Management, 335, 117534.

Falchi, F., Bará, S., Cinzano, P., Lima, R. C., & Pawley, M. (2023). A call for scientists to halt the spoiling of the night sky with artificial light and satellites. Nature Astronomy, 7(3), 237-239.

Plotard, C. (2024). France, world champion in lighting reduction. https://darkskylab.com/www/en/france-world-champion-lighting-reduction/

Uranometry: luminescence identified in the skies of the State of São Paulo, Brazil

Theme: *Measurement and Modeling*

Elvo C. Burini Junior,[1,*] José C. M. Melero,[2] Hédio Tatizawa,[2] Iván Kopaitić,[3,*] and Ramachrisna Teixeira,[4]

[1] *Instituto de Energia e Ambiente (IEE), University of Sao Paulo (USP), Sao Paulo, Brazil*
[2] *Programa de Pós-Graduação em Energia (PPGE), Instituto de Energia e Ambiente (IEE), University of Sao Paulo (USP), Sao Paulo, Brazil*
[3] *Escuela Ingeniería Eléctrica, Pontificia Universidad Católica de Valparaíso, Valparaiso, Chile*
[4] *Instituto de Astronomia, Geofísica e Ciências Atmosféricas (IAG), University of Sao Paulo (USP), Sao Paulo, Brazil*
*elvo@iee.usp.br; *presenting author*

Introduction

Considered the Brazilian technical standard sector, the concept of "light pollution" was introduced in 2012 (revision of ABNT NBR 5101, 1992). In 2021, a law draft on this subject was proposed and presented at the Brazilian National Congress [1]. This draft is currently being processed. It defined light pollution as something that is not aligned with international terminology (CIE, ISO, IEC). This article introduces the discussion on the topic of light pollution in Brazil, signaling is made to expand the sampling locations in Latin America where there is available information on zenithal luminescence from only one area, Buenos Aires, Argentina (see http://128.199.94.197:8080/map/map.php). Measurement for the sky luminance at locations in the State of São Paulo, Brazil, is considered. Data collection on sunlight reflected by our satellite, the Moon, began in 2008 (see Fig. 1), as references for luminance meters led to the development of our methodology that considered four measuring points of the sky (A, to D, see Fig. 2).

Fig. 1: Photographic record taken through the luminance meter eyepiece. Source: NIKON, model COOLPIX, S210, #DSCN2057, May 2010 [2].

Method and Results

The lunar disk and four external points were sampled (see Figs. 1 and 2). Some of the available records on the luminance of the Moon in the city of São Paulo (23° N; 47° W) were presented in 2012 [2]. Figure 1 shows the lunar disk on the left and a black circle on the right, the interior of which is the sampled area (equipment brand Minolta). The average luminance of the sky (points A to D), in the city of São Paulo, in 2008, was determined around the lunar disk with values in the range of (0.72 to 1.00) cd/m^2 or (12.9 to 12.6) mag/arcsec^2, with the standard deviation calculated in the range of (0.20 to 0.40) cd/m^2, and using two devices [2]. For another experiment carried out at sea level [3], the average luminance range of (2.2 to 2.6) cd/m^2 or (11.7 to 11.5) mag/arcsec^2 was obtained. To conversion, a tool obtained from: http://unihedron.com/projects/darksky/magconv.php?ACTION=SOLVEMAGS&txtCDM2=2.6 was used and no correction was applied because the light source was the Moonlight. During road luminance measurements at the IEE-USP test site, the sky at USP was sampled, it was slightly cloudy, in the north direction (approximate). The Ramos de Azevedo Monument was used as a reference. The elevation angle was estimated at approximately 9.6 degrees. The luminance was sampled at the Zenith, in the central region of the Monument (position # 1), the sky (# 2 to # 4), and the facade of the building (# 5 to # 7), see marking in Fig. 3, and the values measured are presented in Table 1.

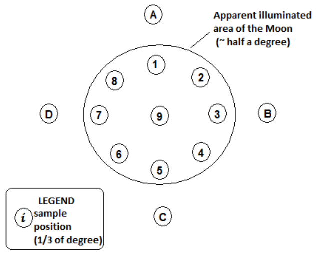


Fig. 2: Diagram indicating the regions where the equipment was pointed during luminance measurements [2, 3].

Table 1 - Luminance sampled at CUASO, USP, of the sky and points, March 26, 2025, 8:30 p.m.

Measurement Point	**Luminance** (cd.m^{-2})	(mag/arcsec^2)
# 1	1.01	12.6
# 2	0.46	13.4
# 3	0.49	13.4
# 4	0.49	13.4
# 5	0.12	14.9
# 6	0.17	14.5
# 7	0.12	14.9
At Zenith	0.28	14.0

Note: No correction was used because the artificial primary light source was the SSL technology (LED).

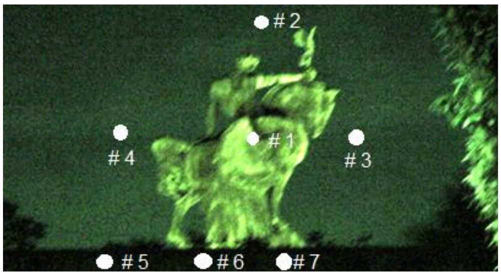


Fig. 3: Image of the Monument to Ramos de Azevedo (File ref.: DSC05682; 26/Mar./2025) adjusted (ImageJ software used) and an indication of luminance measurement points (8:30 p.m.).

Information was obtained about the instruments for collecting data on the luminance of the sky, installed in a Brazilian location (Ouro Fino, MG), but without access to data. On March 30, 2025, at 7:10 p.m. (Brasília, or 22:10:00 UTC), the value of 10.2 mag/arcsec^2 was obtained for the zenithal luminescence of the night sky in Buenos Aires. This value was converted to 8.98 cd/m^2, which is considered quite high when compared to the average luminance prescribed for roads with motorized traffic. The Unihedron (SQM) conversion calculator was used [http://unihedron.com/projects/darksky/magconv.php] and no correction was applied for the spectral power distribution of the artificial light source with SSL technology (LED). There is no prescription in the Brazilian technical standard for public road lighting (ABNT NBR 5101) for maximum values of either luminance or illuminance, a fact that may have a negative impact on light pollution.

Conclusions

In Brazil, a lack of knowledge and data on the relevant quantities was identified. Quantitative data on the luminescence present in the skies of the State of São Paulo, Brazil were presented. The aim is to establish the basis for the implementation and operation of a network to collect data on the luminescence of the skies over a long period. This could provide a solid basis for countering initiatives that result in the increasing increase in inappropriate artificial light (either in intensity or in the wrong direction) for road users and the environment. There are no maximum light level limits prescribed for the Brazilian Standard for public lighting.

References

[1] PL n. 1400 (2021) A draft of a proposed law. https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra?codteor=1992014&filename=PL%201400/2021.

[2] E. C. Burini Junior (2012) A LUMINÂNCIA DA LUA NA CIDADE DE SÃO PAULO (LAT. 23° 27 MIN. SUL). Anais do XI Congreso Panamericano de Iluminación - Lux América 2012, Cartagena, Colômbia.

[3] Elvo Calixto Burini Junior (2016) A LUMINÂNCIA DA LUA AO NIVEL DO MAR. Anais do XIII Congreso Panamericano de Iluminación - LUXAMÉRICA 2016, La Serena, Chile.

Assessment of the effects of light source shielding on insects, bats and their interactions

Theme: Biology and Ecology

Samuel BUSSON,[1,2,*] Vincent BOUCHER,[1] Florian GREFFIER,[1] and Franz HÖLKER,[3]

[1] Cerema, EL, F-49130, Les Ponts-de-Cé, France
[2] Cerema, F-13100, Aix-en-Provence, France
[3] Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany
Samuel.busson@cerema.fr
[*] *presenting author*

Introduction

Various complementary approaches are proposed to reduce the negative impact of artificial light at night (ALAN) on biodiversity, on several scales. On a territorial scale, the green and blue infrastructure approach, and in particular the dark infrastructure, aims to create a set of suitable interconnected habitat that allows nocturnal species to carry out their life cycle while being protected from ALAN (Sordello et al., 2022), and then to identify parts of the territory that must be preserved from any introduction of light. However, there are sectors where human activity requires the use of ALAN, even when night-time biodiversity issues are at stake. In such cases, measures to reduce light pollution must be applied directly to the light fixture, seeking the best possible compromise between the quality of service provided to human users (CEN, 2015a & 2015b) and the least possible impact on biodiversity.

The lighting parameters most commonly identified as having an impact on biodiversity, and the adaptations proposed to reduce them, are: Correlated Color Temperature (CCT), which should be reduced to limit the proportion of blue light emitted; light quantity, which should be reduced; light distribution in space, which should be limited to diffusion below the horizon, or even on the useful surface only (Jägerbrand et al., 2021; Gaston et al., 2022).

Another parameter, less clearly defined and studied, but which can be linked to light distribution, is the visibility of the light spot. This parameter raises a basic question: irrespective of its characteristics, does the mere fact that the light spot is seen make it impactful, i.e. does it influence the behavior of individuals as soon as it is seen?

In scientific and technical literature, we regularly find the recommendation to only light where it's needed (Dark Sky Guideline, 2020), and more occasionally to “shield light/create obstacles/barriers to light”, which indirectly refers to the question of visibility and, by extension, to the influence of the light source at a distance. For example, Reed et.al (1985) showed that shielding the sources so that they no longer emitted light towards the sky reduced their power of attraction by 40% on seabirds; he also showed that the full moon greatly reduced the phenomenon of attraction. Pendoley & Kamrowski (2016) and Chih-Hao Yen et.al (2023) showed that shielding a light source behind the beach reduces its disruptive effect on the sea-finding behavior of turtle hatchlings, a disruption that is observed as soon as an artificial light is visible behind the beach. Seewagen et al. (2023) showed that the activity of a light-averse bat was still negatively affected at 75m from a light source, even though the illuminance at this distance was less than 1 lux, and recommended shielding light sources in the vicinity of bat habitats. Bolliger et.al (2022) showed that increasing the diffusion of a light source increased its attractiveness to insects and seemed to negatively affect the hunting activity of certain bats. Finally, using the opposite approach, Dietenberger et al. (2024) showed that shielding a light source significantly reduced its attractiveness to a large number of insect groups, for different color temperatures and illuminance levels.

Shielding the light source therefore seems an appropriate approach for significantly reducing the negative impact of LAN on several groups of animal species. However, to date, there are few technical solutions on the market that meet this objective. Furthermore, some of the existing systems have generally been designed primarily to address this environmental impact issue, sometimes to the detriment of the quality of service provided to the human user.

This research will therefore focus on the development of a light source shielding system, which should meet the following two objectives:

- Reduce the impact of the light source on insects and bats;
- Guarantee optimum quality of service for human users.

Methods

To validate these hypotheses, we plan to:

- Develop a system for shielding the light source at a distance while maintaining the photometric performance criteria of a lighting installation, in partnership with an industrial company.
- To test this system in outdoor conditions, assessing its influence on insect attraction and bat activity. To do this, we plan to use a Before-After-Control-Impact-*paired* experimental protocol based on acoustics bat monitoring and insect trapping by comparing the behavior of insects and bats in unmasked, masked and unlit conditions.

References

Bolliger J et al. (2022) Low impact of two LED colors on nocturnal insect abundance and bat activity in a peri-urban environment. Journal of Insect Conservation (2020) 24:625–635

CEN (2015a). FD CEN/TR 13201-1:2015. Road lighting—Part 1: Guidelines on selection of lighting classes. European Committee for Standardization (ECS).

CEN (2015b). EN 13201-2:2015. Road lighting—Part 2: Performance requirements. ECS.

Chih-Hao Yen et al. (2023) The Effect of Light Pollution on the Sea Finding Behavior of Green Turtle Hatchlings on Lanyu Island, Taiwan. Zoological Studies 62:47

Dietenberger et al. (2024) Reducing the fatal attraction of nocturnal insects using tailored and shielded road lights. Communication biology|(2024)7:671

Gaston KJ, Sanchez de Miguel A (2022) Environmental Impacts of Artificial Light at Night. Annu. Rev. Environ. Resour. 2022. 47:373–98

Hartley R., Liebel B. (2020) Five principles for responsible outdoor lighting. https://darksky.org/news/joining-forces-to-protect-the-night-from-light-pollution/

Jägerbrand AK, Bouroussis CA (2021) Ecological Impact of Artificial Light at Night: Effective Strategies and Measures to Deal with Protected Species and Habitats. Sustainability 2021, 13, 5991

Pendoley & Kamrowski (2016) Sea-finding in marine turtle hatchlings: What is an appropriate exclusion zone to limit disruptive impacts of industrial light at night? Journal for nature conservation 30 (2016) 1-11

Reed et al. (1985) Light Attraction in Endangered Procellariiform Birds: Reduction by Shielding Upward Radiation. The Auk, Volume 102, Issue 2, April 1985, Pages 377–383

Seewagen et al. (2023) Far-reaching displacement effects of artificial light at night in a North American bat community. Global Ecology and Conservation 48 (2023) e02729

Sordello R et al. (2022) A plea for a worldwide development of dark infrastructure for biodiversity – Practical examples and ways to go forward. Landscape and Urban Planning, 2022, 219, pp.104332

Comparative effect of 1800K and 3000K LED lighting on the overall activity of bats

Theme: Biology and Ecology

Samuel BUSSON,[1,*] Matthieu IODICE,[1] Louis RUBINI,[1] Thomas BROUSSIGNAC,[1] Alexane CLERJON,[1] Christian KERBIRIOU,[2] Aurélien BESNARD,[3] Romain SORDELLO,[4] and Raphaël COLOMBO[5]

[1] Cerema Méditerranée, Aix en Provence, France
[2] CESCO
[3]CEFE-CNRS
[4] PatriNat (OFB-MNHN)
[5] Asellia ecologie, ecology consulting firm
Samuel.busson@cerema.fr
[*] *presenting author*

Introduction

Among the strategies to reduce the impact of ALAN on biodiversity, one is to seek a spectral composition of light that has less impact on living organisms (Jägerbrand, 2021), for example by reducing the proportion of blue light / short wavelength content in the spectral power distribution of the light source, and to decrease the correlated color temperature (CCT) (Jägerbrand, 2021). Somer-Yates (2013) showed that shorter wavelengths light stimuli were more attractive to moths than longer wavelengths. In France, public lighting CCT threshold is thus limited to 3000K (Cerema, 2019), making 3000K a standard. Simultaneously, to meet this recommendation for warmer light, manufacturers developed LED sources from 2700K down to 1700K, including LED sources called PC (= Phosphor Corrected) Amber LED that offer correct light output and a rendering close to that of older High Pressure Sodium lamps.

Our study focuses on the effect of CCT on bats. Spoelstra (2015) demonstrated that bat activity was less affected by red light (poor in blue content) than by white or green light (both enriched in blue content), but transferring these results into a lighting strategy is tricky since white light (whether warm or cool) is commonly preferred for street lighting than a monochromatic red light. He also showed that “light-shy bats” reduce their activity in white and green, but retain it in red light; and that “non-light-shy-species” are significantly more active under white and green light, assuming that this behavior is caused by an increased insect density.

In this field study, we therefore wanted to assess whether a 1800K PC Amber LED source, available for public lighting, has fewer negative effects on bat activity than a 3000K standard LED source. Our two hypotheses were: (1) a 1800K LED, being poor in blue content, is likely to attract less insects and therefore will reduce *Pipistrellus* activity compared to 3000K LEDs; (2) activity of light-shy bats under a 1800K LED will be higher than activity under 3000K LEDs.

Methods

To validate or refute these hypotheses, we performed a BACIP (Before-After-Control-Intervention-Paired) experimental protocol based on an acoustic survey (Audiomoth recording devices), using in-situ public lighting as treatments. Thus, the Energy Syndicate of Seine-et-Marne Department has made available public lighting installations on which the LED luminaires could be replaced. 13 sectors were sampled, each consisting of 3 study sites: Treatment site was lit by a 3000K LED during “year 1” and by a 1800K LED during “year 2”;

Control site was always lit by a 3000K LED; Reference site had no public lighting. A site was defined as a 100m diameter area with an acoustic recorder at its center. The sites were selected to be as homogeneous as possible according to environmental and technical criteria (distance to the nearest forest edge and water point, percentage of urban and forest coverage, height and light flux of the lighting source, etc.). Sound recordings took place during at least four nights at the three sites of each sector, for six or seven sectors simultaneously, at the same period and time of the year for “year 1” and “year 2”. The gathered acoustic data were analyzed using the software *Tadarida* to identify species, via an online deposit on a server of the French National Museum of Natural History. *Tadarida* also provided a level of confidence (C) on its identifications, expressed as a percentage.

Results

A total of more than 360.000 contacts of bats were retrieved by *Tadarida* with a C of 50% (C50), and 188.000 contacts with a C of 90% (C90). *Pipistrellus pipistrellus* accounted for more than 90% of contacts. Bats have been categorized into various guilds according to the distance at which their echolocation signals are perceived: Short, Middle and Long Range Echolocators (SRE, MRE, LRE). SRE includes *Myotis*, *Plecotus*, *Rhinolophus* and *Barbastella* and count for 0.5 % of the total number of contacts at C90. MRE includes *Pipistrellus, Miniopterus* and *Hypsugo* and count for 96,7 % of the total number of contacts at C90. LRE includes *Nyctalus, Eptesicus* and *Tadarida* and count for 2,7 % of the total number of contacts at C90.

A first manual acoustic checks of these automatic identifications showed that the SRE data had a not insignificant level of error, which, combined with the low number of contacts, means that we are unable to draw any conclusions at this stage. Further manual analysis is underway. On the other hand, the volume of MRE contacts, coupled with better automatic identification performance, led us to conclude that for this group, the change in color temperature did not have any significant effect on overall activity. We were also able to verify that MRE activity was significantly lower in control sites than in treated sites (whatever the light treatment).

Conclusions and perspectives

Switching from 3000K LED to PC Amber 1800K LED does not seem to affect MRE overall activity. This conclusion is consistent with a recent published study which showed with a different experimental protocol that the usual LED CCTs (1750K, 3000K and 4000K) had not influenced overall bat activity, but confirmed that the lowest CCTs were less attractive to insects (Bolliger et al., 2022).We will now carry out an analysis of overall SRE activity based on checked acoustic identifications, and an analysis of hunting activity, to see whether or not this reflects the drop in insect concentration expected in the vicinity of PC Amber LEDs.

References

Bolliger J et al. (2022) Low impact of two LED colors on nocturnal insect abundance and bat activity in a peri-urban environment. Journal of Insect Conservation (2020) 24:625–635
Cerema (2019) Décryptage : l’arrêté ministériel “Nuisances lumineuses »
Jägerbrand AK, Bouroussis CA (2021) Ecological Impact of Artificial Light at Night: Effective Strategies and Measures to Deal with Protected Species and Habitats. Sustainability 2021, 13, 5991
Somer-Yates R et al. (2013) Shedding light on moths: shorter wavelengths attract noctuids more than geometrids
Spoelstra K et al. (2015) Response of bats to light with different spectra: light-shy and agile bat presence is affected by white and green, but not red light. Proc. R. Soc. B 284: 20170075

Lighting for Coexistence: A Collaborative Approach to Protecting Wildlife

Theme: Technology and Design

Chiara Carucci[1,*]

[1] *Noctua Cultural & Natural Heritage Lighting Design, Camerota, Italy*
chiara@noctua.life
[*] *presenting author*

Introduction

Actions aimed at preventing, reducing and mitigating the negative effects of Artificial Light at Night (ALAN) on biodiversity (Longcore et al., 2004) should not be reductionist or unidirectional (Sanders et al., 2021), nor based only on the existing regulatory framework, often incomplete and unevenly implemented across different countries. Adopting an ecosystemic approach in lighting projects is possible, and rewarded by tangible results, as demonstrated by case studies developed over the past five years. In fact, this presentation is based on the lessons learned from two touristic caves in Italy, designated as Sites of Community Importance, particularly for bats conservation, and the pilot project for a *Caretta caretta* nesting site, included in the EU LIFE21 Turtlenest initiative. These case studies will demonstrate how research-informed lighting design, is vital for mitigating the effects of ALAN and fostering coexistence between humans and wildlife. Having established the significance of collaboration in addressing ecological challenges, especially after dark, the case studies will also show how such collaboration is crucial to achieving more effective projects, optimizing both timing and costs. Finally, this presentation aims to challenge attendees' perspectives on mitigating measures (UNEP 2023), with the hope of enriching the discussion for sustainable lighting practices.

Fig. 1: Daylight and anthropogenic lighting in Collepardo Caves.
Ph.: Jansin & Hammarling.

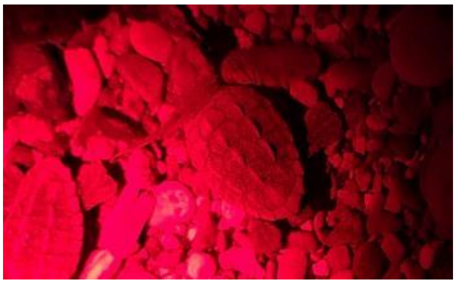


Fig. 2: Loggerhead turtles hatchling at the Tutlenest Pilot Project site.
Ph.: Chiara Carucci.

Methods

In the Collepardo and Pastena caves, the new lighting design aimed to preserve habitats for bat species such as *Rhinolophus ferrumequinum* and *Myotis myotis*, protected under Annex II of the EU Habitats Directive (Straka et al., 2020). Collaboration with local managers, guides, and researchers allowed to minimize the effect of anthropogenic lighting on geological formations and wildlife, while addressing *lampenflora* as an ecological issue. The project included innovative design strategies to reduce operating times, and dark aerial corridors to maintain undisturbed bat flight paths (Sordello et al., 2021). This case study presentation will also cover the ongoing research on site, and feedback reported by the experts involved throughout the projects: the local chiropterologist, two environmental scientists, and a geologist.

The EU LIFE21 Turtlenest project focuses on the preservation of the loggerhead turtles nesting sites in the Western Mediterranean. The first pilot project in Ascea, Italy, coordinated by the Marine Biology Institute Anton Dohrn, aimed at monitoring and raising awareness of anthropogenic disturbance. Therefore, this presentation covers the results of the local survey on ALAN perception, and introduces the specific Lighting Guidance currently in force in the municipality of Ascea. Moreover, along a 1 km stretch of beach, lighting fixtures are being upgraded to shielded, warm-temperature LEDs (Robertson et al., 2016), balancing ecological sensitivity with cost-effectiveness. The collaboration with marine biologists and municipal authorities ensured that technical solutions aligned with both conservation goals and tourism management needs.

The case studies share an adaptive management framework, using field research and stakeholder feedback to test and refine interventions. This will be presented alongside the importance of tailoring solutions to the specific ecological and social contexts of each site.

Conclusions

Preliminary observations and lessons learned suggest that perceived constraints in lighting design for sensitive ecosystems can be transformed in opportunities, providing a framework for more precise and sustainable lighting solutions. The case studies demonstrate that when ecological expertise informs lighting design through collaborative approaches, a balance between conservation and tourism - particularly supporting educational goals - is achievable. This methodology, combining scientific knowledge and stakeholder engagement, offers a model for successfully addressing ecological issues in other protected areas, while fostering coexistence between humans and wildlife.

References

Longcore, T., & Rich, C. (2004). Ecological light pollution. Frontiers in Ecology and the Environment, 2(4), 191-198. https://doi.org/10.1890/1540-9295(2004)002[0191:ELP]2.0.CO;2

Sanders, D., Frago, E., Kehoe, R., Patterson, C., & Gaston, K. J. (2021). A meta-analysis of biological impacts of artificial light at night. Nature Ecology & Evolution, 5, 1-8. https://doi.org/10.1038/s41559-020-01322-x

UN Environment Programme, UNEP Secretariat. (2023). Light Pollution Guidelines for Wildlife. [Online]. Available: https://www.cms.int/sites/default/files/document/cms_cop14_doc.30.4.4_light-pollution-guidelines_e_0.pdf

Straka, T. M., Greif, S., Schultz, S., Goerlitz, H. R., & Voigt, C. C. (2020). The effect of cave illumination on bats. *Global Ecology and Conservation, 21*, e00808. https://doi.org/10.1016/j.gecco.2020.e00808

Sordello, R., Busson, S., Cornuau, J. H., Deverchère, P., Faure, B., Guetté, A., Hölker, F., Kerbiriou, C., Lengagne, T., Le Viol, I., Longcore, T., Moeschler, P., Ranzoni, J., Ray, N., Reyjol, Y., Roulet, Y., Schroer, S., Secondi, J., Valet, N., Vanpeene, S., & Vauclair, S. (2021). A plea for a worldwide development of dark infrastructure for biodiversity – Practical examples and ways to go forward. *Land Use Policy, 104*, 104332. https://doi.org/10.1016/j.landurbplan.2021.104332

Robertson, K., Booth, D. T., & Limpus, C. J. (2016). An assessment of 'turtle-friendly' lights on the sea-finding behaviour of loggerhead turtle hatchlings (*Caretta caretta*). *Wildlife Research, 43*, 1-7. https://doi.org/10.1071/WR15138

Focus on Local Governments and Their Needs for Better Lighting Policies

Conclusions of a survey by the Flemish Government

Theme: Governance & Regulation

Tanya Cerulus,[1*] Stijn Vanderheiden, [1]

[1] Department of Environment and Spatial Planning, Flemish Government, Brussels, Belgium
tanya.cerulus@vlaanderen.be
[*]presenting author

Flanders, the northern region of Belgium, carries out a Flemish action plan on wild pollinators as part of a European directive (2022-2030). To improve the habitat of wild pollinators - but also other fauna and flora - many efforts are needed in many areas. Limiting light pollution is one of them. The Flemish government is therefore drawing up a specific policy action plan on light pollution within this framework.

In 2025, the five Flemish provinces and many partners drew up an online inspiration guide on artificial light at night (ALAN). This guide is mainly aimed at local authorities and informs and inspires policy makers to deal with lighting in the right way. The included good practice examples help to make well-considered decisions not only based on aspects such as safety or the perception of it, but also from the point of view of human health and biodiversity. We hope to develop this guide further in the coming years, if possible also tailored to other target groups such as sports clubs or companies.

These initiatives show that the attention for tackling light pollution has grown considerably in Flanders and that several governments are now taking steps to protect darkness as an environmental quality. To deliver the right information to the target groups with our actions on light pollution, it is necessary to fully and nuanced map the issues and thus find out their (knowledge) needs, motives, obstacles and (good or bad) practical experience.

Therefore, the Flemish government's Environment Department engaged a market research agency to conduct a 2-part stakeholder survey among Flemish municipalities, cities, provinces and police districts as this is the target group we will focus on in 2025.

Local authorities, together with the network operator, take care of the planning, installation and maintenance of ALAN. They are often also the first line contact point for questions or complaints from the public and businesses. The local police districts are on their turn responsible for maintaining order, but are also involved in (burglary) prevention, reducing crime, monitoring traffic safety, environmental offences and so on. So they too have valid information about light pollution ior specific (knowledge) needs.

The stakeholder survey consisted of 2 parts:

In phase 1, a large-scale online survey was distributed to all Flemish local authorities and police districts with the aim of getting as many responses as possible from various angles/departments. Within the same administration, ALAN is dealt with from different disciplines such as environment and climate, spatial planning, mobility, public domain and green management. But equally the technical department and departments responsible for sports, welfare and culture, youth, seniors, heritage and buildings sometimes (unwittingly) come into contact with public lighting. Within the police districts, too, there are various entities that deal with ALAN. Therefore, the survey was sent out very widely including to politicians and councilors.

The survey covered the following topics: policy, knowledge and information, regulations and control and data (on e.g. complaints or violations). For 1 month, the +/- 1,500 contacts who were contacted could share their knowledge on light pollution and the relevant regulations, indicate which lighting programs they use and so on.

In phase 2, we then set up a set of roundtable discussions with local authorities and other stakeholders such as policy officers of regional authorities, nature organizations or network managers. In doing so, we went deeper into certain questions or themes from the survey. These sessions also provided interaction between participants from different backgrounds and allowed them to see what is concerning other departments in lighting projects. As a result, participants gained a better understanding of each other's point of view and priorities.

At the time of submitting this abstract, we couldn’t yet anticipate on the conclusions of the stakeholder survey. These will only be available from September 2025 onwards. Regardless, this study will provide the Department of Environment and other organizations with good insights. The information obtained will help determine policy priorities, the deployment of resources and the drawing up of a list of light pollution actions, e.g. the development of a framework that helps weigh up the various interests against each other.

The policy action plan on light pollution and the supporting instruments drawn up by the Department of Environment and future versions of the inspiration guide will thus be much better tailored to the specific needs of the target groups. As a result, the theme of light will have a better place within all these organizations and there will be a visible improvement in lighting and tackling light pollution.

During our presentation, we will mainly explain the results of this stakeholder survey. In doing so, we want to focus on the policy recommendations and priorities that emerged from it. These results are obviously instructive for Flanders, but they are also useful within an international context for other, densely populated regions.

Finally, we show how we will work with these results, what steps the Flemish government will take next and what the expected results of this will be.

References

A De Decker, I Wolters, I Gabaret, L De Prins, E Den Hond (2023). Artificiële nachtelijke buitenverlichting en verbanden met fysieke en mentale gezondheid. Rapport literatuurstudie. Provinciaal Instituut voor Hygiëne (PIH), 2023

D Dekeukeleire, R Gyselings, L De Bruyn (2023). Effecten van nachtelijke verlichting op biodiversiteit. Een literatuurstudie voor beleidsondersteuning. Rapporten van het Instituut voor Natuur- en Bosonderzoek (INBO), 2023 (32). DOI: http://doi.org/10.21436/inbor.96637982

https://omgeving.vlaanderen.be/nl/vlaams-actieplan-wilde-bestuivers

https://ec.europa.eu/commission/presscorner/detail/nl/ip_23_281

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2023%3A35%3AFIN&qid=1674555285177

Mitigating obtrusive light on the night sky in regional areas.

Theme: Measurement and Modelling

M. Chapman[1*]

[1] *Sydney Outdoor Lighting Improvement Society, Sydney, Australia*
Mbc1961@gmail.com
[*] *presenting author*

Introduction

The recent programs to convert street lighting from the technologies of high intensity discharge lamps to light emitting diodes has seen a rush for local governments to reduce power consumption costs and carbon footprints. These programs driven by a direct involvement of government by way of funding programs based on carbon emissions. An outcome of these programs has seen a division in the community between astronomers, professional and amateur with the lighting industry, as well as division within the lighting community. The issues at conflict: the use of high correlated colour temperature, adequate colour rendering, ground uniformity, visual comfort, and visibility. Many jurisdictions in many countries regulate the issues in conflict with standards often based on CIE standards such as CIE-150 Obtrusive Lighting and may be supplemented with additional controls. This standard has application in individual and specific situations but is not able to be applied to wide scale situations such as the total effect of a town or city.

The impact of light pollution from a town or city can only be assessed either after the lighting is installed. Here an approach to modelling presents using a modelling package called Illumina. A using regional town of New South Wales, Australia selected as a case study. This town with a current population 50,000 people will become a town of 100,000 people. The impact of this in increased lighting will be significant. This study presents the results of modelling this town using various street lighting technologies and discusses the impact on the night sky and mitigation strategies that would limit impact on rural night skies.

Methods

Using the Illumina software package two models of town are presented. The town is modelled as it currently exists with a population of 50,000 people and it's existing luminaire fleet. The second model of the town uses a proposed population of 100,000 people and replacing the luminaire fleet with narrow band full cut-off amber spectrum luminaires..

Conclusions

The results show that despite employing good lighting techniques light pollution is still a major factor in deteriorating condition of the night. It also emphasises the need to deploy modelling techniques to assess area lighting techniques to establish a baseline for final ground measurements of a completed lighting solution.

References

Aubé, M.A.R.T.I.N., 2007, April. Light pollution modeling and detection in a heterogeneous environment. In *Proceedings of Starlight 2007 conference, La Palma, Spain*.

Spatiotemporal dynamics of insect phototaxis under artificial light at night

Theme: Biology and Ecology

Gabriel A. Charvalakis [1,2,*], Doekele G. Stavenga [2], Marcel E. Visser [1,2], Nina van Boxem[1], Kamiel Spoelstra[1] and Roelof A. Hut[2]

[1] *Department of Animal Ecology, Netherlands Institute of Ecology (NIOO-KNAW), Netherlands*

[2] *Groningen Institute for Evolutionary Life Sciences, University of Groningen, Netherlands*

Corresponding author: G.Charvalakis@nioo.knaw.nl

**Presenting author*

Introduction

Artificial illumination at night is an anthropogenic disturbance which severely impacts our societies and ecosystems. Nocturnal insects are crucial ecosystem service providers, and their fitness can be greatly affected by anthropogenic light at night, among others via positive phototaxis. The rising popularity and efficiency of light emission diode (LED) lighting technology accentuate the need to understand how both spectrum and intensity affect insect behaviour, especially when building spectral tuneable lighting systems to mitigate the impact of light pollution.

The degree of phototaxis may vary greatly with taxon, light intensity and colour but also in night-time. Interestingly, how the phototaxis of different taxa is temporally distributed over the night remains largely uncharted. A better understanding of when and which light colours affect insect phototactic patterns is essential when building tuneable time-scheduled lighting systems to temporally mitigate the impact of light pollution.

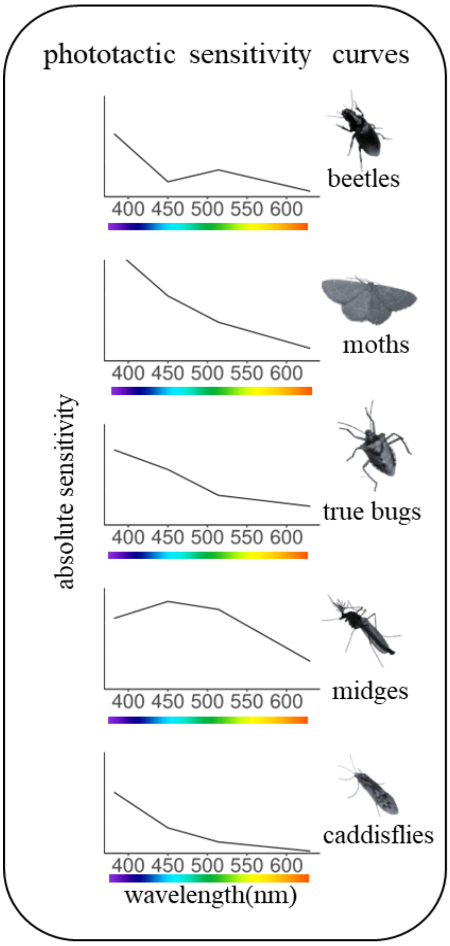


Fig. 1: *Absolute sensitivity curves per insect order plotted over spectral wavelength.*

Methods

Phototactic responses of different taxa to LED spectrum and intensity

In this field study the LED traps emitted light at four narrowband wavelengths of three intensity levels of equal photon emission (per level) using custom LED light traps. We sampled insects over eleven nights at two locations in natural forested areas in the Netherlands.

Temporal patterns of attraction to LED spectra

In a second study we investigated the interaction between narrowband light colours and the time of attraction of different nocturnal insect taxa. We developed camera-light-traps fitted with calibrated monochromatic LED lights and monitored the phototactic arrival time of insects over twelve nights in forested areas in the Netherlands.

Results

By applying a range of light intensities and colour, we established taxon-specific sensitivity curves (**Fig. 1**). Our data from both field studies show an interaction between insect order and narrowband spectra, with marked differences in attraction between Lepidoptera(moths) and Diptera(midges). Phototactic responses peaked in the early to-middle parts of the night. However, the timing of the phototactic peak varied across different taxonomic groups, with dipteran midges exhibiting phototactic peaks earlier in the night in comparison to moth species.

Conclusions

Attraction of insects to artificial light at night is clearly strongest for short wavelengths of high intensity, and around the midpoint of the night. Hence, reduction of impact of light on insects can potentially be best achieved by using narrowband long wavelength, low intense light and ceasing or lowering light emissions in the early-mid parts of the night.

Understanding Public Preferences for Light and Darkness in Aotearoa New Zealand

Theme: Social Sciences & Humanities

Ellen Cieraad,[1,2,*] Jeff Dalley [2]

[1] Nelson-Marlborough Institute of Technology, Nelson, New Zealand
[2] Department of Conservation, New Zealand
ellen.cieraad@nmit.ac.nz
[*] presenting author

Introduction

While serving many useful functions, anthropogenic light at night (ALAN) also leads to the erosion of natural darkness, and of the various benefits that exposure to darkness provides. The emission of night-time light well above natural levels is resulting in negative impacts for human health and wellbeing, the physiology and behaviour of plants and animals around us, astronomical research, and personal and cultural connections with the night sky.

Despite all the benefits lights can provide (including road and personal safety, orientation recreation and many more), we know little about how people perceive light at night - where they want it, why, and when they prefer darkness. Existing social studies have focussed mainly on light as pollution, which can bias responses and overlook its benefits.

Using a representative population survey, we assessed New Zealanders' self-declared importance of different benefits derived from ALAN and from natural darkness, and determined to what extent this is driven by background variables. We then assessed what people felt was the most appropriate mode of delivery for a subset of lighting purposes (i.e. always on at night, on-when-needed (using sensors), or bring-your-own).

Methods

We purposefully designed a quantitative survey instrument to capture both the benefits of light and darkness, as well as the attitudes towards those, and not to frame questions using phrases such as 'light pollution'. Recruitment of the 1000 participants was through an online panel, and had quota based on region, sex, and age, which were based on the 2018 New Zealand census.

For each benefit derived from light and darkness at night, we fitted a conditional inference tree (further referred to as 'tree'), with demographic, dark-sky related and context-related as explanatory variables. Our response variable was a 5-point unipolar ordinal rating scale, ranging from 'not at all important' to 'extremely important' for each benefit. We used a similar approach to model the appropriateness of delivery type of light for a subset of light benefits. We used ordinal weights Scott's π metric to evaluate the classification performance while accounting for the ordinal nature of the importance rating, imbalance in the number of respondents in each class and heterogeneous performance across classes.

Results

Benefits derived from light at night were generally rated as more important than those derived from darkness, especially for safety functions and orientation. Darkness benefits rated lower overall, and showed less variability.

Trees for all benefits derived from darkness consistently explained the variability in responses fairly well, and contained two top explanatory variables: Frequency of gazing up to the night sky and agreement with the statement 'Darkness enhances human wellbeing'. Trees for benefits of light at night performed less well, and contained more variables. For all benefits, except for Advertising, respondents living further away from the city rated the importance of light lower; and an increased positive association with light (e.g. agreement with statements such as 'light at night is associated with a prosperous economy') was related with an increased importance score of the benefits. Many other demographic variables were also included in different trees.

The proportion of respondents who felt 'permanently lit at night' was the most appropriate delivery mode was dependent on the function, varying from highest ratings of 64% for Traffic safety to 27% for Recreation. There was strong support for lights that were only on when needed (e.g. using sensors), ranging from 31% for Traffic safety to 58% for Recreation, and intermediate values for Personal safety and Orientation. Trees explained the associations of these delivery modes poorly.

Conclusions

This study reports a nationally representative study exploring public perceptions of both light and darkness at night – the first of its kind in Aotearoa New Zealand, and possibly globally. We contribute to reframing the discourse around ALAN to consider both light and dark as essential resources. Our results provide a foundation upon which we can build to develop policy focussing on context-specific trade-offs between benefits of light and darkness and implementation of principles of sustainable lighting.

Perceiving cultural heritage in the dark

Theme: Technology and design

Julieta Cignacco,[1,*] Mette Hvass,[2] and Georgios Triantafyllidis[3]

[1] Aalborg University, Copenhagen, Denmark
juci@create.aau.dk
[2] Aalborg University, Copenhagen, Denmark
mh@create.aau.dk
[3] Aalborg University, Copenhagen, Denmark
gt@create.aau.dk
[*] presenting author

Introduction

Since January 2025, the Art of Darkness as Cultural Heritage of Urban Landscape project (AoD) has been funded under Horizon Europe, the EU's research and innovation framework programme. This initiative seeks to redefine the role of darkness in urban landscapes and cultural heritage, with the objective of preserving and developing cultural heritage sites. Integrating the principles of the New European Bauhaus (NEB), the project explores darkness' value as an essential element of urban spaces (EU Funding & Tenders Portal, n.d.).

Figure 1: Copenhagen inner city at night. Self-produced photo.

Within this context, an examination of Copenhagen's nighttime environment and its lighting's masterplan revealed that, compared to other cities, it is relatively dark (Københavns Kommune, 2014). This impression is likely to give Copenhagen a more distinctive context and a unique expression through lighting. It suggests that darkness is a valued resource that needs to be understood and embraced, rather than something to compete against.

Research in lighting design has increasingly shifted towards luminance-based metrics to assess lighting perception (Hvass, et. al, 2021). Sensory experience can be then comprehended through the performance of luminance studies. Luminance is the most representative photometric measurement of the brightness perceived when a set of illuminated objects are observed (Valetti et al., 2021). Luminance studies, therefore, provides a deeper understanding of the relationship between quantitative data and the qualitative experience of how a space is endured.

What would happen if we could somehow systematize luminance metrics? Would that make the incorporation of darkness in our design easier? How can lighting design harmonize with night scene of cultural heritage landscapes, ensuring inclusion, aesthetics and sustainability?

Methods

This article builds on after a literature study, which explored the connections between darkness, cultural heritage and lighting design.

Conclusions

The literature study provides a deep understanding of luminance ratios as the methodology to consider for lighting design in cultural heritage sites. This approach ensures that lighting is suitable for city residents and their visual sensory experience of the place. It also considers darkness and its values for both people and the environment.

The study invites for a re-examination of how we illuminate cities at night, especially referring to cultural heritage landscapes. Luminance ratio study is suggested as a parameter to identify the best gradients of light to be used within a dark environment. This could potentially facilitate the iteration of lighting proposals and lighting scenarios, when designing with software.

References

EU Funding & Tenders Portal. (n.d.).

https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/projects-details/43108390/101177779/HORIZON

Hvass, M., Wymelenberg, K. V. D., Boring, S. & Hansen, E. K. (2021). Intensity and ratios of light affecting perception of space, co-presence and surrounding context, a lab experiment. Building and Environment 194 107680.

Københavns Kommune, Teknik- og Miljøudvalget (2014). Belysningsmasterplan København.

https://www.kk.dk/

Valetti, L., Floris, F., & Pellegrino, A. (2021). Renovation of public lighting systems in cultural landscapes: lighting and energy performance and their impact on nightscapes. Energies, 14(2), 509. https://doi.org/10.3390/en14020509

Mitigating Satellite Light Pollution with Vantablack Coatings: A Collaborative Approach to Protecting Astronomy

Theme: Technology and Design

Keiran Clifford [1,*], Astha Astha [2], James Whitfield [1], Noelia Noel [2]

[1] Surrey Nanosystems Ltd, Newhaven, United Kingdom
[2] University of Surrey, Guildford, United Kingdom
** k.clifford@surreynanosystems.com*

The rapid expansion of low Earth orbit (LEO) satellite mega-constellations, such as Starlink and OneWeb, has transformed global connectivity but poses a growing challenge to ground-based optical astronomy (Lawrence et al. 2022; Witze 2025). Satellite reflections disrupt imaging pipelines, degrade signal-to-noise ratios, and compromise the scientific output of major observatories, including the Vera C. Rubin Observatory, which is expected to detect satellite trails in a significant fraction of its wide-field observations (Hu et al. 2022). Additionally, small space objects (ranging from millimetres to metres in size) contribute approximately 10% to the natural sky brightness, while planned mega-constellations are projected to increase sky brightness by up to 1% in the worst-affected regions through discrete contamination (Tyson et al. 2020).

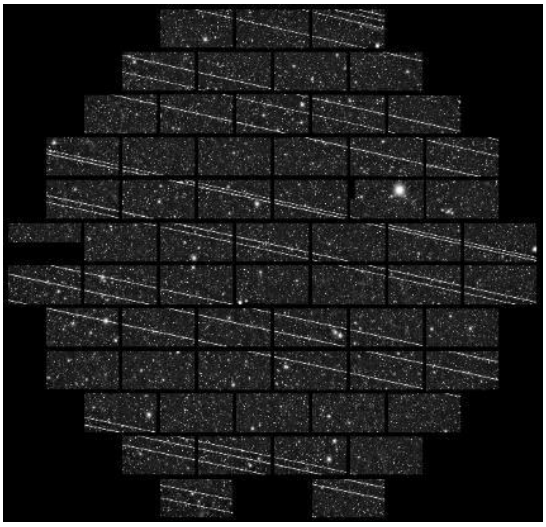


Fig. 1: Starlink trails detected by the Dark Energy Survey camera in 2019. Credit: CTIO/NOIRLab/NSF/AURA/DECam DELVE Survey. Licensed under CC BY 4.0.

With thousands more satellites planned for launch over the next decade, the urgency to develop effective mitigation strategies is growing. In this context, we present an interdisciplinary collaboration between astronomers and space engineers at the University of Surrey, and materials scientists at Surrey Nanosystems, aimed at reducing the optical brightness of satellites through novel surface treatments. We report on the qualification of Vantablack® 310, a low-reflectance, space-grade coating, for application on a student-led satellite mission. The coating has been engineered to withstand the harsh conditions of LEO while significantly reducing visual signatures across a range of viewing angles.

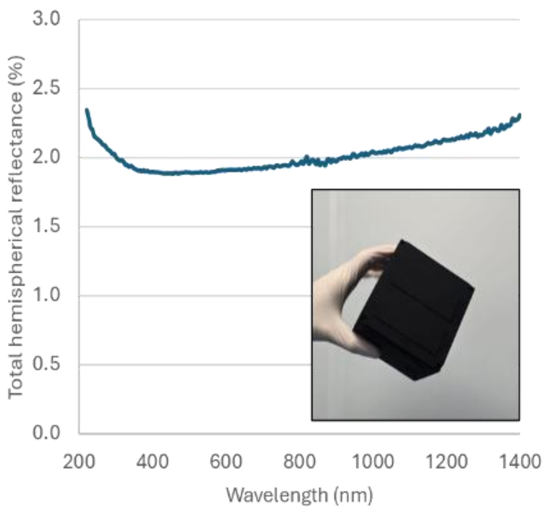


Fig. 2: Total hemispherical reflectance profile of Vantablack® 310. Inset: the coating applied to 1U cubesat model.

This study represents a key step toward the sustainable use of orbital space and the preservation of the night sky as a shared scientific and cultural resource. We discuss the expected impact on satellite photometric profiles, its potential integration into standard satellite design, and the broader implications for astronomy–satellite coordination frameworks. By addressing the increasing threat of satellite interference, this work contributes to harmonizing the benefits of global connectivity with the protection of astronomical research and the natural night sky.

References

Hu, Jinghan Alina, Meredith L. Rawls, Peter Yoachim, and Željko Ivezić. 2022. 'Satellite Constellation Avoidance with the Rubin Observatory Legacy Survey of Space and Time'. *The Astrophysical Journal Letters* 941(1): L15. doi:10.3847/2041-8213/aca592.

Lawrence, Andy, Meredith L. Rawls, Moriba Jah, Aaron Boley, Federico Di Vruno, Simon Garrington, Michael Kramer, et al. 2022. 'The Case for Space Environmentalism'. *Nature Astronomy* 6(4): 428–35. doi:10.1038/s41550-022-01655-6.

Tyson, J. Anthony, Željko Ivezić, Andrew Bradshaw, Meredith L. Rawls, Bo Xin, Peter Yoachim, John Parejko, et al. 2020. 'Mitigation of LEO Satellite Brightness and Trail Effects on the Rubin Observatory LSST'. *The Astronomical Journal* 160(5): 226. doi:10.3847/1538-3881/abba3e.

Witze, Alexandra. 2025. 'Swarms of Satellites Are Harming Astronomy. Here's How Researchers Are Fighting Back'. *Nature* 639(8055): 564–66. doi:10.1038/d41586-025-00792-y.

Evaluating the effect of artificial light at night (ALAN) on predation risk in an urban lake

Theme: Biology and Ecology

Tessa J Code[1,*] and David A Beauchamp[1]

[1] *University of Washington, Seattle, WA, USA*
tcode@uw.edu
[*] *presenting author*

Introduction

Daily and seasonal light-dark cycles are important cues for ecological processes and species interactions. Artificial light at night (ALAN) disrupts natural light cycles by extending twilight, increasing nocturnal light levels, and blurring lunar cycles. Since the mid-20th century, ALAN increased an average 6% per year ranging 0-20% depending on region (Hölker et al., 2010). ALAN threatens salmon populations by disrupting migration (Tabor et al., 2004), behavior, and increasing predation mortality (Clark, 2017; Mazur & Beauchamp, 2006; Tabor et al., 2004, 2017). Salmon predators are primarily visual foragers that exhibit peak predation during twilight periods (Beauchamp et al., 1999; Mazur & Beauchamp, 2006). ALAN extends the duration and depth of these low light conditions (Mazur & Beauchamp, 2006), increasing the susceptibility of juvenile salmon to predation and potentially influencing survivorship.

Lake Washington, a large natural lake adjacent to Seattle, WA, USA, is heavily urbanized with a dwindling population of sockeye salmon (*Oncorhynchus nerka*) and threatened Chinook salmon (*O. tshawytscha*). Both initially occupy nearshore and then migrate offshore for pelagic rearing for multiple months before migrating to the sea. While rearing, salmon diel-vertically migrate, feeding at shallow depths during low-light periods while minimizing predation risk (Scheuerell & Schindler, 2003). Cutthroat trout (*O. clarkii*), a major pelagic predator of the juvenile salmon, improve foraging ability exponentially with slight increases in ambient light during twilight (Beauchamp et al., 1999; Mazur & Beauchamp, 2006). ALAN increases light through the water column and artificially extends twilight, dramatically increasing times and depths of highly effective visual predation on juvenile salmon in urbanized watersheds (Mazur & Beauchamp, 2006; Tabor et al., 2004, 2017).

In the Seattle area, a shift in LED streetlighting, increased urban development and the use of more artificial lighting by residential and commercial sources, have amplified the influence of both direct lighting and skyglow (anthropogenic light scattered and reflected by the atmosphere and clouds) and increased predation risk for juvenile salmon. Determining the relationship between ALAN, predation risk, and juvenile salmon behavior, can guide actions to increase salmon survival by reducing anthropogenic pressure in urban freshwater systems.

Methods

ALAN intensity by light spectra was quantified using a Compact Optical Profiling System (C-OPS, Biospherical Instruments, San Diego, CA) spectroradiometer surface and profiling unit which measures light at 18 wavelengths and broadband PAR (photosynthetically active radiation, 400-700nm). We measured the spatial variability of ALAN intensity under completely clear and cloudy skies. Vertical profiles of light attenuation were obtained seasonally, to capture changes to light attenuation rates due to water condition. Ambient light measurements by depth were converted to predator ability using previously published visual foraging models (Hansen et al., 2013). Depth distribution of salmon was converted to visual prey encounter rates using results from in-situ hydroacoustic surveys and depth discrete mid-water trawling. Stationary hydroacoustic data were used to assess depth responses of the fish community to ambient light levels from the lunar cycle and skyglow through spring and summer.

Conclusions

Artificial light at night is an added stressor for salmon in an urban environment. ALAN is spatially variable throughout urban systems, creating a patchwork of predation risk that fluctuates with weather conditions. Increasing temperatures due to climate change condense native predators and juvenile salmon into similar depths, increasing likelihood of encounter. Planktivores are forced to occupy waters with higher predation risk presumably to maintain sufficient feeding and growth rates. Additionally, warmer waters increase activity and metabolic capacity of warm water invasive predators, elevating the threat of predation in shallower depths. Reducing efficiency of predators by decreasing the light environment are the main goals of this work. Approaches will need to include decreasing light intensity of direct lights during periods of outmigration, to lessen brightness in the shallow migratory pathway from fresh to saltwater. Incentives to reduce lighting must be regional, as skyglow has a much larger impact in the pelagic area due to its diffuse qualities and regional sources. Strategic light reduction can increase salmon survivorship in urban waterways.

References

Beauchamp, D. A., Baldwin, C. M., Vogel, J. L., & Gubala, C. P. (1999). Estimating diel, depth-specific foraging opportunities with a visual encounter rate model for pelagic piscivores. *Canadian Journal of Fisheries and Aquatic Sciences*, *56*, 128–139.

Clark, C. P. (2017). *Quantifying the impact of two native predators on juvenile sockeye salmon survival in Lake Washington* [M.S. Thesis].

Hansen, A. G., Beauchamp, D. A., & Schoen, E. R. (2013). Visual Prey Detection Responses of Piscivorous Trout and Salmon: Effects of Light, Turbidity, and Prey Size. *Transactions of the American Fisheries Society*, *142*(3), 854–867. https://doi.org/10.1080/00028487.2013.785978

Hölker, F., Moss, T., Griefahn, B., Kloas, W., Voigt, C. C., Henckel, D., Hänel, A., Kappeler, P. M., Völker, S., Schwope, A., Franke, S., Uhrlandt, D., Fischer, J., Klenke, R., Wolter, C., & Tockner, K. (2010). The Dark Side of Light: A Transdisciplinary Research Agenda for Light Pollution Policy. *Ecology and Society*, *15*(4), art13. https://doi.org/10.5751/ES-03685-150413

Mazur, M. M., & Beauchamp, D. A. (2006). Linking piscivory to spatial–temporal distributions of pelagic prey fishes with a visual foraging model. *Journal of Fish Biology*, *69*(1), 151–175. https://doi.org/10.1111/j.1095-8649.2006.01075.x

Scheuerell, M. D., & Schindler, D. E. (2003). Diel Vertical Migration by Juvenile Sockeye Salmon: Empirical Evidence for the Antipredation Window. *Ecology*, *84*(7), 1713–1720. https://doi.org/10.1890/0012-9658(2003)084[1713:DVMBJS]2.0.CO;2

Tabor, R. A., Bell, A. T. C., Lantz, D. W., Gregersen, C. N., Berge, H. B., & Hawkins, D. K. (2017). Phototaxic Behavior of Subyearling Salmonids in the Nearshore Area of Two Urban Lakes in Western Washington State. *Transactions of the American Fisheries Society*, *146*(4), 753–761. https://doi.org/10.1080/00028487.2017.1305988

Tabor, R. A., Brown, G. S., & Luiting, V. T. (2004). The Effect of Light Intensity on Sockeye Salmon Fry Migratory Behavior and Predation by Cottids in the Cedar River, Washington. *North American Journal of Fisheries Management*, *24*(1), 128–145. https://doi.org/10.1577/M02-095

Skyglow facilitates prey detection in a crepuscular insectivore: distant light sources create bright skies

Theme: Biology & Ecology

J. Creemers,[1,2,*] M. Eens,[2] E. Ulenaers,[3] M. Lathouwers,[4,5] R. Evens[1,2]

[1] Université Catholique de Louvain (UCL), 1384, Louvain-la-Neuve, Belgium
[2] University of Antwerp, B-2610, Wilrijk, Belgium
[3] Agentschap Natuur en Bos, Regio Noord-Limburg, 1000, Brussels, Belgium
[4] Hasselt University, 3590, Diepenbeek, Belgium
[5] University of Namur, 5000, Namur, Belgium
jitse.creemers@uclouvain.be
[*] presenting author

Introduction

Light profoundly shapes ecosystems, influencing the behaviour and niche specialisation of many species. This is especially true for visual predators, particularly crepuscular and nocturnal animals, to which adequate illumination is essential for foraging. Despite this, how these animals perceive and respond to different light sources remains poorly understood[1].

In this study, we investigate light perception in the European Nightjar (*Caprimulgus europaeus*, hereafter nightjar), a crepuscular insectivore that depends on light to discern flying insects as dark objects against a brighter background. Previous studies show that nightjar activity increases with both moonlight[2] and artificial skyglow[3], suggesting these birds may use multiple light sources to enhance prey detection.

The observed activity patterns in response to lunar- and skyglow-mediated sky brightness, along with nightjars' light-dependent foraging strategies, raise the question how nightjars may use different sources of sky brightness for prey detection during foraging.

Method

Foraging events were identified from acceleration data by detecting a distinct leaping behaviour characteristic of nightjar prey capture. We used a modified dead-reckoning approach[4], integrating GPS, accelerometer, and magnetometer data, to reconstruct body orientation and estimate the birds' line of sight during these events. This was then compared to the positions of the moon and artificial skyglow, derived from moonlight models and VIIRS satellite data, respectively. To assess the brightness of these light sources, we used moon altitude and cloud cover as proxies. This allowed us to examine the conditions under which nightjars orient towards natural versus artificial light to enhance prey detection during foraging.

Conclusions

Nightjars tended to align with brighter parts of the sky, though not always the brightest. On full moon nights, they positioned the moon within their line of sight when it was low on the horizon, but this decreased as it rose. During other phases, alignment with the moon increased with its altitude. In moonless periods, nightjars appeared to use sufficiently bright skyglow as a background for prey detection, showing a preference for moonlight when both were present.

These findings suggest that European Nightjars use illuminated sky sections, including artificial skyglow, to enhance visual prey detection. In the absence of moonlight, they may actively exploit light pollution for foraging. However, the effectiveness of skyglow as a visual aid likely depends on its brightness and spectral composition. Further research is needed to clarify how contrast detection functions under different light conditions.

References

[1] Stöckl A.L., Foster, J.J. (2022). Night skies through animals' eyes – quantifying night-time visual scenes and light pollution as viewed by animals. *Front. Cell. Neurosci.,* 16, 984282.

[2] Evens R., Kawalczyk C., Norevik G., Ulenaers E., Davaasuren B., Bayargur S., Artois T., Åkesson S., Hedenström A., Liechti F., Valcu M., Kempenaers B. (2020). Lunar synchronization of daily activity patterns in a crepuscular avian insectivore. *Ecol. Evol.,* 10(14), 7106-7116.

[3] Evens R., Lathouwers M., Pradervand J.N., Jechow A., Kyba C.C.M., Shatwell T., Jacot A., Ulenaers E., Kempenaers B., Eens M. (2023). Skyglow relieves a crepuscular bird from visual constraints on being active. *Sci. Total Environ.* 900.

[4] Gunner R.M., Holton M.D., Scantlebury M.D., van Schalwyk O.L., English H.M., Williams H.J., Hopkins P., Quintana F., Goméz-Laich A., Börger L., Redcliffe J., Yoda K., Yamamoto T., Ferreira S., Govender D., Viljoen P., Bruns A., Bell S.H., Marks N.J., et al. (2021). Dead-reckoning animal movements in R: a reappraisal using Gundog.Tracks. *Animal Biotelemetry*, 9(1).

Evaluating the efficacy of wearable light loggers for monitoring the effects of blue light exposure on human health in Ireland.

Theme: Measurement and Modelling

Anna Crowley[1,2,*], Grainne Scanlon[1,2], Antonello Durante[3], Siofra Harrington[1,2], Paul Hynds[3], George Amarandei[1,2].

[1] School of Physics and Clinical and Optometric Sciences, Technological University Dublin, Grangegorman, Dublin 7, Ireland.

[2]The Group of Applied Physics, Technological University Dublin – City Campus Grangegorman

[3]SpatioTemporal Environmental Epidemiology Research (STEER), Sustainable and Health Research Hub (SHRH), Technological University Dublin, Grangegorman, Dubin 7, Ireland.

Anna.crowley@tudublin.ie
[*] *Presenting author*

Since the discovery of the intrinsically photosensitive retinal ganglion cells (ipRGCs) in 2002, a significant volume of research has shown that light exposure affects both visual and non-visual health, including impacts on the circadian rhythm and mood[1]. Notably, ipRGCs are shown to be most sensitive to light in the blue range (450-490nm)[2]. Accordingly, the recent global shift from classical lighting (using incandescent, halogen or fluorescent bulbs (Figure 1a)) to LED lighting represents a concern due to the high blue content associated with LED's (Figure 1b). This increase in blue light exposure for humans and environment requires appropriate quantification to identify and address the potential risks.

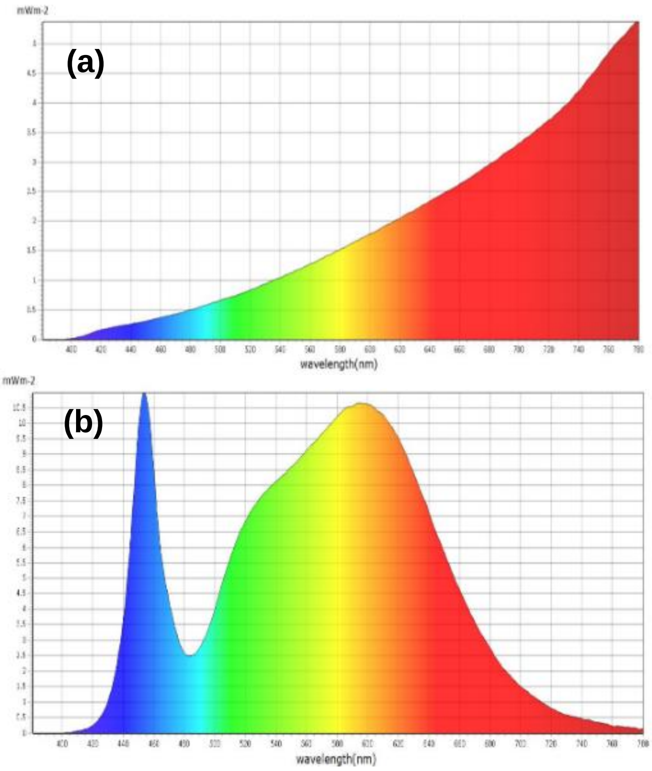


Figure 1: Typical irradiance spectrum for (a) incandescent and (b) LED bulb.

Laboratory studies evaluating light exposure in strictly controlled environments have added invaluable insights regarding the non-visual human health effects of light, but they often fail to capture light exposure under real-world conditions[3]. Where real-world exposure is measured, the use of wearable light monitors has become the most common approach. However, the various methodological protocols used, to date, are inconsistent across studies. To better understand the methodology required to evaluate the Irish populations blue light exposure baseline (BLU-RAY project), a pilot study of fourteen volunteers was conducted. Volunteers wore light loggers (LYS buttons) in concurrence with fitness watches over a 7-day collection period. The fitness watches were worn for sleep monitoring to identify if correlations could be identified between sleep quality/duration and light exposure. The light exposure data gathered from the devices were illuminance and mEDI (melanopic Equivalent Daylight Illuminance) which represents an increasingly blue light specific metric. Light exposure was delineated into 4 equal periods for analysis, namely, morning (6 am – 12 pm), afternoon (12 pm – 6 pm), evening (6 pm – 12 am) and overnight (12 am – 6 am).

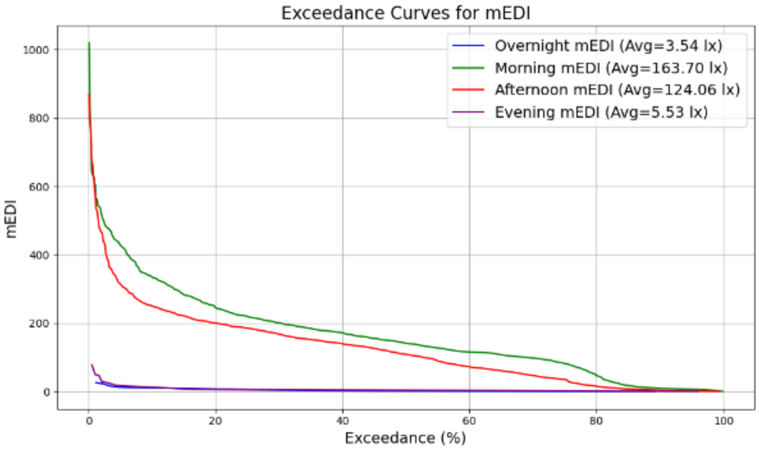


Figure 2: Light exposure duration curve.

In the first instance, a significant issue was identified which was the large exposure range and variance exhibited over short time periods. This tended to skew means to artificially high levels. For example, if a volunteer was located within a low light environment for the majority of an hour but had a brief period of direct sunlight exposure, the mean exposure was unrealistically elevated. To counteract this, a technique from hydrological modelling, flow duration curve development, was successfully employed. This technique was adapted to create light exposure duration curves or "LED curves" which express the percentage of time a particular light level is met or exceeded (Figure 3). The overall mean was then simply calculated as the integral of this curve. Utilising this method, the longer period of low light has a greater influence on the average than a short period of bright light making the resulting average more representative of the actual exposure.

Using exposure means calculated via this LED curve approach, we found that increased morning illuminance (ρ=0.552, p=0.041) and morning mEDI (ρ=0.556, p=0.039) had a positive correlation with deep sleep duration. Conversely, increased overnight illuminance (ρ=-0.623, p=0.017) and overnight mEDI (ρ=-0.573, p=0.032) were negatively correlated to REM sleep duration. This negative correlation is concerning as ALAN levels continue to rise both indoors and outdoors. Our results also mirror recent studies, that used controlled lighting methodologies, showing using daily exposure studies can have similar results.

The second identified issue in this study was the consistency of the data gathered from the wearable light loggers. Thus, the reliability and validity of light sensors requires significant further study, validation and standard protocol development.

Presently, the BLU-RAY team is undertaking a controlled validation study, with devices being evaluated in dark room conditions using state of the art spectrometers and calibrated lamps for both indoor and outdoor lighting conditions.

References

1. Blume, C., Garbazza, C. & Spitschan, M. Effects of light on human circadian rhythms, sleep and mood. Somnologie 23, 147–156 (2019). https://doi.org/10.1007/s11818-019-00215-x
2. S. Hattar et al. ,Melanopsin-Containing Retinal Ganglion Cells: Architecture, Projections, and Intrinsic Photosensitivity.Science295,1065-1070(2002).DOI:10.1126/science.1069609
3. Manuel Spitschan, Johannes Zauner, Maria Nilsson Tengelin, Constantinos A. Bouroussis, Patrik Caspar, Fabien Eloi, Illuminating the future of wearable light metrology: Overview of the MeLiDos Project, Measurement, Volume 235, 2024, 114909,ISSN 0263-2241, https://doi.org/10.1016/j.measurement.2024.114909

How the erosion of natural darkness affects tree-covered urban areas worldwide

Theme: Measurement and Modeling

Stefania Cupillari[1,*] Costanza Borghi,[2,3] Saverio Francini[4], Stefano Mancuso[2], Gherardo Chirici[2,3], Giuseppe De Luca[1]

[1] University of Florence, Department of Architecture, Florence, Italy
[2] University of Florence, Department of Agriculture, Food, Environment and Forestry, Florence, Italy
[3] Fondazione per il Futuro delle Città, Florence, Italy
[4] University of Bologna, Department of Agri-Food Science and Technology, Bologna, Italy

stefania.cupillari@unifi.it
[*] presenting author

Light pollution significantly impacts urban green areas, affecting both the environment and people who rely on these areas for recreation and nature connection. The G20 summit 2021 proposed planting 1 trillion trees by 2030 to restore nature in future cities, emphasizing the multipurpose role of urban forests in carbon absorption, biodiversity conservation, heat island reduction, and water cycle regulation (Francini et al. 2024). However, artificial light at night (ALAN) disrupts urban green areas globally, negatively impacting ecological processes crucial for tree health and growth (Lian et al. 2021). Not only ALAN interferes with natural cycles of trees, thus altering carbon sequestration processes (Lo Piccolo et al. 2023, Meng et al. 2022) and increasing their vulnerability to stressors (Wei et al. 2023, Bará et al. 2023), but it also disrupts nocturnal pollination networks and reduces biodiversity. Nevertheless, public illumination affects perceived safety, walkability, and inclusivity of spaces, even with gender-related differences (Rahm et al. 2021), highlighting the complex balance between the ecological and the social perspectives. While the state of the art in research on light pollution's effects on plant physiology and phenology is well-documented (Friulla et al. 2025), research is still limited compared to studies on its impact on humans and wildlife, highlighting the need for further studies across urban, suburban, and natural environments (Bennie et al. 2016). This work explores the pivotal role of remote sensing technologies in monitoring the global impacts of ALAN on urban green areas, integrating satellite-based light pollution radiance (obtained through the Visible Infrared Imaging Radiometer Suite NASA's satellite mission) and the use of night-time light images for mapping hotspots in urban green spaces at the global level. The multidisciplinary approach aimed at supporting global urban planning of resilient green infrastructures, also suggesting future analysis to explore correlations with ecological factors like carbon absorption, plant health, and resilience to disturbances.

Methods

This study involved several steps to identify cities, focus on tree-covered areas, and quantify light pollution in urban green areas. First, a 500m resolution map was created to identify cities, considering areas with at least 20% of urban classification by the Copernicus Global Human Settlement Layer. Second, cities smaller than 10 pixels (2.5 km²) were excluded, and non-city gaps within cities were reclassified. Third, tree-covered areas were identified using the ESA World Cover dataset. Next, to quantify light pollution, a time series from 2013 to 2023 was analysed, applying linear regression to assess trends in light intensity for each pixel. Finally, the trend's reliability was assessed using p-values and the Pearson correlation coefficient.

Results

Preliminary results show that the average trend (i.e., the slopes of the linear regression), is growing globally in the studied period (0.103), with the biggest increasing trend in the Asian continent (0.206), led by Western Asia region (Fig. 1). The opposite trend was observed for the European continent (-0.104), where Southern Europe region registered the largest decreasing trend in light pollution (-0.378), especially in smaller states. In detail, at the country level, the top five increases are recorded in Finland, Iraq, Kwait, Norway and Bahrain (from highest to lowest). On the opposite, the five countries recording the largest decrease are – in order – Holy See, Iceland, Turkmenistan, Yemen and Macao. Overall, half of the investigated countries reported a trend above the global average value.

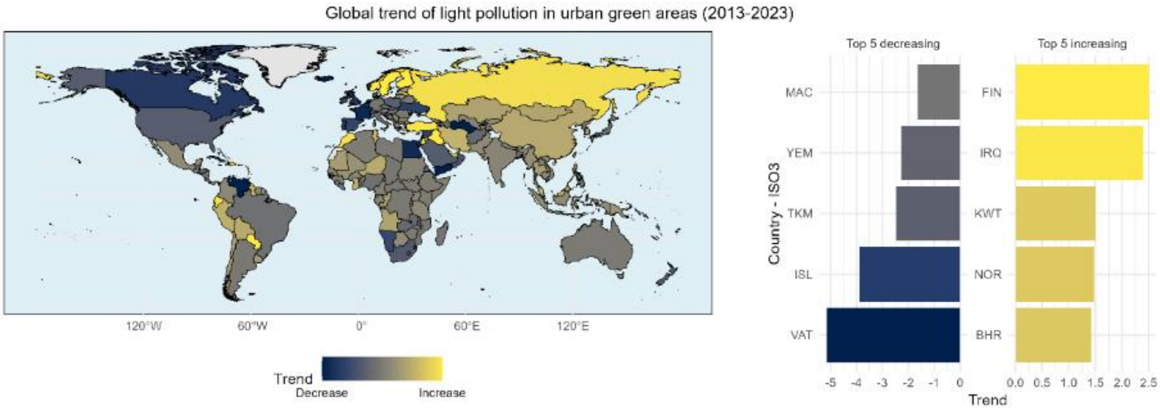


Fig. 1 Global trend of light pollution in urban green areas (2013-2023).

References

Francini, S., Chirici, G., Chiesi, L. et al. (2024) Global spatial assessment of potential for new peri-urban forests to combat climate change. Nat Cities 1, 286–294

Xihong Lian, Limin Jiao, Jing Zhong, Qiqi Jia, Jiafeng Liu, Zejin Liu, (2021) Artificial light pollution inhibits plant phenology advance induced by climate warming, Environmental Pollution, Volume 291, 2021, 118110, ISSN 0269-7491.

Rahm, J., Sternudd, C. & Johansson, M. (2021) "In the evening, I don't walk in the park": The interplay between street lighting and greenery in perceived safety. Urban Des Int 26, 42–52

Gaston, K.J., Davies, T.W., Bennie, J. and Hopkins, J. (2012), REVIEW: Reducing the ecological consequences of night-time light pollution: options and developments. J Appl Ecol, 49: 1256-1266.

Luisa Friulla, Laura Varone (2025) Artificial Light at Night (ALAN) as an Emerging Urban Stressor for Tree Phenology and Physiology: A Review, Urban Science, 10.3390/urbansci9010014, 9, 1, (14), .

E. Lo Piccolo, G. Lauria, L. Guidi, D. Remorini, R. Massai, M. Landi (2023) Shedding light on the effects of LED streetlamps on trees in urban areas: Friends or foes?, Science of The Total Environment, Volume 865, 161200, ISSN 0048-9697.

Lin Meng, Yuyu Zhou, Miguel O Román, Eleanor C Stokes, Zhuosen Wang, Ghassem R Asrar, Jiafu Mao, Andrew D Richardson, Lianhong Gu, Yiming Wang (2022) Artificial light at night: an underappreciated effect on phenology of deciduous woody plants, PNAS Nexus, Volume 1, Issue 2, pgac046.

Wei Y, Li Z, Zhang J and Hu D (2023) Effects of artificial light at night and drought on the photosynthesis and physiological traits of two urban plants. Front. Plant Sci. 14:1263795.

Bará Salvador and Falchi Fabio (2023) Artificial light at night: a global disruptor of the night-time environmentPhil. Trans. R. Soc. B37820220352

Bennie, J., Davies, T.W., Cruse, D. and Gaston, K.J. (2016), Ecological effects of artificial light at night on wild plants. J Ecol, 104: 611-620.

Impact of light spectrum on biota: a meta-analysis

Theme: Biology & Ecology

M. Czarnecka[1]*, M. Grubisic[2,3], F. Pilotto[4], A. Jechow[2,5], F. Hölker[2,6]
[1] *Nicolaus Copernicus University, Toruń, Poland*
[2] *Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany*
[3] *The State Office for Flood Protection and Water Management, Magdeburg, Germany*
[4] *Norwegian Institute for Nature Research, Oslo, Norway*
[5] *Brandenburg University of Applied Sciences, Brandenburg an der Havel, Germany*
[6] *Freie Universität Berlin, Berlin, Germany*
mczarn@umk.pl
* *presenting author*

Introduction

Research on the biological effects of artificial light at night (ALAN) demonstrates that widely applied light with higher correlated colour temperature (CCT) has a particularly strong and often negative effect on many organisms[(1)]. Accordingly, light with a lower CCT is believed to be less disruptive to animal physiology and behaviour. However, knowledge about spectrum-specific behavioural and physiological responses is still limited or inconsistent. Hence, there is a risk that recommendations of spectral tuning may benefit some taxa while harming others, leading to the emergence of novel ecological communities and cascading effects on ecosystem functioning. To better understand the influence of ALAN on biological processes, it is also important to recognize the relationship between illuminance level and spectral response. Therefore, we conducted a meta-analysis to investigate how different wavelengths and intensities of ALAN (here categorized by illuminance) affect animal physiology and behavior. In our analysis, we considered the response of different taxa and functional groups (nocturnal vs. diurnal species, carnivores vs. non-carnivores).

Methods

We surveyed the literature in Web of Science and Scopus for peer-reviewed papers published until 30 August 2023. We selected studies: (1) testing biological effects of ALAN on animals; (2) with a control (dark night conditions) and treatment groups exposed to ALAN with illuminance up to 180 lx; (3) providing information on applied light types and light levels; (4) containing data on means, sample size and estimation of variation. In total, 314 studies (with 4 905 effect sizes) met our inclusion criteria. For each study, we classified illuminance as low (≤ 5 lx), moderate (>5 ≤20 lx) and high (> 20 lx). As moderators, we used the following broad-spectrum (white) light types: with CCT > 3000 K (**BS cool**); 2) with CCT < 3000 K (**BS warm**); 3) with CCT > 3000 K, but also containing UV radiation (**BS_UV**). We tested the effects of ALAN on circadian physiology, reproduction and development, nocturnal activity of nocturnal and diurnal animals, foraging in nocturnal carnivores and non-carnivores, and insect abundance. The meta-analysis was conducted using IBM SPSS Statistics 29. Effect sizes were computed as standardized mean difference (Hedges g) between control and effect treatments, which we considered significant when their 95% CIs did not overlap zero.

Conclusions

The strongest response on biota was produced by BS_UV light, which contains a relatively high amount of blue light, which is known to affect the circadian clock in many species(2) and also emits light in the UV range, which may be biologically relevant(3). The impact of BS warm light on biota was higher than expected, as effects caused by BS cool and BS warm light did not differ significantly. This was a result of the strong influence of BS warm light on nocturnal rodents and diurnal birds. The effect of illuminance was largely dose-independent for the individual categories of response variables, and we found that even dim light influenced significantly both physiology and behaviour. Physiological processes were strongly affected by BS_UV and BS cool light due to disruption in circadian rhythms and suppression of melatonin levels. BS_UV light intensified the metabolic response in animals, while BS cool light increased oxidative stress and decreased reproductive success. We found no effect of different light types and levels on animal development. The behavioral response to ALAN was specific to taxa and functional groups. BS cool light and, to lesser extent, BS warm light impaired successful mating (especially in nocturnal moths, fireflies and amphibians). ALAN suppressed nocturnal activity of nocturnal species, however, bats responded to BS cool light, while rodents to all types of illumination. Nocturnal species also consistently reduced their foraging activity and consumption under ALAN. Carnivores negatively responded to BS cool light, while non-carnivores to both BS cool and BS warm light. Nocturnal activity in diurnal species (birds, lizards, and fish) was stimulated by ALAN, regardless of the type of light. Surprisingly, all types of light were equally attractive to insects increasing their abundance, even though many studies reported strong attraction to short wavelengths, especially UV radiation(3,4), and we observed their increased activity in BS cool light.

Our study shows that replacing “cool” light by illumination with a lower CCT may not always be an effective solution, because the spectra of BS warm light cover wavelengths that fall within the sensitivity range of many species. Therefore, spectral tuning may have limited capacity to reduce adverse effects of ALAN. Furthermore, there is not always one safe dose of ALAN, as dim light produces relatively high impact on biological processes. This suggests that dimming would be most appropriate for limiting high ambient light levels and the use of ALAN should be restricted to the minimum possible.

References

[1] Gaston KJ, de Miguel AS (2022) Environmental impacts of artificial light at night. Annu Rev Environ Resourc 47: 373-398

[2] Grubisic M, Haim A, Bhusal P, Dominoni DM, Gabriel KMA et al. (2019) Light pollution, circadian photoreception, and melatonin in vertebrates. Sustainability 11: 6400

[3] van Langevelde F, Ettema JA, Donners M, WallisDeVries MF, Groenendijk D (2011) Effect of spectral composition of artificial light on the attraction of moths. Biol Conserv 144: 2274–2281

[4] Brehm J, Niermann J, Jaimes Nino LM, Enseling D, Jüstel T et al. (2021). Moths are strongly attracted to ultraviolet and blue radiation. Insect Conserv Diver 14: 188–198

Introducing the Global Ocean Artificial Light at Night Network

Theme: Governance & Regulation

Thomas Davies[1,*] and Tim Smyth[2]

[1] University of Plymouth, Plymouth, UK
[2] Plymouth Marine Laboratory, Plymouth, UK
thomas.w.davies@plymouth.ac.uk
[*] presenting author

Ten years ago, we knew almost nothing about how much light pollution the oceans were exposed to, the ecological harm this caused, or whether management interventions were needed to help ecosystem recovery. After a decade of concerted research effort from ecologists, oceanographers and social scientists around the world we are beginning to answer these questions. 22% of the world's coastlines are impacted by light pollution nightly. 1.6 million kilometres squared of the worlds exclusive economic zones are exposed to biologically important light pollution to a depth of at least 10m. There have been more than two hundred documented impacts of light pollution on marine wildlife, including in the worlds most important ecosystems. Despite this, light pollution at sea remains almost completely unregulated by national and international policy.

This presentation will briefly introduce the Global Ocean Artificial Light at Night Network UN Ocean Decade programme (GOALANN, www.goalann.org). GOALANN is an international network of the world's leading experts in marine light pollution providing the science we need to better manage light emissions into the sea. Our mission is to conserve the oceans by improving knowledge and awareness of marine light pollution, its ecological and societal impacts, and management options. GOALANN brings together research professionals, NGO's and government entities to provide a central resource of expertise, projects and tools for policy makers, environmental managers, and maritime industries. We are an interdisciplinary network addressing all dimensions of the light pollution issue including the existing and new policy landscapes, stakeholder perceptions and awareness among environmental managers. We are developing novel tools to improve ALAN management in the sea, including open access datasets, interactive mapping tools and policy briefings on ALAN.

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

AquaPLAN Aquatic Pollution from Light and Anthropogenic Noise: Management of Impacts on Biodiversity

GOALANN THE GLOBAL OCEAN ARTIFICIAL LIGHT AT NIGHT NETWORK

Lights, camera, action: Unravelling zooplankton diel vertical migration under light at night

Theme: Biology & Ecology

Ashton L. Dickerson,[1,*] Andreas Jechow,[1,2] Jens Nejstgaard,[1] and Franz Hölker[1]

[1] *Leibniz-Institute for Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany*
[2] *Brandenburg University of Applied Sciences, Brandenburg an der Havel, Germany*
ashton.dickerson@igb-berlin.de
[*] *presenting author*

Introduction

Freshwater ecosystems are vital for human well-being, supporting biodiversity, sustaining primary production and regulating carbon fluxes (Dudgeon et al. 2006). Despite covering less than 1% of the Earth's surface, they host approximately 10% of all known species. However, with over 50% of the global population living within 3 km of freshwater bodies (Kummu et al. 2011), these ecosystems are increasingly vulnerable to urban pollutants, including artificial light at night (ALAN) (Hölker et al. 2023). Light serves as a key environmental cue in freshwater systems, regulating critical biological processes such as diel vertical migration (DVM)—the largest synchronized migration on Earth (Bandara et al. 2021). Zooplankton rely on DVM to balance feeding opportunities with risk, ascending to surface waters at night and descending during the day to avoid visual predators and harmful UV radiation. This migration plays a fundamental role in ecosystem function by regulating biomass transfer, limiting harmful algal blooms, and transporting carbon and nutrients throughout the water column (Bandara et al. 2021).

Because DVM is tightly regulated by natural light cycles, including variations in lunar light, disruptions to these cues, such as those caused by ALAN, could have profound consequences. ALAN alters the timing, intensity, and spectral composition of light cues, yet its precise effects on DVM remain unclear. Furthermore, research on natural lunar influences on zooplankton DVM has been hindered by technical challenges in tracking zooplankton movements with high temporal and spatial resolution (Bandara et al. 2021). As a result, even baseline understanding of how moonlight shapes DVM remains incomplete, making it difficult to predict how artificial light might alter these patterns. In this research, we used state-of-the-art *in situ* imaging and high-throughput image analysis to determine zooplankton vertical distribution in open waters at unprecedented spatiotemporal resolution. We first established baseline DVM patterns under natural lunar cycles in a near-pristine lake environment, then tested responses to artificial lighting by simulating a harbour scenario.

Methods

Sampling – Baseline data were collected at Lake Stechlin, Germany, a near-pristine freshwater lake with minimal light pollution. *In situ* measurements were conducted using a modular Deep-focus Plankton Imager (mDPI) with a vertical resolution of 10 cm. We focused on Cladocera and Copepods, as they are abundant at the study site, known to migrate, and can be accurately identified using AI. To examine the effects of ALAN, we compared DVM under new and full moons, as well as under LED lighting designed to simulate artificial illumination from a harbour (Figure 1).

Figure 3. Photo of the experimental design, where LED lights are attached to a boat to simulate a habour environment at the experimental field site, Lake Stechlin, Germany. Photo used with permission of co-author, Andreas Jechow

Data processing and analysis – We used AI-based Convolutional Neural Networks (developed at IGB; Walles, 2020) to classify zooplankton taxa and size classes (small, medium, large). Mean depth for each species and size class was plotted against time across the lunar cycle under both natural and artificial lighting conditions to assess changes in DVM behaviour.

Conclusions

Our findings confirm that DVM is readily observable at Lake Stechlin and that zooplankton behaviour is influenced by moonlight, size, and species. Using this dataset as a baseline, we examined the effects of ALAN under a simulated harbour environment. Our results show that ALAN reduces the magnitude of zooplankton DVM, with individuals remaining deeper in the water column. This study highlights the importance of understanding natural light dynamics as a foundation for assessing ALAN's effects on freshwater ecosystems. Future research should focus on the broader ecological implications of these behavioural shifts.

References

Bandara, K., Varpe, Ø., Wijewardene, L., Tverberg, V., & Eiane, K. (2021). Two hundred years of zooplankton vertical migration research. *Biological Reviews*, *96*(4), 1547-1589.

Behrenfeld, M. J., Gaube, P., Della Penna, A., O'Malley, R. T., Burt, W. J., Hu, Y., ... & Doney, S. C. (2019). Global satellite-observed daily vertical migrations of ocean animals. *Nature*, *576*(7786), 257-261.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Lévêque, C., ... & Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological reviews*, *81*(2), 163-182.

Hölker, F., Jechow, A., Schroer, S., Tockner, K., & Gessner, M. O. (2023). Light pollution of freshwater ecosystems: principles, ecological impacts and remedies. *Philosophical Transactions of the Royal Society B*, *378*(1892), 20220360.

Kummu, M., De Moel, H., Ward, P. J., & Varis, O. (2011). How close do we live to water? A global analysis of population distance to freshwater bodies. *PloS one*, *6*(6), e20578.

Kyba, C. C., Altıntaş, Y. Ö., Walker, C. E., & Newhouse, M. (2023). Citizen scientists report global rapid reductions in the visibility of stars from 2011 to 2022. *Science*, *379*(6629), 265-268.

Walles, T. J. W. (2020). PhD Thesis "Mesozooplankton studies through automation and machine learning" (Technische Universität Berlin, IGB, supervised by J.C. Nejstgaard).

Effects of tailored and shielded road lights on parasitoid wasps

Theme: Biology and Ecology

Manuel Dietenberger[1,2*], Andreas Jechow[1, 2], Manuela Sann[3], Franz Hölker[1]

[1] Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Müggelseedamm 310, 12587 Berlin, Germany

[2] Department of Engineering, Brandenburg University of Applied Sciences, Magdeburger Str. 50, 14770 Brandenburg an der Havel, Germany

[3] Natural History Museum Bern, Bernastraße 15, 3005 Bern, Switzerland

manuel.dietenberger@igb-berlin.de

[*] presenting author

Introduction

Artificial light at night (ALAN) is known to be one of the causes of the global decline in insect populations (Owens et al., 2020), affecting important ecosystem functions and services associated with insects, including biological control. Among *Hymenoptera*, parasitoid wasps represent a hyper diverse functional group with a wide range of undescribed species and host organisms, many of them playing important roles in integrated pest management. However, while in pest control (e.g. light trapping in greenhouses) attraction is often a desired effect, the attraction of insects to ALAN constitutes a major problem in natural environments. By affecting host and parasitoid species and life stages differently, this will likely have an influence on top-down control in insect food webs with unknown consequences for associated ecosystem functions (Sanders et al., 2018). Mitigation strategies to reduce insect attraction are therefore urgently needed. In a previous study we showed that tailored and shielded LED road lights can effectively reduce the attraction of nocturnal insects via reduced spill light and a reduced visibility of luminaire heads (Dietenberger et al., 2024). In this study, we tested the effect of these novel luminaires on the attraction of parasitoid wasps as a sensitive indicator group at species level in an experimental BACI design (Before-After-Control-Impact).

Methods

We monitored the attraction effect of individual luminaires (n=28) on nocturnal insects with flight interception traps over a period of two years (2021-2022) at three municipal streets (study sites) close to nature reserves in Southern Germany, representing a gradient in skyglow and urbanisation. At each study site, paired control and impact sites with similar numbers of replicate subplots (luminaires) were selected. At the impact sites, we converted different types of road lights with less shielded emission (LED 4000K, high pressure sodium 2000K) to tailored and shielded LED luminaires (LED 4000K, 2700K, 2000K) after one year while the other half served as controls. Parasitoids were determined to family/genus level morphologically and target DNA sequences of 106 attracted individuals were analysed and searched against BOLD and NCBI database using the Basic Local Alignment Search Tool BLAST. A phylogenetic tree confirmed our identifications.

Results

Modelling parasitoid abundance in different treatments (Figure 1), analysis showed that tailored and shielded luminaires attracted significantly less parasitoid wasp individuals (Abundance) and species (Species richness) than conventional luminaires in the same year. We identified 106 parasitoid individuals (62 morphotypes) of a minimum of 45 genera out of 13 families. Out of 21 different identified species, 14 were not reported in Baden-Württemberg (3 not in Germany) in the Global Biodiversity Information Facility GBIF. Of these, 11 species were not reported for Baden-Württemberg elsewhere in the available literature and newly reported on a molecular basis.

Conclusion

Our study indicates, that tailored and shielded road lights will reduce the ecological impact of ALAN on parasitoid wasps across many taxa and host associations. Considering the different life-histories of attracted species, the potential impacts of ALAN include an influence on nocturnal pollination and Lepidoptera populations via parasitism, biological control of invasive pest species and tritrophic interactions between primary and secondary parasitoids, with unknown consequences for ecosystem functioning. To our knowledge, this is the first study investigating the attraction of parasitoid wasps to public outdoor lighting under field conditions at this level of taxonomic resolution. This was achieved by applying an integrative taxonomic approach, including morphological, molecular and phylogenetic analyses.

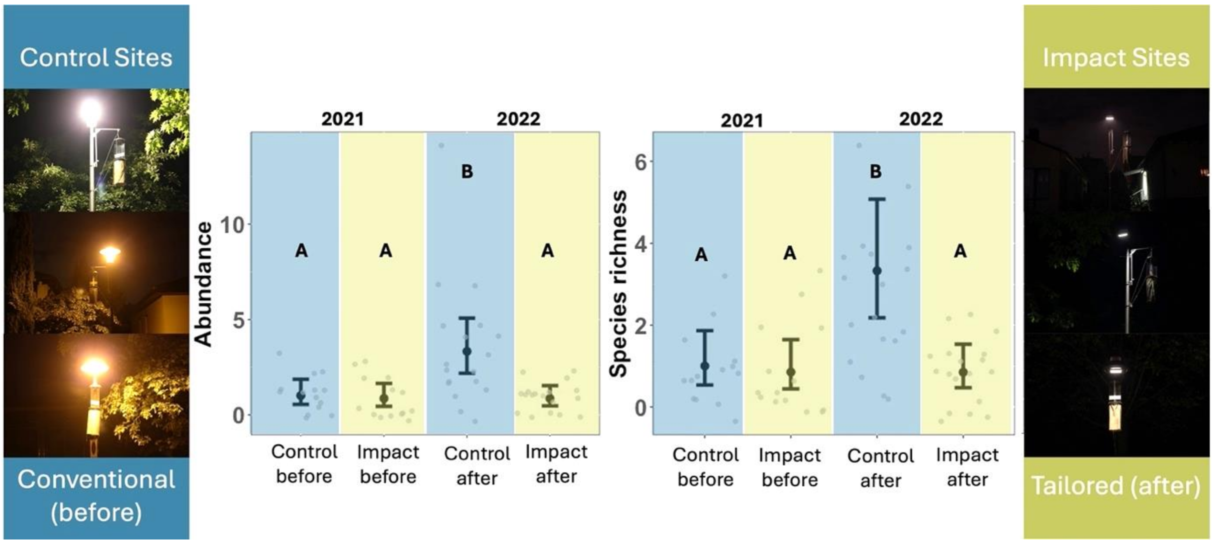


Figure 1: Generalized linear model showing the effect of different treatment groups on the number of individuals (abundance) and species (species richness) of attracted parasitoid wasps per luminaire and treatment (grey points). Error bars show model predictions and 95% confidence intervals. Letters refer to a pairwise comparison (Tukey post-hoc test). Different letters indicate significant difference. Only the conventional road lights (LED 4000K, HPS 2000K) in the Period After (Control After) attracted significantly more parasitoids than all other treatment groups ($p < 0.001$***, $p < 0.001$***, $p < 0.001$***) and there were no further differences (© photographs Andreas Jechow).

References

Owens, Avalon C. S., Précillia Cochard, Joanna Durrant, Bridgette Farnworth, Elizabeth K. Perkin, and Brett M. Seymoure. 2020. 'Light Pollution Is a Driver of Insect Declines'. *Biological Conservation* 241:10859. doi: 10.1016/j.biocon.2019.108259

Sanders, Dirk, Rachel Kehoe, Dave Cruse, F. J. Frank van Veen, and Kevin J. Gaston. 2018. 'Low Levels of Artificial Light at Night Strengthen Top-Down Control in Insect Food Web'. *Current Biology* 28(15):2474-2478.e3. doi: 10.1016/j.cub.2018.05.078

Dietenberger, Manuel, Andreas Jechow, Gregor Kalinkat, Sibylle Schroer, Birte Saathoff, and Franz Hölker. 2024. 'Reducing the Fatal Attraction of Nocturnal Insects Using Tailored and Shielded Road Lights'. *Communications Biology* 7(1):1–12. doi: 10.1038/s42003-024-06304-4

Ecological implications of electric lighting altered by weather and sky conditions in suburban environments

Theme: Technology and Design

Seren Dincel,[1,*] Arne Lowden,[2]

[1] *School of Architecture, KTH Royal Institute of Technology, Stockholm, Sweden*
[2] *Department of Psychology, Stockholm University, Stockholm, Sweden*
dincel@kth.se, arne.lowden@su.se
[*] *presenting author*

Introduction

Areas where electric lighting systems are installed and their far-reaching effects increasingly intersect with where wildlife communities inhabit. Recent investigations point out towards technological adaptations, e.g., changing illumination levels, spectral composition (Jägerbrand & Spoelstra, 2023; Longcore, 2023) and optical distribution of light sources (Abelson et al., 2023), to enable the reduction of ecological effects while keeping lighting infrastructures for affording pedestrian visual functions. Ecological studies conducted in lab environments may either conceal responses produced in a real-world context (Aulsebrook et al., 2022) or neglect linkages between animal physiology, life history and sensory stimulation (Dominoni et al., 2020). Temporal atmospheric shifts could alter electric lighting effects, thus affecting the magnitude of sensory pollutants in masking or deceiving natural cues from moonlight animals need to moderate their behaviours. Illumination from moonlight varies between 0.001 lux on a clear starry sky and a full moon at 0.1-0.3 lux (Rich & Longcore, 2006), where even very low illuminances of 0.001 demonstrated movement changes, distressing breeding and singing behaviours (Aulsebrook et al., 2022). Other environmental factors that transiently affect light environments are derived from cloud cover, which has been shown to reproduce light pollution (Kyba et al., 2011), and when combined with the albedo of snow that has reflectance up to 95% (Demers, 2015) indicated two times higher illuminance of full moon under overcast skies (Jechow & Holker, 2019).

Field investigation and methods

We conducted fieldworks on a pedestrian pathway traversing an urban forest of Uppsala, Sweden as part of the NorDark research project to study the produced effects of diverse lighting scenarios. The two light sources included in the study were an LED lamp of 3000K with a light output of 2100 lm (LED A) and a prototypical LED of 2300K, 2100 lm (LED B), designed by using clear and amber-coloured optic lenses. LED A and LED B installations were measured at the fully operational level (100%); additionally, LED B was measured under dimmed conditions at 10% level.

Illuminances were recorded at horizontal and vertical planes with hand-held measurement devices (GL Spectis regular probe and Salli diffusor) on the points defined by a grid stretching from the path every 4 meters up to 20 meters into the woods between two lamp posts at the testbed (Dincel, 2023) between November 2022 and January 2025. Six scenarios included in our study were recorded in overcast skies after dark with and without snow coverage on site.

Results

The lowest average horizontal illuminance was 0.01 lux when LED B operated at 10% level without snow starting from 12 to 20 meters into the woods. The highest average horizontal illuminance was 56.97 lux on the path when LED B fully operated under snow cover (Fig. 1). Additionally, results from the statistical analysis of horizontal values indicated that the effect of each light source (A and B), snow coverage (snow and no-snow) and illumination level (100% and 10%) are significant (P>0.001) when logged lux values were used in calculations.

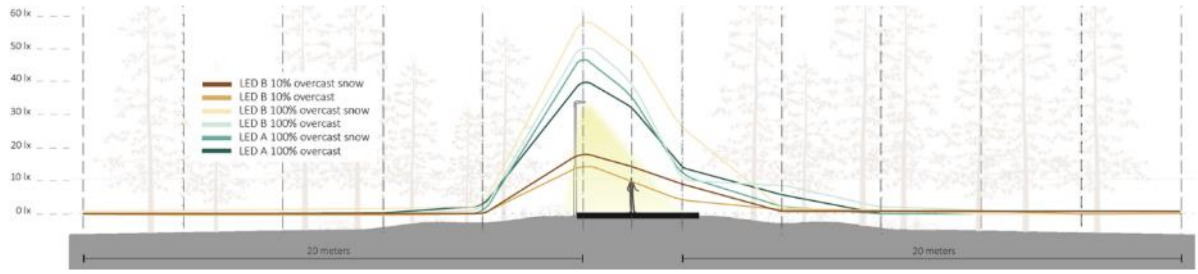


Fig. 1: The average horizontal illuminances estimated on the grid section crossing two lamp posts at the testbed illustrating six scenarios from two light sources (A and B) and two light settings (100% and 10%).

Conclusions

Fluctuating real-world conditions can inform adaptive lighting technologies more realistically in accommodating species' habitats. Provisional changes, e.g., weather and sky, could become the basis for shifting between lighting scenarios via lowered light output and spectral alteration given the significant effects electric lighting might produce on local ecology. Additionally, lowering light levels can save energy, while simultaneously modifying spectral composition by reducing short-wavelength content might counter energy efficiency and present visual challenges for pedestrians. Different metrics can be prioritised (Fotios, 2019) based on the specific habitat, visual demands and temporal conditions.

Acknowledgments

This study is supported by NordForsk (Grant #105116) and the Swedish Energy Agency (Grant #P2021-00024).

References

Abelson, E., Seymoure, B., Jechow, A., Perkin, E., Moon, H., Hölker, F., White, J., & Longcore, T. (2023). Ecological Aspects and Measurement of Anthropogenic Light at Night. *SSRN*. https://doi.org/https://dx.doi.org/10.2139/ssrn.4353905

Aulsebrook, A. E., Jechow, A., Krop-Benesch, A., Kyba, C. C. M., Longcore, T., Perkin, E. K., & van Grunsven, R. H. A. (2022). Nocturnal lighting in animal research should be replicable and reflect relevant ecological conditions. *Biol Lett*, *18*(3), 20220035. https://doi.org/https://doi.org/10.1098/rsbl.2022.0035

Demers, C. (2015). *Lighting diversity and adaptability to climate: a quantitative and qualitative urban survey methodology* PLDC 5th Global Lighting Design Convention, Rome.

Dincel, S. (2023). *Technical Report, Part I: NorDark Testbed, Uppsala/SE Light Level Measurements, Methods and Values*. K. R. I. o. Technology. https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-329469

Dominoni, D. M., Halfwerk, W., Baird, E., Buxton, R. T., Fernandez-Juricic, E., Fristrup, K. M., McKenna, M. F., Mennitt, D. J., Perkin, E. K., Seymoure, B. M., Stoner, D. C., Tennessen, J. B., Toth, C. A., Tyrrell, L. P., Wilson, A., Francis, C. D., Carter, N. H., & Barber, J. R. (2020). Why conservation biology can benefit from sensory ecology. *Nat Ecol Evol*, *4*(4), 502-511. https://doi.org/10.1038/s41559-020-1135-4

Fotios, S. (2019). *Which metrics are needed to specify good lighting for pedestrians?* 29th CIE SESSION, https://dx.doi.org/10.25039/x46.2019.op11

Jägerbrand, A. K., & Spoelstra, K. (2023). Effects of anthropogenic light on species and ecosystems. *Science*, *380*(6650), 1125-1130. https://doi.org/https://doi.org/10.1126/science.adg3173

Kyba, C. C., Ruhtz, T., Fischer, J., & Holker, F. (2011). Cloud coverage acts as an amplifier for ecological light pollution in urban ecosystems. *PLoS One*, *6*(3), e17307. https://doi.org/10.1371/journal.pone.0017307

Longcore, T. (2023). A compendium of photopigment peak sensitivities and visual spectral response curves of terrestrial wildlife to guide design of outdoor nighttime lighting. *Basic and Applied Ecology*, *73*, 40-50. https://doi.org/https://doi.org/10.1016/j.baae.2023.09.002

Rich, C., & Longcore, T. (2006). *Ecological Consequences of Artificial Night Lighting*. Island Press. http://ebookcentral.proquest.com/lib/kth/detail.action?docID=3317409

Current understanding of blue light impact on human health and biodiversity

Theme: Health

Antonello Durante,[1,*] Paul Hynds,[1] Anna Crowley,[2,3] Siofra Harrington,[2,3,4] Grainne Scanlon,[2,3,4] George Amarandei [2,3]

[1]*Spatio Temporal Environmental Epidemiology Research (STEER), Sustainability and Health Research Hub (SHRH), Technological University Dublin, Dublin, Ireland*
[2] *School of Physics and Clinical and Optometric Sciences, Technological University Dublin, Dublin, Ireland*
[3] *The Group of Applied Physics, Technological University Dublin, Dublin, Ireland*
[4] *The Centre for Eye Research Ireland (CERI), Technological University Dublin, Dublin, Ireland*
antonello.durante@tudublin.ie
[*] *presenting author*

Plants and animals follow a natural 24-hour cycle influenced by the sun, while humans depend on environmental cues, such as daylight patterns (*e.g.*, diurnal cycles) to regulate their internal biological clock and essential physiological functions, including sleep, blood pressure, heart rate, and hormone production (Janse van Rensburg *et al*., 2021). However, the human relationship with lighting has evolved significantly in recent decades. Modern lifestyles have reduced outdoor exposure, in concurrence with increasing exposure to artificial lighting from self-illuminated devices like computers, tablets, TVs, and smartphones for both work and leisure. Simultaneously, light-emitting diodes (LEDs) have steadily replaced traditional light sources due to their superior energy efficiency.

According to the International Energy Agency (IEA), residential LED sales rose from approximately 5% of the market in 2013 to approximately 50% in 2022. LED illumination, along with computers and smartphones, emit significantly more high-energy blue light than traditional incandescent bulbs (IEA, 2005). Depending on their correlated colour temperature (CCT) and brightness, blue light content can range from 15% to 47%, compared to just 9% of incandescent lighting. This excess exposure can adversely affect human health and the environment. Short-wavelength electromagnetic radiation, including blue light, can harm the retina, contributing to visual disorders including digital eye strain, retinal damage and phototoxicity linked to age related macular degeneration (AMD), myopia progression and associated pathologies (detachment and maculopathy), with the prevalence of myopia anticipated to rise significantly in the coming decades (Morgan *et al.*, 2021).

Beyond its impact on vision, blue light exposure can also disrupt non-visual wellbeing by interfering with circadian rhythms. This disruption has been linked to sleep disorders, hormonal imbalances, increased stress levels, and a higher risk of conditions such as diabetes, as well as breast and prostate cancers (Kogevinas *et al.*, 2018). Additionally, blue light pollution can negatively affect the environment, altering biodiversity by influencing animal behaviours, including predation and migration patterns.

Accordingly, the European Environment Agency (EEA) has recently recommended the introduction of new thresholds, guidelines, and policies to minimise the effects of blue light exposure. However, EU member states including Ireland lack specific binding regulations. The EPA-funded Blu-RAY project aims to address this gap, representing the first Irish study to assess the potential toxicity of short-term and cumulative long-term blue light exposure.

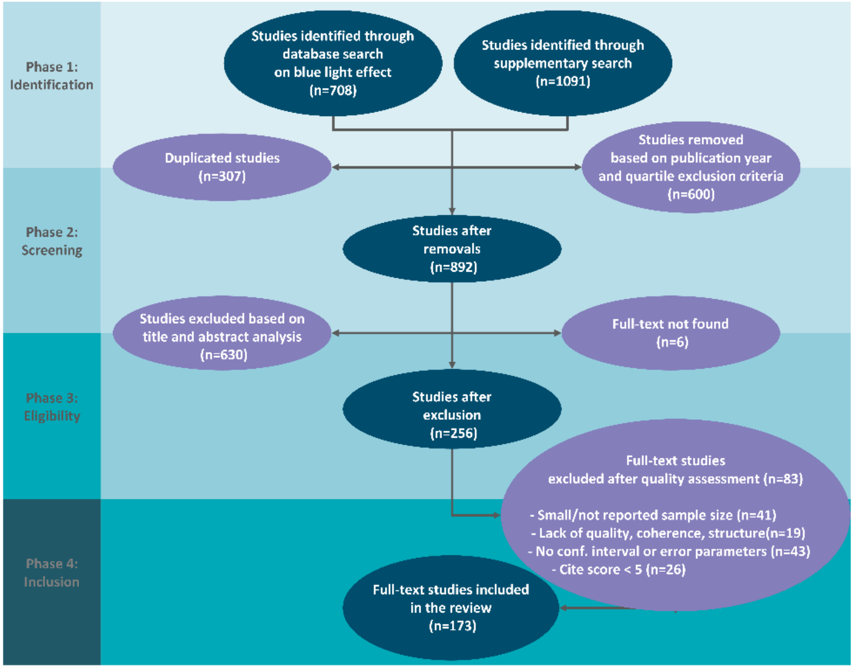


Fig. 1: PRISMA diagram outlining the four phases of the search. (Image by the authors)

Our analysis of current global knowledge began with a scoping review involving four phases, (Fig. 1). The review includes peer-reviewed articles from Q1 and Q2 journals published in English since 2000.

Overall, 173 studies were identified, with a significant proportion coming from North American and Chinese institutions (43%). More than half (53%) were published between 2018 and 2024.

The studies were grouped into clusters according to their main topics (Fig. 2). The analysis found a weak but statistically significant relationship between location and year of publication (τ_b = -0.159; $p < 0.005$). However, no significant associations were observed between year of publication and subject (τ_b = 0.028; p = 0.636), or between location and subject (τ_b = 0.083; p = 0.176). Additionally, findings highlight a notable absence of substantial academic research on this topic in Ireland. Future work will examine LED technology features that may mitigate blue light toxicity and inform future environmental and public health guidelines in Ireland and Europe. Additionally, a nationwide survey will capture public perceptions and experiences of blue light's impact on health and the environment.

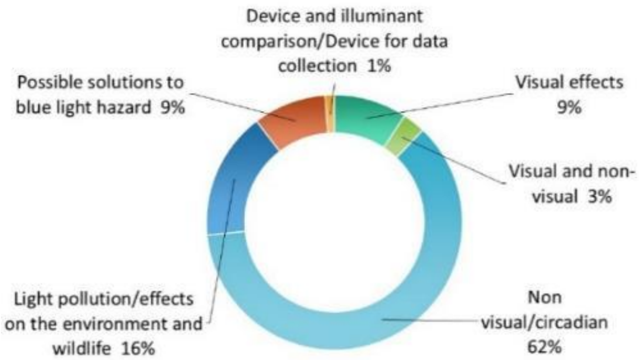


Fig. 2: The six clusters identified according to papers' main subject. (Image by the authors)

References

Janse van Rensburg DC, Jansen van Rensburg A, Fowler PM, *et al*. (2021) Managing travel fatigue and jet lag in athletes: a review and consensus statement. Sports Med, 51(10), 2029-2050

IEA (International Energy Agency). (n.d.) Lighting. International Energy Agency. Retrieved March 18, 2025, from https://www.iea.org/energy-system/buildings/lighting

Morgan IG, Wu PC, Ostrin LA, *et al.* (2021) IMI risk factors for myopia. Investigative Ophthalmology and Visual Science, 62(5), 3

Kogevinas M, Espinosa A, Castelló A, *et al.* (2018) Evaluating the association between artificial light-at-night exposure and breast and prostate cancer risk in Spain (MCC-Spain study). Environmental Health Perspectives, 126(4), 047011

Fine Scale Satellite Measurements of Time-Variable ALAN

Theme: Measurement and Modelling

Brian R. Espey [1,*]

[1] *School of Physics, Trinity College Dublin, University of Dublin, Ireland*
brian.espey@tcd.ie
[*] *presenting author*

Introduction

Artificial light emissions are increasing worldwide and are a major problem in terms of health and environmental impacts, including the energy waste of the light itself. To understand the causes and implications of light pollution it is necessary to have sufficient information to enable action to be taken, including determining the responsible parties. Unfortunately, the apportioning of this light between different sources and types has, in the past, been difficult to determine from relatively low resolution satellite data such as that from SUOMI VIIRS Day-Night Band (DNB) with a nominal equatorial resolution of 742m and relatively large inter-night variations from the effects of a wide range of angles and intermixing of ground sources with differing time characteristics. While higher resolution International Space Station colour imagery has been available for some time it is limited in terms of coverage and quality and requires radiometric calibration to be of utility.

Methods

With the launch of the Chinese SDGSAT-1 in 2021, the ALAN community now has free access to 10m resolution calibrated night-time panchromatic imagery covering 450-900nm[1]. In addition, contemporaneous 40m resolution RGB imagery and 30m resolution thermal imagery is also available, with all data being taken in near-nadir conditions. Since the orbit is sun-synchronous, images are taken at roughly 21:40 local time on different overpasses when human activity levels are higher, which compares with the lower resolution VIIRS DNB data taken at roughly 01:30 when activity is much lower. The availability of detailed data enables

Fig. 1: An area of Dublin viewed on different dates shows striking differences due to illumination of sports areas. Images are for a weekend and weekday night (left and right images, respectively).

[1] https://sdg.casearth.cn/en/mobile/datas/SDGSAT

day-to-day and month-to-month variations to be studied at fine scales, including the impact of seasonal holidays. As examples of day of week differences, Fig. 1 shows that there is a striking difference in the use of sports areas, with the weekend showing relatively few lit areas, while the converse is true when we look at data centres (Fig. 2).

Our previous light censuses have been of relatively coarse and uncertain results due to the relatively low resolution and inter-night variability of the VIIRS DaDue to its combination of sensitivity and high resolution, the SDGSAT data permit relatively weak features to be distinguished, increasing the level of utility for tracing the behaviour of a range of light sources down to the scale of individual houses and even cars.

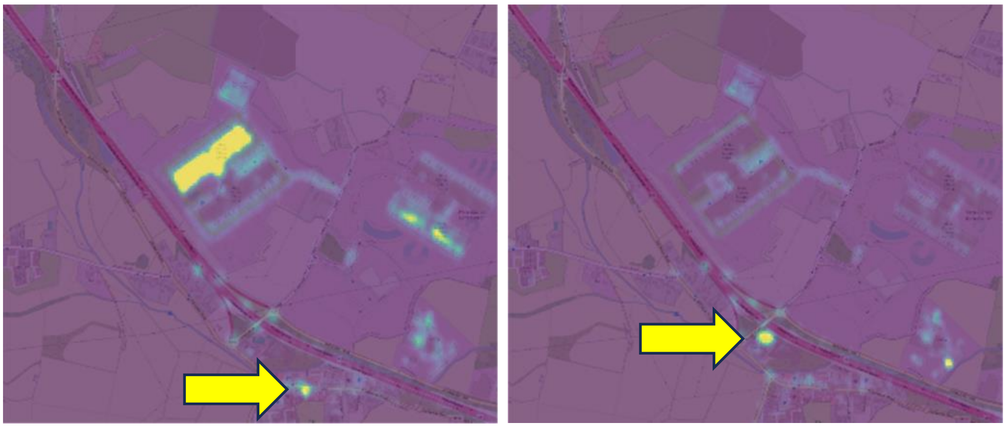


Fig. 2: Data centres (left and right of centre) show the opposite lit behaviour to that of Fig. 1. The brightest areas below centre are a car park (arrow tip in left image) and a tennis court (arrow tip right image). As before, a weekend and weekday night are shown in the left and right images, respectively.

Presentation

In this presentation we will discuss the time variations of lighting on day-of-week and seasonal effects together with estimates of total energy loss for a range of land use types and population centre sizes ranging from rural communities to large urban areas. Additionally, to study the impact of ALAN on the local environment, we will compare our satellite measurements of upwelling light with high cadence contemporaneous data from a number of ground-based Sky Quality Meter locations to indicate their sensitivity to changes in the surrounding lit environment. Our work will demonstrate the importance of high resolution satellite data for understanding the intricate details of light at night and the connection between upwelling light and zenith sky brightness.

Acknowledgements

This work was supported by the Sustainable Energy Authority of Ireland research funding **SEAI 22RDD868.** SDGSAT-1 data were kindly provided by the Center of Big Data for Sustainable Development Goals (CBAS).

References

Guo H, Dou C, Chen H, Liu J, Fu B, Li X, Zou Z, Liang D (2022) SDGSAT-1: the world's first scientific satellite for Sustainable Development Goals. Science Bulletin. 68. 10.1016/j.scib.2022.12.014.

Guided by skyglow: The Subtle Appeal of Artificial Skies

Theme: Biology and Ecology

Ruben Evens,[1,*] and Jitse Creemers,[1,2]

[1] *Université Catholique de Louvain (UCL), 1384, Louvain-la-Neuve, Belgium*
[2] *University of Antwerp, B-2610, Wilrijk, Belgium*
ruben.evens@uclouvain.be
[*] *presenting author*

Introduction

Animal behaviour has evolved under relatively consistent cycles of daylight and nocturnal darkness. At night, both diurnal and nocturnal species align their behaviour with predictable, recurring, yet subtle changes in light governed by the lunar cycle[1]. With the advent of artificial night lighting, much of the inhabited world has lost naturally dark skies. However, the consequences for individuals, species, and ecosystems have primarily been studied in the context of direct light emissions—whether chronic or temporary—that infiltrate local nocturnal habitats[2].

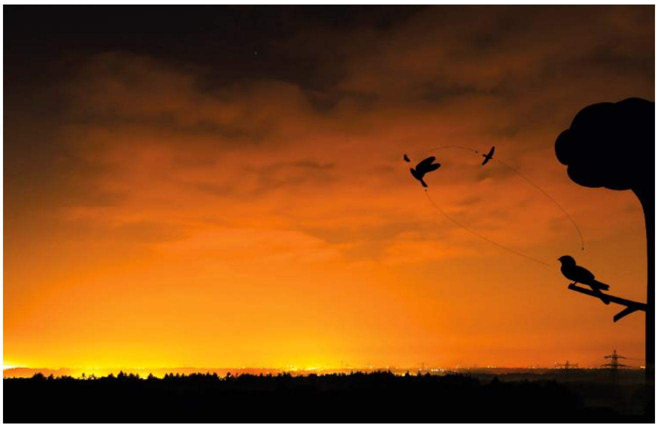


Fig. 1: Illustration of a nightjar performing a "flycatch", using the brightness of skyglow to detect its prey, a flying moth. Image by Tim Visser and edited by Ruben Evens.

In contrast, the effects of a more diffuse form of light pollution—skyglow—remain largely undocumented[3]. Skyglow is the broad-scale illumination of the night sky, caused by artificial light emitted upward, which reflects off atmospheric particles and scatters back toward Earth. As a result, artificial light from urbanized areas can brighten natural night skies tens of kilometres away. Skyglow is known to mimic the brightness of a full-moon night, especially under overcast conditions, when the sky would otherwise remain dark[4]. Unlike the predictable variation in moonlight, however, the intensity and direction of skyglow-mediated sky brightness can shift rapidly over the course of a night. Given that skyglow now affects the night-time environment in 95% of Europe's important biodiversity areas[4], it is essential to understand how animals respond to such dynamic changes in artificial nocturnal light regimes.

Methods

Given that even low-intensity changes in moonlight affect the behaviour of most species on Earth[1], our research group investigates whether nocturnal, visually-oriented predators can respond rapidly to skyglow-mediated brightness during previously dark periods of the night. To explore this, we collect two main types of data: tracking data of nocturnal species and information on their experienced light environment.

We focus on the European Nightjar (*Caprimulgus europaeus*), a ~70 g, visually-oriented aerial insectivore that uses twilight and moonlight for activity timing, navigation, and resource identification. During the breeding season, we deploy GPS-accelerometers across six sites that differ markedly in skyglow exposure, ranging from six to 90 times brighter than natural starlight. GPS loggers record movement at three-minute intervals, while accelerometers capture high-resolution (25 Hz) data on behaviours (resting, flying, singing, and foraging).

We collect five types of light data, of which only the first three are currently used. First, we use the R-package "skylight"[5] to estimate moonlight exposure (lux) and moon altitude (degrees) for each accelerometer data point. Second, we extract skyglow levels from www.lightpollutionmap.info (VIIRS data; 300 m resolution; 10^{-9} W/cm²·sr) for each GPS point. Third, we obtain hourly cloud cover data from ECMWF's ERA5 reanalysis (31 × 31 km resolution; Hersbach, 2016). Additionally, we collect site-specific sky luminance data (SQM, three minute interval) and all-sky images across lunar phases and cloud conditions.

Conclusions

Nightjars in our studies adjust the timing and intensity of their crepuscular and nocturnal flight and foraging activity in response to both sunlight and moonlight[6-8]. Cloud cover further modulates ambient light by dimming the twilight sky—advancing activity at dusk and delaying it at dawn. At night, however, clouds amplify skyglow, brightening an otherwise moonless sky and promoting nocturnal activity. These findings support the idea that natural light cycles strongly influence the daily rhythms of visual predators, while also identifying skyglow as an emerging driver of nocturnal behaviour. Given that nightjars detect flying insects by silhouetting them against the illuminated sky, our recent study[9] further shows that nightjars actively orient toward moonlit and skyglow-lit sections of the sky.

Results from several of our studies suggest that nocturnal species can quickly adjust their behaviour in response to the rapidly changing nature of skyglow[6-9]. At the same time, they also underscore a pressing gap: the lack of fine-scale, biologically meaningful measurements of skyglow variability—especially regarding its intensity, spectral composition, and spatial directionality. Besides raising awareness for the impact of skyglow on nocturnal communities, this talk aims to initiate the development of tools capable of capturing high-frequency, ecologically relevant data on natural and artificial night-time light in a cost-effective manner—enabling researchers to monitor multiple sites simultaneously.

References

1. Kronfeld-Schor N, Dominoni D, de la Iglesia H, Levy O, Herzog ED, Dayan T, Helfrich-Forster C. (2013) Chronobiology by moonlight. Proc Biol Sci. 280 (1765): 20123088.
2. Longcore, T., Rich, C. (2004) Ecological light pollution. Frontiers in Ecology and the Environment, 2(4), 191–198.
3. Seymoure, B.M., Buxton, R., White, J.M., Linares, C.R., Fristrup, K., Crooks, K., Wittemyer, G., Angeloni, L. (2025) Global artificial light masks biologically important light cycles of animals. Frontiers in Ecology and the Environment, e2832.
4. Kyba, C., öner Altintas, Y., Walker, C., Newhouse, M. (2023) Citizen scientists report global rapid reductions in the visibility of stars from 2011 to 2022. Science379,265-268
5. Hufkens, K. (2023) skylight: A Simple Sky Illuminance Model (Version 1.2) [R package]. CRAN.
6. Evens, R., Lathouwers, M., et. al. (2023) Skyglow relieves a crepuscular bird from visual constraints on being active. Science of The Total Environment 900, 165760.
7. Evens, R., Kowalczyk, C., et. al. (2020) Lunar synchronization of daily activity patterns in a crepuscular avian insectivore. Ecology and Evolution 10, 7106–7116.
8. Evens, R., Creemers, J., et.al. (Unpublished) Skyglow mediates foraging tactics of a crepuscular insectivore.
9. Creemers, J., Eens, M., et. al. (2025) Skyglow facilitates prey detection in a crepuscular insectivore: Distant light sources create bright skies. Environmental Pollution 369, 125821.

Shedding light on solutions: Applying Network Ecology to Test How Street Light Mitigations Impact Lepidoptera Networks

Theme: Biology & Biology and Ecology

Madeleine Fabusova,[1,*] Darren Evans,[1] Katherine Baldock[2], Paula Banza[3], Richard Fox[4], Michael Pocock[5]

[1] Newcastle University, Newcastle upon Tyne, UK
[2] Northumbria University, Newcastle upon Tyne, UK
[3]A Rocha Portugal, Mexilhoeira Grande, Portugal
[4]Butterfly Conservation, Dorset, UK
[5]UKCEH, Wallingford, UK
m.fabusova2@newcastle.ac.uk
[*] presenting author

Introduction


Fig. 1: Experimental lighting rig. This image is by Madeleine Fabusova.

Modern landscapes are increasingly dominated by artificial light at night (ALAN). Concurrently, most invertebrates (60 % (Hölker et al., 2010)), are nocturnal, and as such, particularly sensitive to light (Schroer & Hölker, 2017). ALAN is known for its impacts at individual, population and community levels, across a range of taxa (e.g. (Boyes et al., 2021; Gaston et al., 2021)). Recent switch to energy-saving light-emitting-diodes (LEDs) has significantly altered nocturnal landscapes. However, evidence suggests that modifying the properties of LEDs allows for the negative impacts of ALAN to be mitigated (Evans, 2023). Mitigation strategies such as changing light colour (CCT), shielding, part-night lighting, dimming, are suggested (Gaston et al., 2012). However, we lack concrete evidence to support how these mitigations limit impacts on ecosystem services and ecological networks (Evans, 2023; Knop et al., 2017).

Ecological networks (EN) provide a useful framework for investigating how street light mitigation measures affect interactions between species, and thus the function and stability of ecosystems (Montoya et al., 2006). They have been successfully used to elucidate the effects of various anthropogenic activities (e.g. (Macgregor et al., 2019)). Knop et al. 2017, in particular, highlights how examining community level responses to ALAN through ENs is a practical way of investigating direct and indirect effects of streetlighting (Knop et al., 2017). Whilst a variety of taxa have been the subject of ALAN studies, moths, key pollinators and prey food for many predators, are a great indicator species (Hahn & Brühl, 2016; Macgregor et al., 2015). Here, we aim to combine a variety of direct sampling methods and new technologies, to understand how street light mitigation measures could impact moth (Lepidoptera) ecological networks.

Methods

We aim to test the short-term responses of nocturnal moths to 4 light mitigation measures. We use mobile experimental lighting rigs which mimic conventional streetlights and are fitted with timers and dimmers. These can be positioned in light-naïve environments thus removing any effects of existing lighting sources (Boyes et al., 2021). We test 5 treatment levels: full-night lighting (positive control), part-night lighting (one light turned off at midnight [industry standard (Evans, 2023)]; one turned off 3-h after sunset [seasonally-adapted to match changes in activity related to sunset]), dimming (to minimally acceptable standards), and dark control. During 4-night blocks, we monitor moth activity every 3 hours, using flight-interception traps, beam-counts, and netting. Once caught, each moth is kept in a separate pot, cooled, identified to species level (where possible from visual identification) and its body is swabbed for pollen (to reconstruct flower-visitor networks). The pollen is kept frozen for metabarcoding analysis. On the last day of the sampling block, we use sweep nets to assess the short-term effects of mitigations on caterpillar activity. Sub-sample of caterpillars is kept for analysis to establish the levels of parasitism in our system to inform future work.

Conclusions

By combining a variety of sampling methods and reconstructing ecological networks using molecular methods, such as metabarcoding, this project will allow us to assess the short-term effects of mitigation measures across Lepidoptera life cycle to thus understand how modifying ALAN impacts moth ecological networks.

References

Boyes, D. H., Evans, D. M., Fox, R., Parsons, M. S., & Pocock, M. J. O. (2021). Street lighting has detrimental impacts on local insect populations. *Science Advances*, *7*(35). https://doi.org/10.1126/sciadv.abi8322

Evans, D. M. (2023). Mitigating the impacts of street lighting on biodiversity and ecosystem functioning. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *378*(1892), 20220355.

Gaston, K. J., Ackermann, S., Bennie, J., Cox, D. T. C., Phillips, B. B., Sánchez de Miguel, A., & Sanders, D. (2021). Pervasiveness of biological impacts of artificial light at night. *Integrative and Comparative Biology*, *61*(3), 1098–1110.

Gaston, K. J., Davies, T. W., Bennie, J., & Hopkins, J. (2012). Reducing the ecological consequences of night-time light pollution: options and developments. *The Journal of Applied Ecology*, *49*(6), 1256–1266.

Hahn, M., & Brühl, C. A. (2016). The secret pollinators: an overview of moth pollination with a focus on Europe and North America. *Arthropod-Plant Interactions*, *10*(1), 21–28.

Hölker, F., Wolter, C., Perkin, E. K., & Tockner, K. (2010). Light pollution as a biodiversity threat [Review of *Light pollution as a biodiversity threat*]. *Trends in Ecology & Evolution*, *25*(12), 681–682. Elsevier BV.

Knop, E., Zoller, L., Ryser, R., Gerpe, C., Hörler, M., & Fontaine, C. (2017). Artificial light at night as a new threat to pollination. *Nature*, *548*(7666), 206–209.

Macgregor, C. J., Kitson, J. J. N., Fox, R., Hahn, C., Lunt, D. H., Pocock, M. J. O., & Evans, D. M. (2019). Construction, validation, and application of nocturnal pollen transport networks in an agro-ecosystem: a comparison using light microscopy and DNA metabarcoding. *Ecological Entomology*, *44*(1), 17–29.

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

Montoya, J. M., Pimm, S. L., & Solé, R. V. (2006). Ecological networks and their fragility. *Nature*, *442*(7100), 259–264.

The Southern Arizona Dark Sky Network

Theme: Measurement and Modeling

Emilio Falco,[1,*] John C. Barentine,[2] and Albert D. Grauer[3]

[1] DarkSky Southern Arizona, Tucson, USA
[2] Dark Sky Consulting LLC, Tucson, USA
[3] Catalina Sky Survey, Tucson, USA
soazchair@darksky.org
** presenting author*

Introduction

Southern Arizona, USA, has historically been called the "world capital of astronomy". Its many amateur and professional astronomical observatories and International Dark Sky Places, and its long tradition of outdoor lighting policies aimed at controlling light pollution, have made it famous in the world of dark-sky advocacy. These activities generate more than USD 550m per year in regional economic activity and support thousands of jobs. (Burtch-Buus 2023) Furthermore, the biogeographic setting of southern Arizona, the Sonoran Desert – among the world's most biodiverse deserts – hosts a number of plant and animal species that are sensitive to artificial light at night (ALAN). Like much of the western U.S., southern Arizona consists of inhabited cities separated by large tracts of mostly public lands, but skyglow is known to "drift" hundreds of kilometers from sources. Special concerns also exist, such as outdoor lighting at prisons and along the U.S.-Mexico border barrier.

Motivation

In 2023, area advocates re-launched the Southern Arizona chapter of DarkSky International, which had gone dormant. We reorganized it and adopted a new strategic plan that focuses on protecting natural nighttime darkness in the region and slowing, or even reversing, the spread of ALAN from area cities. We will achieve this goal through continually improving public policies at various jurisdictional levels as well as by pursuing a program of public outreach and education, leveraging existing public support for astronomy and dark skies. To allocate its resources effectively, the chapter must understand the spatiotemporal dynamics of light emissions across its territory. It is therefore building a connected system of night-sky brightness (NSB) monitors: the Southern Arizona Dark Sky Network (DSN).

The Network

We modeled the DSN on the Central Oregon Skyglow Measurement Network (Kowalik and McKeag 2025). We have begun to deploy a network of 35 NSB monitors across our chapter's territory (Figure 1) with a special emphasis on the Tucson area (metropolitan area population 1m).

We plan to use the DSN data for several purposes. First, the DSN will reveal changes that may be early warnings of increasing light pollution, which in turn will better direct the chapter's work and allocation of its resources. This approach complements satellite radiance remote sensing observations. Second, the DSN supports the missions of the area's astronomical observatories and can help with advocacy for evidence-based policy making.

Fig. 1: Map showing locations of nodes in the Southern Arizona Dark Sky Network (red symbols). The base map is a Google Earth satellite view over which are laid color contours of predicted zenith sky brightness from Falchi et al. (2016). White lines show Arizona state and county boundaries. The inset map at lower left shows the location of southern Arizona (red) inside the United States. Inset by Wikimedia Commons user TUBS, licensed under CC BY-SA 3.0. Google Earth data from SIO, NOAA, U.S. Navy, NGA and GEBCO; imagery from Landsat and Copernicus.

And third, the DSN assists planning for a future, experimental “lightshed” management pilot project in the area centered on the Tucson metro.

First results and future plans

Deployment of monitors began in spring 2025. We used data from existing monitors in the region in development of software to aggregate and visualize the data with the goal of making the DNS results publicly available. We plan to deploy all of the monitors by the end of 2025, and we expect to disseminate the data through our website (darkskysoaz.org).

References

Burtch-Buus L (2023) Economic impact of UArizona space sciences rivals that of Super Bowl. University of Arizona News. https://news.arizona.edu/news/economic-impact-uarizona-space-sciences-rivals-super-bowl

Falchi F, et al (2016) The new world atlas of artificial night sky brightness. Sci. Adv. 2: e1600377

Kowalik W, McKeag M (2025) Oregon Skyglow Measurement Network Technical Report Edition #9 (31 January 2025) https://static1.squarespace.com/static/64325bb7c8993f109f0e62cb/t/679c8b55f32ba64b8739b9c2/1738312560582/DarkSky_Oregon_SQM_Network_TechnicalReport_Edition_09_v3_cmpress.pdf

Bugged by the light – How artificial illumination reshapes forest invertebrate communities

Theme: Biology & Ecology

Bridgette Farnworth[1,2,*], Ellen Cieraad[1]

[1] *Nelson-Marlborough Institute of Technology, Nelson, New Zealand*
[2] *Victoria University, Wellington, New Zealand*
bridgette.farnworth@outlook.com
[*] *presenting author*

Artificial light at night (ALAN) has become an increasingly prevalent disturbance and is proposed as a major driver of global invertebrate declines. ALAN also impairs interactions *between* species and can decouple critical predator-prey relationships, such as attracting predators like spiders while deterring their prey (or vice versa). Understanding how ALAN influences the densities and behaviours of predators and prey is essential, as these changes may reverberate throughout communities and influence ecosystem services.

To assess to what extent light affects invertebrate community composition, we used a field experiment with a Before-After-Control-Impact (BACI) design - the gold standard for research examining environmental impacts in disturbance ecology - at Maungatautari Ecological Island, New Zealand. Twelve sites were located at least 25 m apart, with six randomly assigned to the 'treatment' (white light 400-700 nm; 2200K, on from one hour before sunset to one hour after sunrise) and six were dark 'controls'. Each site contained eight pitfall traps, three replicates of a pair of day-time and night-time traps immediately under the light (approx. 10 lux), one pitfall trap at the edge of the illumination (i.e. dimly lit) and one in the dark immediately adjacent to the site.

Sampling periods consisted of invertebrate collections over 5 consecutive nights shortly before the start of the treatment, and two periods after treatment had started (one week and four weeks after treatment started). Invertebrates were identified to the family level. We assessed impacts of ALAN on univariate responses of biodiversity (species richness, evenness), and on multivariate responses (i.e. community composition). We used Bray-Curtis similarity metrics to quantify the compositional dissimilarity between plots and treatments over time, and estimated statistical differences in composition with a nonparametric PERMANOVA.

More than 25,000 ground-dwelling invertebrates were identified, across more than 100 invertebrate families, and nine classes. In addition to expected seasonal changes in communities, we found differences in both the night-time communities of the light treatment compared with the dark control. Effects of the light treatment on community composition were discernable beyond the lit area. Hence, the influence of ALAN on forest-floor invertebrate communities is substantial, with effects that persist beyond both the illuminated zones.

Challenges in Implementing a National Light Pollution Regulation in Chile

Theme: Governance & Regulation

Daniela P. González,[1,*] Juan Pablo Valenzano,[1]

[1] Skies of Chile Foundation, Santiago, Chile
dgonzalez@cieloschile.cl
[*] Daniela P. González

Introduction

Light pollution is an environmental issue gaining global recognition, yet its regulation remains challenging. In Chile, a national light pollution standard was published in October 2024 as artificial light at night (ALAN) increasingly impacts biodiversity, human health, and astronomical research. Despite hosting world-class observatories, Chile's regulations remain fragmented. While protected areas have strict lighting guidelines, for the rest of the national territory, light pollution does not appear to be an urgent problem.

Key challenges include a lack of awareness in municipalities without direct ties to astronomy, bureaucratic complexities involving multiple institutions, limited municipal budgets, and competing priorities such as national security. Addressing these obstacles is crucial for effective policy development that balances environmental sustainability with public concerns.

Methods

Until last year, Chile's light pollution regulations apply mainly to northern regions housing astronomical observatories. Expanding these regulations nationally presents several difficulties:

1. Bureaucratic Complexity: The process involves multiple government agencies, including environmental, energy, and municipal authorities. Coordinating efforts is time-consuming, and municipalities often lack technical expertise to implement new lighting regulations.

2. Limited Awareness: Beyond Astronomy Hubs: While the north benefits from strong astronomical advocacy, other regions view light pollution as a low-priority issue. Coastal and urban areas often prioritize infrastructure and economic growth over environmental concerns, leading to uneven policy adoption.

3. Municipal Budget Constraints: Implementation costs primarily fall on municipalities, many of which face tight budgets. Upgrading public lighting requires investment in LED technology, shielding, and monitoring systems. Without national financial support, compliance remains difficult for smaller municipalities.

4. Public Safety and Over-Illumination: Many municipalities equate increased lighting with improved security. Over-illumination is often a rapid response to crime concerns, conflicting with efforts to reduce unnecessary light emissions. Policymakers must balance security with sustainable lighting strategies, demonstrating that well-designed lighting can enhance safety without excessive energy use.

Policy Recommendations:
This paper explores some alternatives arising from observed national good practices. Key recommendations include:

- Improved Institutional Coordination: A dedicated national agency should oversee light pollution regulations, ensuring streamlined communication between government bodies, municipalities, and scientific organizations.

- Public Awareness Campaigns: Education initiatives should extend beyond astronomical regions, highlighting ALAN's impact on ecosystems, health, and energy efficiency.

- Financial Support for Municipalities: National funding or subsidies can alleviate the financial burden of responsible lighting upgrades, encouraging wider adoption.

- Security-Oriented Lighting Strategies: Crime prevention strategies should incorporate guidelines on light intensity, direction, and color temperature to balance safety and sustainability.

Conclusions

Implementing a national light pollution regulation in Chile presents challenges but also opportunities. While bureaucratic complexity, financial limitations, and security concerns hinder progress, strategic policy interventions can help overcome these barriers. A coordinated approach involving education, funding, and institutional collaboration is essential for implementing effective lighting standards.

Light pollution extends beyond astronomy, affecting ecosystems, public health, and energy consumption. Chile has the potential to lead Latin America in sustainable lighting policies if these challenges are proactively addressed. Engaging municipalities, policymakers, and the public in a collaborative effort will be crucial in establishing an effective regulatory framework for present and future generations.

Glowatch: A Citizen Science Tool for Raising Awareness on Light Pollution

Theme: Social Sciences & Humanities Society

Daniela P. González,[1,*] Juan Pablo Valenzano,[1]

[1] Skies of Chile Foundation, Santiago, Chile
dgonzalez@cieloschile.cl
[*] Daniela P. González

Introduction

Light pollution is a growing concern worldwide, with significant environmental, health, and cultural implications. While scientific research has contributed to understanding the impact of artificial light at night (ALAN), public engagement and awareness remain key challenges (Kocifaj, Wallner & Barentine, 2023). Citizen science initiatives offer a powerful approach to bridging this gap by involving non-experts in data collection and analysis (Giardullo, 2023) fostering a deeper understanding of light pollution and its consequences. Glowatch (glowatch.cl) is a citizen science project designed to empower individuals to monitor and report light pollutant sources using accessible digital tools. This initiative aims to promote and educate in the control of light pollution generating a national cadastre of light pollution sources, contributing to the development of educational resources.

Light pollution not only affects astronomical observations but also disrupts ecosystems and human health (Longcore & Rich, 2004). Addressing these issues requires a comprehensive strategy that integrates scientific research, public policy, and community engagement.

Methods

Glowatch integrates mobile and web-based applications to enable users to report light pollutant sources data using a standardized methodology. Participants contribute by identifying light pollution sources in different locations, even if their knowledge of light pollution is low or poor, which are then aggregated into an open-access database.

A critical aspect of the Glowatch methodology is the ease of participation. By ensuring that the tools used for data collection are intuitive and accessible, the project maximizes engagement from diverse audiences. The integration of georeferenced data allows for detailed spatial analysis of light pollution trends.

Preliminary data from Glowatch indicate a high level of participation, with contributions from several Chilean cities, with a large territorial representation. In the Chilean case, this is an interesting result, given that it is in the north of Chile where astronomical activity is concentrated, and therefore this particular geographic area has had a greater awareness of the need for dark skies.

As more data is entered it is interesting to see how the different forms of expression of light pollution are distributed, with over-illumination and glare being the main causes that motivate people to make their reports on the platform. This gives clues that people recognize the forms of light pollution to the extent that they are directly affected, which highlights the need to create educational resources to generate the link that relates these externalities of exposure to ALAN to the manifestations of light pollution.

On the other hand, the spatial distribution of the sources of light pollution makes it possible to generate a living map of the advance of light pollution and its spatial patterns. The data collected have made it possible to identify that certain activities are important sources of light pollution, such as, for example, amateur sports venues that keep their lights on even when they are not being used. The intensity of illuminated signs is another of the main sources reported, where users' comments point to sleep disturbances caused by intrusive light, even late at night, when the circulation of people is low and does not justify these lights remaining on. This information is crucial to guide policy recommendations to reduce unnecessary lighting and implement sustainable urban planning strategies.

Community activation has been essential to raise awareness of the project and add new reports. Through the “Light Walks” activation, which take place during the months of May and October, where people gather in different cities at the same time, and together they make a tour where they identify sources that can be reported to the platform. During the tour, they discuss the appropriate use of ALAN in different public spaces, and the particularities of each territory that should be considered in the lighting designs. Workshops, webinars and field activities have allowed participants to directly observe the effects of artificial lighting on the night sky. These hands-on experiences reinforce the importance of responsible lighting practices and encourage behavioral changes at both the individual and municipal levels.

Conclusions

Citizen science initiatives such as Glowatch represent a valuable tool for both scientific data collection and public awareness of light pollution. Involving communities in ALAN monitoring fosters a sense of environmental responsibility and generates practical information for policy makers and educators. Future developments of Glowatch aim to expand its scope, improve data validation methodologies, and strengthen collaborations with global dark sky initiatives. By equipping citizens with knowledge and tools, projects such as Glowatch contribute to the collective effort to mitigate light pollution and protect the nighttime environment.

To ensure the long-term impact of Glowatch, it is essential to continue to improve technology and outreach strategies. Expanding the scope of the project to include ways of recognizing different pollutant sources would be helpful to researchers and policy makers. In addition, fostering partnerships with international organizations will help establish Glowatch as a global model for citizen-led environmental monitoring.

References

Giardullo, P. (2023). Non-experts’ participation in processes of scientific knowledge creation: The case of citizen science. *Sociology Compass*, *17*(9), e13100.

Kocifaj, M., Wallner, S., & Barentine, J. C. (2023). Measuring and monitoring light pollution: Current approaches and challenges. *Science*, *380*(6650), 1121-1124.

Longcore T., Rich C. (2004). Ecological light pollution. *Frontiers in Ecology and the Environment*, 2(4), 191-198.

Artificial Light at Night (ALAN) advances reproductive phenology and disrupt circadian rhythm of wild flowers

Theme: Biology and Ecology

Vincent Grognuz,[1,2,*] Katja Gisler, [1,2] and Eva Knop[1,2]

[1] *Agroscope, Reckenholzstrasse 191, 8046 Zurich, Switzerland*

[2] *Department of Evolutionary Biology and Environmental Studies, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland*

v.grognuz@gmail.com
[*] *presenting author*

Introduction

Plants have evolved under a natural regime of 24-h cycle of darkness and light, and, outside of the tropics, seasonal variation in day length. Light is used by plants as a source of information and many physiological responses rely on availability of external sources of light. Over the last decades, Artificial light at night (ALAN) rapidly increased all over the world and has caused an unprecedented disruption to these natural day-and-night cycles. Surprisingly, very little is known about the effects of ALAN on reproductive phenology of wild plants.

Methods

To assess the effects of ALAN on reproductive phenology, we conducted a two-year field experiment in the Swiss lowlands. We illuminated ten independent wildflower strips while keeping ten as dark controls. To examine its influence on germination time, we filmed the germination of sown native wild plants in situ under ALAN and control conditions. Blooming phenology was monitored by weekly counting the number of flowering plants within 108 established plots, where standardized wildflower communities were sown with and without ALAN treatment. Lastly, to determine whether ALAN affects the circadian activity of wildflowers, we recorded floral nyctinastic movements—daily petal opening and closing—in a day-pollinated (*Malva moschata*) and a night-pollinated (*Silene noctiflora*) species under both treatment conditions.

Results

We found that ALAN advances germination and blooming phenology in most of the wild plant species investigated and disrupts the circadian timing of both a day-pollinated and a night-pollinated species.

Conclusions

These results suggest that ALAN could impact the reproductive capacity of wild plants and have consequences for ecosystem stability.

AN INVESTIGATION OF THE MAGNITUDE NIGHT SKY BRIGHTNESS (NSB) AND POTENTIAL ASTROTOURISM IN TAMAN NEGARA PAHANG

Theme: Social Sciences & Humanities

Z.S.Hamidi,[1,*] , N.N.M.Shariff[2]

[1] Faculty of Applied Sciences, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia
[2] Academy of Contemporary Islamic Studies, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia
[3] Institute of Science, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia
[4]Islamic Astronomy and Solar Astrophysics, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia
zetysh@uitm.edu.my
[*] presenting author

Introduction

In Malaysia, Taman Negara, Pahang is one of the protected areas that should be gazetted for eco-astrotourism. This site is not only rich in flora and fauna, but also allows one to observe the Milky Way with the naked eye. Astrotourism, also called celestial tourism, astronomical tourism, or star tourism is the practice of visiting places where celestial phenomena can be observed clearly and sustainably. People are fascinated by astronomical phenomena such as stars, meteor showers, and comets.

Fig. 1: Milky Way at Taman Negara, Pahang Malaysia with 20-21 magnitude/ arcseconds^2.

In order to observe them, however, good night sky conditions are required. Our research focuses on the magnitude of the Night Sky Brightness (NSB), which is the visual perception of the sky and how it scatters light. It is rare for the night sky to be completely dark at night. There are two types of magnitudes: apparent magnitudes and absolute magnitudes. The quality of the sky is determined by how dark the sky is, which allows the detection of very faint stars. In comparison to a city with skyscrapers, this type of scenery is not is feasible in an urban setting.

Light pollution has several detrimental effects, including skyglow, glare, light trespass, light clutter, reduced nighttime visibility, and energy waste. Beyond its impact on astronomy, light pollution also has direct consequences for human health, such as increasing the risk of cancer, disrupting wildlife, and leading to the inefficient use of energy, resources, and financial expenditure. Additionally, it diminishes our ability to appreciate the beauty of the night sky.

Methods

This study aims to develop and evaluate a probabilistic model for nocturnal sky brightness using real-world sky brightness data. To ensure consistency in sky brightness measurements, a thorough investigation is necessary. This research will employ a sky quality meter and a DSLR camera to measure the distribution of magnitudes and compare the recorded values with photographic data. The objective is to identify locations suitable for photometric studies, which could serve as sites for observatories or astro-tourism centers. Furthermore, this study aspires to establish Malaysia’s first dark-sky reserve park, fostering opportunities for eco-astrotourism and promoting the conservation of pristine night skies.

Conclusions

It was found that the magnitude within 3 nights is 20-21 magnitude/ arcseconds^2. This study aspires to establish Malaysia’s first dark-sky reserve park, fostering opportunities for astrotourism and promoting the conservation of pristine night skies. Taman Negara, Pahang is one of the best locations suitable for photometric studies, which could serve as sites for observatories or astro-tourism centers.

References

C-Sánchez, E., Sánchez-Medina, A. J., Alonso-Hernández, J. B., & Voltes-Dorta, A. (2019). Astrotourism and night sky brightness forecast: First probabilistic model approach. Sensors, 19(13), 2840.

Faid, M., Nawawi, M., Norman, M., Irwan, D., Mohd Saadon, M. H., & Nizam, N. K. (2022). The Capability of Astrotourism on Preserving Sustainability: A Case Study in Malaysia. Journal of Contemporary Islamic Studies, 8.

Hailmy, N. A. S. M., & Musa, A. (2024, December). The Impact of Light Pollution on Night Sky at the Potential Astrotourism Site in Johor Bahru: A Feasibility Study. In Journal of Physics: Conference Series (Vol. 2915, No. 1, p. 012005). IOP Publishing.

Faid, M. S., Shariff, N. N. M., & Hamidi, Z. S. (2019). The risk of light pollution on sustainability. ASM Science Journal, 12(2), 134-142.

Shariff, N. N. M., Hamidi, Z. S., & Faid, M. S. (2017). The impact of light pollution on Islamic new moon (hilal) observation. International Journal of Sustainable Lighting, 19(1), 10-14.

Hamidi, Z. S., Abidin, Z. Z., Ibrahim, Z. A., & Shariff, N. N. M. (2011, June). Effect of light pollution on night sky limiting magnitude and sky quality in selected areas in Malaysia. In 2011 3rd International Symposium & Exhibition in Sustainable Energy & Environment (ISESEE) (pp. 233-235). IEEE.

Shariff, N. N. M., Hamidi, Z. S., Osman, M. R., & Ngadiman, N. F. (2020, July). Light Pollution Measurement at Selected Sites of Peninsular Malaysia on 9th of June 2018. In Journal of Physics: Conference Series (Vol. 1593, No. 1, p. 012031). IOP Publishing.

Faid, M. S., Shariff, N. N. M., Hamidi, Z. S., Wahab, R. A., Ahmad, N., Mohd Nawawi, M. S. A., & Nahwandi, M. S. (2024). Alteration of twilight sky brightness profile by light pollution. Scientific Reports, 14(1), 26682.

Ngadiman, N. F., Shariff, N. N. M., & Hamidi, Z. S. (2020, July). Light Pollution: A Preliminary Study in Kundasang, Sabah Based on Sky Quality Meter System. In Journal of Physics: Conference Series (Vol. 1593, No. 1, p. 012023). IOP Publishing.

Shariff, N. N. M., Hamidi, Z. S., Musa, A. H., Osman, M. R., & Faid, M. S. (2015). ‘CREATING AWARENESS ON LIGHT POLLUTION’(CALP) PROJECT AS A PLATFORM IN ADVANCING SECONDARY SCIENCE EDUCATION. In ICERI2015 Proceedings (pp. 6034-6037). IATED.

Comparison of lighting habits in some larger cities

Theme: Social Sciences and Governance

Andreas Hänel[1]

[1] Working Group Dark Sky Germany and Carl von Ossietzky Univ., Oldenburg, Germany
ahaenel@uos.de

More and more cities reduce Artificial Light At Night (ALAN), mainly to reduce their financial expenses. We will compare the lighting habits in some cities with about 100 000 inhabitants.

Gütersloh with about 100 000 inhabitants is the largest city in Germany, that switches off most of the public lighting at midnight. This switch-off has a long tradition, but has been under discussion several times with changing political parties and citizen engagement, which will be discussed in more detail. The switch-off was tracked on a long-term scale from the VIIRS satellite data and documented photographically with all-sky images at 4 places during one night. From these ground based sky brightness/luminance were derived with Sky Quality Camera software (Euromix) and measured at another place with a SQM-LU. From this data, the fraction of public street lighting can be estimated and the resulting energy savings are discussed.

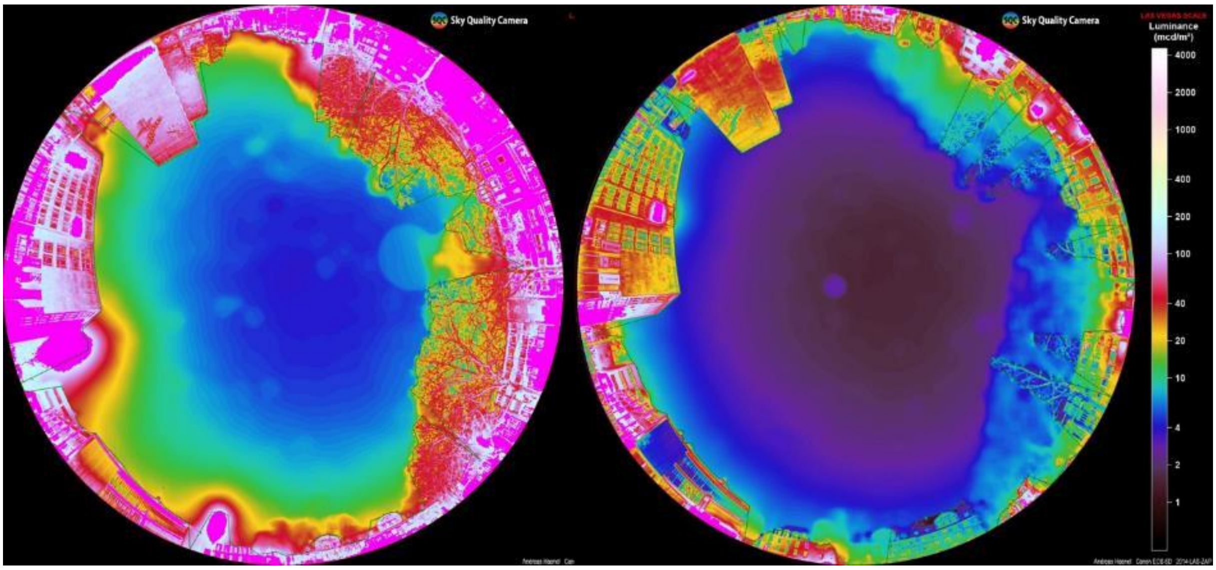


Fig. 1: Sky brightness/luminance maps as derived with Sky Quality Camera at the central place in front of the city hall in Gütersloh, zenith luminance reduced to 32%. (photos: A. Hänel)

Another interesting "test" area are the cities of the "QuattroPole" in the Greater Region "Großregion Saar-Lor-Lux" situated in three countries: Saarbrücken and Trier in Germany, Metz (and the smaller city Thionville) in France and Luxemburg. Here also photographic documentation especially of the switch-offs in France has been done. Comparison of the VIIRS data for the cities reveals the different use and changes of the public lighting.

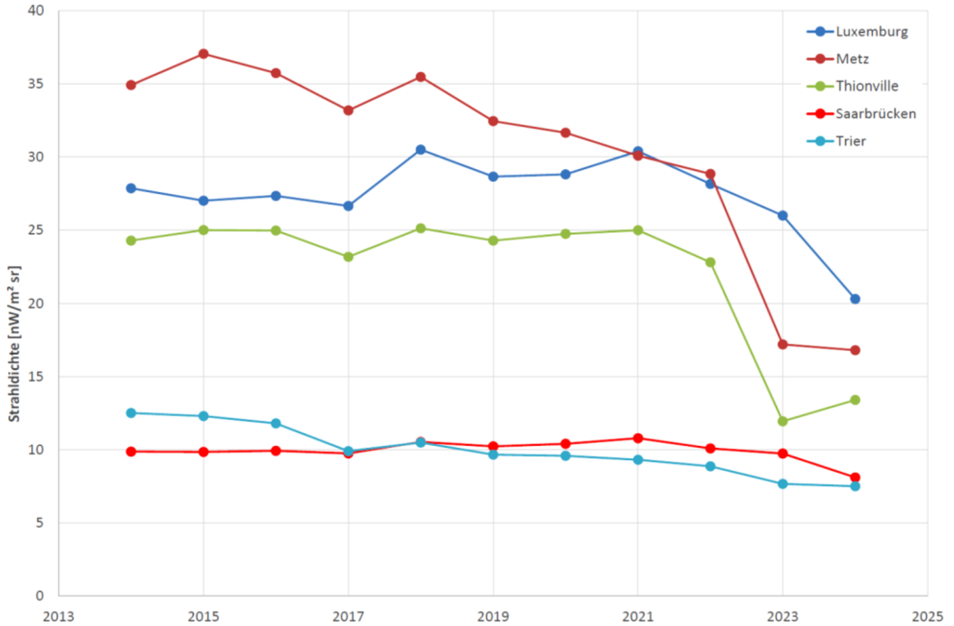


Fig. 2: The evolution of light emission as derived from the VIIRS data for cities in the QuattroPole region.

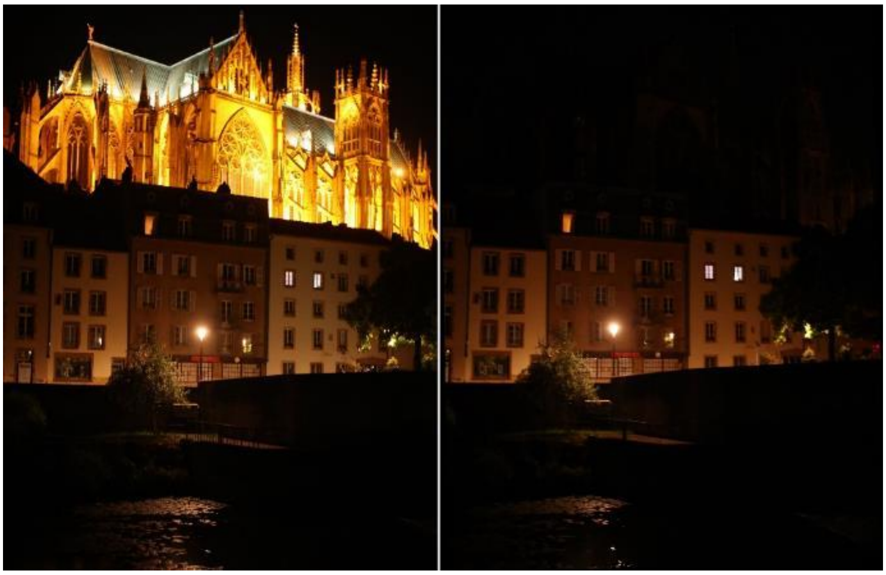


Fig. 3: Switch-off of the cathedral in Metz at 1 o'clock (photos: A. Hänel)

Simple measurements of light pollution

Theme: Measurement and Modeling

Hänel, Andreas,[1,2,*] Nyung, Ninh Khanh[2], Liedtke, Carolin[3], and Poppe, Björn[2]

[1] Working Group Dark Sky, Georgsmarienhütte, Germany
[2] Carl von Ossietzky University, Oldenburg, Germany
[3]University of Applied Sciences HAW, Hamburg, Germany
corresponding.ahaenel@uos.de
[*] presenting author

While light pollution is mostly tracked by measuring sky brightness, it is also important to control too high lighting levels at the sources. Therefore simple measurement techniques that could be used by interested citizens for a rough estimation are essential.

Main measurement quantities to limit light pollution are luminance (e.g. of billboards, signs, illuminated facades), illuminance (e.g. of roads, parking, pathways) and correlated colour temperature (or more detailed spectral power distribution).

Illuminance is measured with an illuminance meter (or luxmeter), which are available at relatively low cost. However in this price range, they do not achieve typical professional uncertainty criteria, so that their accuracy varies considerably and most are not able to measure below 10 lux, which is essential for night time measurements. In addition, many apps for smartphones exist, which however have a large scatter (DIAL, 2016), mainly due to different camera or light sensor models that are used in the phones. We will report about own measurements of the accuracy of different luxmeter models (e.g. the Opple light master, which is proposed by Dark Sky International as measurement instrument) compared to published ones (Tabaka et al., 2022).

In addition it might be interesting to test simplified measurement methods to derive **mean illuminance** and **uniformity** values with a more simple setup instead of using a standard measurement grid as required by standards (e.g. EN 13201-3), which are typically very time consuming. Exemplary tests within the DARKER SKY project will give insights to the robustness of this simplification (Liedtke et al., 2024).

Luminance measurements are taken rarely, as the measurement instruments are much more expensive and often cannot be used at low values such as the range of sky brightness values. For this some special instruments have been developed using a relative large measurement angle to increase the signal level: the Sky Quality Meter SQM (Unihedron) or the TESS instruments (STARS4ALL). Both use the logarithmic scale for astronomical magnitudes per area (mag/arcsec²) which can be approximately transformed to the photometric system (cd/m²). Therefore, especially the SQM could be used as a simplified luminance meter if the luminous surface (e.g. a billboard) completely fills the measurement angle (more than 20°) of the SQM-L (up to about 400 cd/m²).

Digital cameras can also be used as “luminance” measurement devices by using the exposure meter and making the transformation to cd/m² (Kerr, D. 2007). And after calibration of the camera, unprocessed raw images can also be used to derive luminance distributions (Gabele, 2006, Hoger, T., 2016, Fiorentin et al., 2020). Tests with different Canon cameras and lenses will be presented (Nyung, N.K., 2024).

This work has been partially supported By the EU-Interreg North Sea project DARKER SKY.

References:

DIAL, 2016: Luxmeter App vs. measuring device, https://www.dial.de/en-GB/articles/luxmeter-app-vs-measuring-device (02-04-2025)

Fiorentin, P. et al., 2020: Calibration of digital compact cameras for sky quality measures, Jour. Quant. Spec. Rad. Transfer 255, 107235i

Gabele, H. 2006: The Usage of Digital Cameras as Luminance Meters, Diploma thesis, Uni. App. Sci. Cologne

Hoger, T., 2016: Lichttechnische Untersuchungen mit einer Standard-Digitalkamera, Verkehrsunfall und Fahrzeugtechnik, Febr. 2016, 50

Kerr, D.A., 2007: APEX—The Additive System of Photographic Exposure, http://dougkerr.net/Pumpkin/articles/APEX.pdf (02-04.2025)

Liedtke et al., 2024: Light Pollution Mapping Framework, DARKER SKY report, draft 2024

Nyung, Ninh Khanh, 2025: Kalibrierung von DSLR-Kameras zur Qualitätskontrolle medizinischer Monitore, Master thesis Univ. Oldenburg

Tabaka, P., Wtorkiewicz, J., 2022: Analysis of the Spectral Sensitivity of Luxmeters and Light Sensors of Smartphones in Terms of Their Influence on the Results of Illuminance Measurements—Example Cases, Energies 2022, 15, 5847

North York Moors National Park International Dark Sky Reserve – Delivering dark skies friendly lighting projects at scale through community engagement

Theme: Technology and Design

Mike Hawtin*, Head of Nature Recovery Projects

North York Moors National Park Authority. York. UK

m.hawtin@northyorkmoors.org.uk

* *presenting author*

Introduction

Since being designated as an International Dark Sky Reserve in December 2020 the North York Moors National Park Authority (NYMNPA) has undertaken one of the largest dark sky friendly lighting retrofit initiatives of private lighting in the UK with dozens of grant funded projects delivering in excess of 1000 fixtures converted to date

Fig. 1: Hawnby Village scheme – the first complete village retrofit scheme

The Authority was also instrumental in gaining support from North Yorkshire Council for rollout of 'part night' dark skies friendly 2700K public streetlighting beyond boundaries, right across England's largest county.

A significant program of press and community engagement has driven local, regional and national media coverage, with international interest from as far apart as Canada and France.

Public interest continues to develop with many more community schemes planned, to deliver on six key benefits of protecting dark skies: Culture & Heritage, Rural Economy, Education, Wildlife, Human Health and Energy Usage

Methods

Initial project work was underpinned by a significant NYMNPA outreach program to engage, educate and demonstrate. To date over 100 presentations have been delivered to local and regional councils, businesses, community groups and landowners as well as manufacturers, local suppliers and installers. A demonstration project delivery phase was undertaken to upgrade a range of sites including residential properties, public houses, visitor centres, village halls, stables and farms to show what was possible with sensitive and responsible use of lighting and to set up local advice, supply and install chains.

Fig. 2: Community engagement and recognition award

The initiative then moved up in scale to convert whole valleys and villages. To embed conservation and active stewardship at the heart of the community the North York Moors Dark Skies Friendly initiative was expanded to include a Community award. Working in partnership, this scheme is also being rolled out in the Howardian Hills National Landscape and advice is being offered beyond boundaries at sites such as York St John University Campus

Protecting dark skies and nocturnal habitats is being integrated into the wider conservation work of the National Park Authority with Nature Recovery teams, farm advisors and rangers being trained to look out for opportunities to engage with property owners to identify potential improvements. Grant schemes such as hedgerow creation now include identifying light pollution in constraints checking to ensure that ecological benefits are maximized.

Globally, the unprecedented brightening of the night sky poses severe consequences for all living things (Kyba et al. 2023). The call to protect dark skies has seen a growth in national parks also delivering leisure-based festivals to raise awareness of the impact of light pollution. Taking an ecological justice lens that recognises environmental crises are deeply intertwined with social challenges, York St John University's Hall and Paddison's (in press) research explores the experiences and benefits of stakeholder engagement in dark-sky festivals. Conducted during the North York Moors National Park, United Kingdom, Dark-skies Festival in February 2024, the study identified regenerative stakeholder practices and behaviours. The significance of this research is evidenced by the raised ecological awareness of stakeholders engaged in dark-sky festivals, and the sustainable practices that are helping to mitigate light pollution in response to the climate crisis.

As part of working beyond boundaries the NYMNPA is actively pursuing the creation of a buffer zone around the National Park and more widely a group called the Northern England Dark Skies Alliance is being formalised to share best practice and to create a stronger regional voice.

Conclusions

The success of public engagement is proven, and interest in reducing light pollution continues to grow. To date projects have been delivered with dozens of property owners, multiple communities, landowner estates, Ampleforth Abbey religious community, National Trust, Forestry England and Howardian Hills National Landscape. Seven Dark Skies Friendly Community awards have been made with six more in the process. Large scale projects are in progress with Camphill Community Trust at Botton Village, National Trust across all farm holdings in Bransdale and RAF Fylingdales early warning base is now reengaged to look at reducing light pollution at the prominent Ministry of Defence site. The NYMNPA is also helping advise farming advice teams in other protected landscapes and would like to share experiences and knowledge of their work to help others do the same.

References

Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C. C. M., Elvidge, C. D., Baugh, K., Portnov, B. A., Rybnikova, N. A., & Furgoni, R. (2016). The new world atlas of artificial night sky brightness. *Science Advances*, *2*(6). https://doi.org/10.1126/sciadv.1600377

The International Dark-Sky Association. (2012). *Fighting light pollution: smart lighting solutions for individuals and communities*. Stackpole Books.

Schulte-Römer, N., Meier, J., Söding, M., & Dannemann, E. (2019). The LED paradox: how light pollution challenges experts to reconsider sustainable lighting. *Sustainability*, *11*(21), 6160.

Tavares, P., Ingi, D., Araújo, L., Pinho, P., & Bhusal, P. (2021). Reviewing the role of outdoor lighting in achieving sustainable development goals. *Sustainability*, *13*(22), 12657.

Bará, S., Falchi, F., Lima, R. C., & Pawley, M. (2021). Keeping light pollution at bay: A red-lines, target values, top-down approach. *Environmental Challenges*, *5*, 100212.

Hall, J., Paddison, B., & Jones, B., (in Press). The Dark Matters: Dark-Sky Leisure Events as Regenerative Spaces for Climate Justice. *Annals of Leisure Research.*

Local Government Light Pollution Solutions: Through the lens of Kotters Change Theory

Theme: Governance and Regulation

Kate M. Hofmeister[1*], Simone Bright[1], Ebony King[1]

[1] *Sunshine Coast Council, Caloundra, Australia*
Kate.hofmeister@sunshinecoast.qld.gov.au
[*] *presenting author*

Introduction

The Sunshine Coast Council is a local government with a vision to be Australia's most sustainable region. Connected. Liveable. Thriving. Council's Environment and Liveability Strategy recognises that as our population continues to increase, planning for the management of night skies by reducing light pollution on the Sunshine Coast is a priority**.** To respond to this, the strategy incorporates a policy position to recognise, protect and celebrate dark skies.

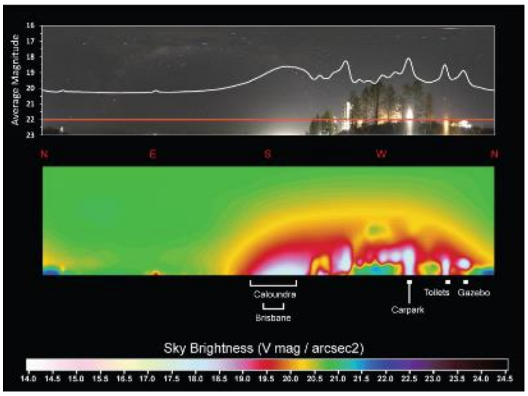


Fig. 1: Benchmark Artificial light at Night study 2017 (Pendoley Environmental)

Sunshine Coast Council is leading a proactive response to light pollution through integrated policy, community engagement and education, responsible lighting outcomes and ecological conservation. Central to this effort is the proposed Dark Sky Reserve, spanning close to 900 square kilometers of hinterland, which aims to preserve natural nightscapes, support nocturnal wildlife, enhance health and wellbeing, reduce skyglow and carbon emissions and support local businesses. A key focus of the Council's light pollution strategy is the protection of endangered marine turtles that nest on Sunshine Coast beaches, undertaken in partnership with citizen scientists.

Case Study

We present a broad overview of our approach to light pollution as a case study through Kotters 8 Step Change Theory (Kotter 2012).

Create Urgency: We shared data and stories to create a sense of urgency for necessary change. This was achieved by sharing the data outcomes of a benchmark survey for light pollution undertaken at turtle nesting beaches, alongside real community stories of hatchling mortality from light pollution disorientation. Community advocacy also highlighted poor lighting outcomes for the local astronomical society, in addition to the human health impacts.

Build Coalition: We assembled technical and community experts from various sectors across our local government and community that could champion dark sky principles and outcomes with authority, expertise and credibility. TurtleCare citizen scientists identified problematic areas, communicated with landholders, started local focus groups and submitted feedback on new developments. Technical specialists reached out to lighting suppliers to seek custom solutions to ecological needs and created custom solutions. Scientific experts shared their knowledge to shape management approaches and policy development. A government community of practice was created for light pollution and marine turtles, which facilitated inter-state communication and knowledge sharing.

Develop a Vision: Initially driven through economic opportunity, engagement of technical experts in the development of an Urban Lighting Master Plan in 2016 facilitated the integration of dark sky principles in the strategic planning for lighting strategy for the region. Similarly, a Technical Advisory Panel was established to develop the 2022 Marine Turtle Conservation Plan, which guided the thematic focus on light pollution. More recently, in 2023 the Environment and Liveability Strategy has cemented the vision for the future, with the inclusion of a policy position: The distinctive and diverse landscape is preserved to maintain the beauty of the area, with Dark skies are recognised, protected and celebrated.

Communicate the Vision: The change vision for the region's night sky was communicated through various channels, targeting stakeholder groups by the geographic location and interest groups. Community evaluation of lighting retrofit projects allowed for two-way communication between government and community, providing a basis for continued investment into dark sky compliant lighting infrastructure. Community co-design was undertaken by researchers in partnership with Council which identified the major barriers for behaviour adoption at a personal, interpersonal, community and policy level.

Empower Others to Act: Investment into ecological research on commercially available lighting and its ecological impact (King *et al.* 2025) has facilitated broader management outcomes, empowering private landholders, private enterprises, and other government organisations to make evidence-based lighting choices, fostering collective action. Development of technical guidance materials integrating dark sky principles and the Australian Governments National Light Pollution Guidelines for Wildlife, for electrical assets on public and private land has empowered local governments across Australia to act.

Short-Term Wins: Various lighting retrofit projects in ecologically sensitive and residential areas have demonstrated a proof of concept to community. Projects at turtle nesting beaches have demonstrated greater turtle hatchling sea-finding behaviour post-change. Social acceptance of a changed landscape of lighting in urban coastal environments have been evaluated and are highly supported by community.

Consolidate: Evaluation of the night sky quality in 2022 against the 2017 benchmark has reinforced the importance of focus on this area, with demonstrated increases between 22 - 77% over the five-year interval. The survey identified an improvement in the direct light impacts to nesting beaches yet highlighted the broader growth of problematic sky glow for the growing regional population.

Anchor Change: Cultural shift has occurred, with an observation of dark sky principles being integrated into design process. This has demonstrated a systems thinking outcome, where the framework we have implemented is accepted as an organisational norm throughout policy and procedure, connecting the complex organisational relationship between departments towards a unifying vision.

References

Kotter, JP (2012) Leading change (New edition) Harvard Business Review Press.

King EJ, Hofmeister KM, Bosshard SC, Limpus CJ, Scales KL (2025) To sea in the dark: assessing effects of LED streetlights on sea-finding in marine turtle hatchlings. *Wildlife Research* 52, WR24151.

From Science to Action: Towards sustainable lighting near freshwater ecosystems
Theme: Biology & Biology and Ecology

Franz Hölker[1,2,*], Alessandro Manfrin[3], Sibylle Schroer[1], Benedikt Huggins[1] & Andreas Jechow[1,4]

[1]Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany
[2]Institute of Biology, Freie Universität Berlin, Berlin, Germany
[3]Institute for Environmental Sciences, RPTU Kaiserslautern-Landau, Landau, Germany
[4]Brandenburg University of Applied Sciences, Brandenburg an der Havel, Germany
franz.hoelker@igb-berlin.de
[*]presenting author

Artificial light at night (ALAN) is increasingly recognized as a major driver of global environmental change (Linares Arroyo et al., 2024). With light emissions rapidly increasing and nearly half of the global population living within 3 km of a freshwater body (Kummu et al., 2011), rivers and lakes are more exposed than ever to light pollution. Despite their critical ecological role - both as biodiversity hotspots and as essential resources for human well-being - freshwater ecosystems have received little attention in ALAN research, even though the impacts of light pollution on freshwaters are broad and affect all levels of biodiversity (Hölker et al. 2023). However, addressing this issue requires innovative lighting strategies that explicitly prioritize the protection of freshwater biodiversity.

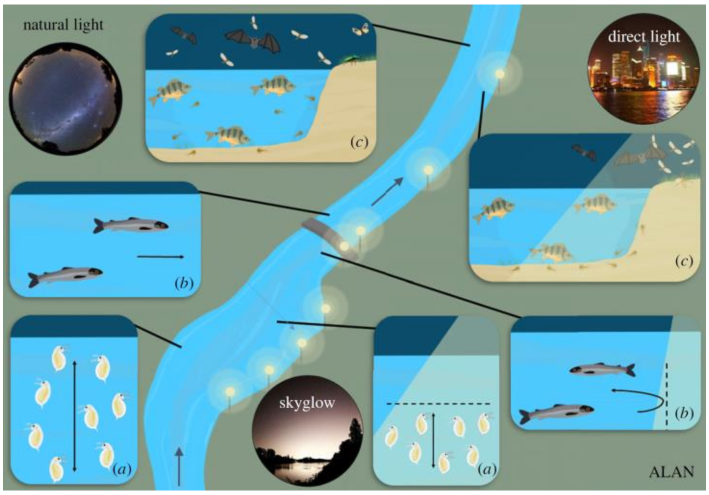


Figure 4. Examples of ecological consequences of ALAN along a river–lake continuum, showing interference (a) with zooplankton diel vertical migration, (b) longitudinal migration of fish and (c) predator–prey interactions, including insect drift and effects across the land–water interface. The left side of the river illustrates the situation under naturally dark skies, and the right side highlights the impacts of ALAN. Arrows show the direction of river flow (from Hölker et al. 2023).

Efforts to reduce light pollution have mainly focused on general approaches rather than those specifically designed for freshwater environments. Well-documented strategies such as proper light orientation, shielding, adjusting intensity as needed, and spectral tuning offer effective ways to reduce light pollution. However, targeted solutions to minimise the impact of ALAN on inland waters and their surrounding habitats remain underdeveloped. This presentation examines ALAN effects on freshwater biodiversity and ecosystems, and explores innovative mitigation strategies. Drawing on recent publications and ongoing research, it highlights approaches to reducing the ecological impact of ALAN near freshwaters.

Freshwater bodies are closely interconnected with terrestrial landscapes, requiring mitigation strategies that address both realms. For example, many ALAN-sensitive species, such as aquatic insects and vertebrates, have life cycles that span both aquatic and terrestrial habitats (Petrović et al., 2025; Kühne et al., 2021). Therefore, effective ALAN management in freshwater ecosystems should focus on four key measures (Hölker et al., 2023; Manfrin et al., in press). First, unnecessary lighting should be avoided near freshwater systems, ensuring that illumination is used only when absolutely necessary to prevent ecological disturbances. Second, lighting should be precisely directed to illuminate only intended areas, preventing unnecessary spillover onto water surfaces or riparian habitats, as well as avoiding upward or horizontal emissions. Third, light levels should be adapted based on ecological sensitivity, both spatially and temporally. This means dimming or switching off lights during critical periods for species, e.g. periods of waterfowl breeding or fish migration, and reducing illumination in sensitive areas like bridges, shorelines, and riverbanks to strike a balance between human safety and environmental protection. Fourth, while spectral tuning - e.g., reducing short-wave emissions - has been suggested to be effective in protecting terrestrial insects and mammals, its impact on freshwater species is limited. Many aquatic organisms rely on the full visible spectrum, making strategies such as minimizing unnecessary lighting, directing light effectively, and adjusting light levels more effective. Finally, environmental regulations often fail to adequately address ALAN. Where legal protections exist, they typically apply only to species with special conservation status, leaving many vulnerable species and ecosystems unprotected (Schroer et al., 2020, Yakushina 2025). A notable exception is Germany's *Insect Protection Act*, which incorporates light pollution considerations into national conservation law. However, specific regulations for inland waters are still pending, which underlines the need for further legislative action.

In conclusion, given the well-documented effects of light pollution on freshwater ecosystems, implementing effective lighting strategies is essential. By integrating ALAN mitigation into broader environmental policies, we can better protect freshwater and riparian food webs while maintaining necessary nighttime lighting for human activities.

References

Hölker, F. et al. (2023). Light pollution of freshwater ecosystems: principles, ecological impacts and remedies. Phil. Trans. Roy. Soc. B, 378, 20220360.

Kühne, J. et al. (2021). Impact of different wavelengths of artificial light at night on phototaxis in aquatic insects. Int. Comp. Biol., 61, 1182-1190.

Kummu, M. et al. (2011). How close do we live to water? A global analysis of population distance to freshwater bodies. PloS one, 6, e20578.

Linares Arroyo, H. et al. (2024). Monitoring, trends and impacts of light pollution. Nat. Rev. Earth Env., 5, 417-430.

Manfrin, A. et al. (in press) Effect of artificial light at night on food webs in freshwater ecosystems.

Petrović, T.G. et al. (2025). Developing under artificial light is not so bright: Oxidative stress as a physiological response to light pollution across amphibian life stages. Comp. Biochem. Physiol., 302, 111819.

Schroer et al. (2020). Working with inadequate tools: legislative shortcomings in protection against ecological effects of artificial light at night. Sustainability, 12, 2551.

Yakushina, Y. (2025). Light pollution regulations and where to find them. J. Env. Man., 373, 123757.

Shifting the Focus: Effective Legislative Strategies for Reducing Light Pollution

Theme: Governance and Regulation

Benedikt Huggins[1,*] Conrad Schittko[1], Sibylle Schroer[1], Sophia Kimmig[1], Sarah Kiefer[1], Franz Hölker[1]

[1] Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
benedikt.huggins@igb-berlin.de
[*] presenting author

Introduction

Research on Artificial Light at Night (ALAN) has in recent years expanded significantly and has helped close many knowledge gaps. However, despite growing awareness of the detrimental effects of ALAN, effective regulation remains a challenge. Currently, lighting practices are governed primarily by technical norms and not by state legislation (Laws 2024). This regulatory gap can be attributed, in part, to a historical focus on the benefits of artificial lighting rather than its detrimental ecological and health effects. Even where legislation to mitigate ALAN exists, approaches vary widely, and success has been limited (Yakushina 2025).

While artificial light enhances safety, productivity, and aesthetics, it can also harm organisms – including humans – and ecosystems when applied in times and places where it does not naturally occur. Hence, legislation must address the spatial and temporal dimensions of ALAN. Crucially, areas where lighting is needed and areas requiring protection do not necessarily overlap, necessitating a more nuanced regulatory approach. Still, comprehensive legislation is rare at best. This presentation argues that effective legislation is lacking because constraints specific to ALAN have not been adequately addressed. Addressing these requires a legal approach that tends to the characteristics of ALAN, not to its particular uses. To ensure effectiveness, regulatory complexity and administrative burdens should be minimized wherever possible.

Key Legal Constraints

Among the key legal constraints that hinder regulatory effectiveness three are highlighted:

1. ALAN has many diverse applications (e.g. street lighting, sports facilities, advertisements, façades, etc.). Existing legislation is often tailored to specific applications, making comprehensive regulation difficult to enact without significant political will.
2. Any regulation must address a very high number of (a broad range of different) emitters. Requiring approval procedures for every application is unfeasible. In addition, insufficient public awareness further complicates compliance.
3. Assessing ecological effects of ALAN is complex. Despite scientific advancements, expertise in light emission assessments remains sparse, making regulatory evaluations imperfect and inconsistent – particularly in protected areas (Schroer et al. 2020).

Regulatory Design Elements

To address these constraints, this presentation proposes a set of design elements that enable to overcome the outlined legal constraints. Using specific legal instruments or approaches could circumvent or mitigate the obstacles. These design elements should be considered if regulatory measures and legislation are recommended. A spatial protection framework should serve as the foundation for any lighting regulation. Key instruments are – ecologically justified – emission thresholds, which limit the spatial and temporal distribution of light but do not inhibit the use of ALAN. Additionally, clear control and calculation mechanisms must be established to ensure both the efficiency and effectiveness of legislative implementation.

A crucial prerequisite is to focus on emission control and not on establishing protection goals. Any comprehensive regulation must be applicable without complex environmental impact assessments. While an abstract regulatory framework may cause unwanted effects in isolated cases, such an approach is essential for the broad application. Specific protection measures – such as those for certain species or ecologically sensitive areas – can be layered onto this general framework, though their scope will inherently remain limited.

The use of and protection from ALAN can be spatially delineated through a zoning system. Such an approach enables the classification of areas based on human lighting needs, allowing a structured system with differentiated ambition levels. Zoning systems exist. But effectiveness and legal certainty require that such a framework should leverage existing, legally established zoning systems rather than creating entirely new classifications, which could introduce – among others – conflicts with land-use planning laws. Utilizing existing zoning not only simplifies administrative procedures but also removes the need for artificial light at night (ALAN)-specific expertise when allocating zones.

Legislation should prioritize installation-specific emission thresholds rather than technical and design requirements, which must account for the intended use of ALAN (e.g., sports parks) and, thus, add significant regulatory complexity. This complexity has likely impeded the development of comprehensive regulations. Instead, the focus should be on controlling illuminance and luminance emissions. Thresholds should be determined through an ecological risk assessment that integrates a broad range of studies to establish lighting levels that do not cause significant ecological harm. Limit values should be enforced at the point where the functional necessity of lighting ends, ensuring that emissions do not extend beyond areas of intended use. Decoupling lighting use and protection goals by imposing vertical illuminance limits is a key design feature.

Regulatory enforcement primarily relies on approval procedures rather than intervention in existing lighting infrastructure, which is often administratively burdensome and difficult to enforce. Compliance with limit values must be verifiable through standardized photometric calculations, which should be a mandatory part of the approval process. This allows authorities to assess compliance without requiring specialized expertise. Direct measurements, which are resource-intensive, should only be used for compliance verification when necessary.

References

Schroer S, Huggins B, Azam C, Hölker F (2020) Working with Inadequate Tools: Legislative Shortcomings in Protection against Ecological Effects of Artificial Light at Night, Sustainability 12: 1-38

Yakushina Y (2025) Light pollution regulations and where to find them, J Environ Manag 373:123757

Law CK, Lai SYT, Lai JHK (2024) Light Pollution Control: Comparative Analysis of Regulations Across Civil and Common Law Jurisdictions, Laws 13:74

The South African Astro-Tourism Strategy, an ally to protect the dark night sky

Theme: Society Governance and Regulation

Laeticia Jacobs

Department of Tourism, Pretoria, South Africa

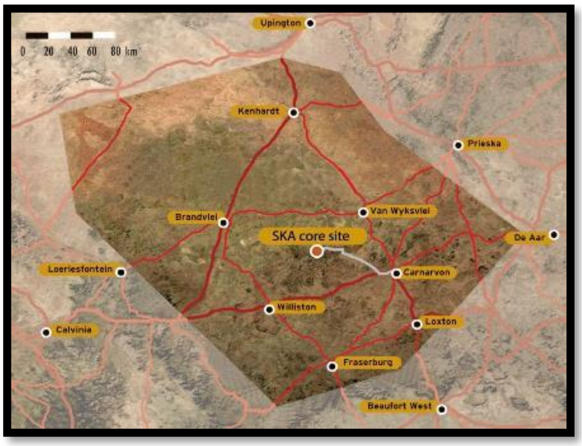
Ljacobs@tourism.gov.za

The South African night sky is largely free from light pollution, with low cloud conditions. With a geographically advantageous position, South Africa points towards the centre of the galaxy, allowing observers to view the densest and most interesting parts of the Milky Way. The Southern Sky offers unique options for astrophotography and star gazing (Department of Tourism, 2024). These aspects are key conditions for growing the niche market, Astro-Tourism. Astro-Tourism is defined as tourism using the natural resource of unpolluted night skies, and appropriate scientific knowledge for astronomical, cultural and environmental activities" (Fayos-Solé et al., 2014: 664).

South Africa is committed and supported by the National Astro-Tourism Strategy, to protect and regulate the use of light and provide resources to conserve the dark night sky. This is in line with the International Dark Sky Principles concerning Responsible Outdoor Lighting.

Light pollution is a rising global challenge that can negatively affect both conservation and human livelihood. Public awareness and education should include the proper application of quality outdoor electric lighting, according to international standards and community and local government awareness. The more the general public is made aware on the impact of light pollution, the more they would value and appreciate the beauty of the sky (van Wyk-Jacobs, 2018). Ultimately, this will grow the country into a leading astro-tourism destination.

A key legislation in South Africa, is the Astronomy Geographic Advantage Act 2007 (Act No. 21 of 2007) developed by the Department of Science, Technology & Innovation (DSTI). The Act aims to protect areas that are of strategic national importance for astronomy and related scientific endeavours through proper regulation. Furthermore, The DSTI furthermore, issued a government gazette in 2019, as notice for regulations of Astronomy Protection for dark-skies within the Sutherland Central Astronomy Advantage Area.



Source: SKA South Africa (2014)

Figure 5: Selected towns within the Astronomy Geographic Advantaged Area, Northern Cape Province

Astro-Tourism in South Africa is led by the Department of Science, Technology and Innovation and the Department of Tourism who established the National Astro-Tourism Governance Body. This body is a collaboration between the many government departments, academic, and private sector institutions that have a major role in the success of this Strategy as well as the advocates to preserve the dark night skies.

Figure 2: Astro-Tourism Governance Body

Source: National Astro-Tourism Strategy, South Africa 2023

The Astro-Tourism Strategy and the Implementation Plan were developed through a qualitative methodology. It was strengthened by the semi-structured and structured focus groups and interviews with key tourism and astronomy stakeholders. The multi-research instrument approach ensured an in-depth understanding of the astro-tourism demand and supply and the impact of its sustainable socio-economic development and dark sky preservation.

This paper, therefore investigates how the development of the National Astro-Tourism Strategy and the establishment of the Governance Body supports the preservation of the dark night sky in South Africa and increased community and local government buy-in and awareness.

References

Department of Science and Innovation (2007). No. 21 of 2007: Astronomy Geographic Advantage Act, 2007.

Department of Tourism (2024) Draft National Astro-Tourism Strategy and Implementation Plan.

Fayos-Solé E, Marín C and Jafari J (2014) Astrotourism: No requiem for meaningful travel. Revista de Turismo y Patrimonio Cultural 12(4): 663-671.

Van Wyk-Jacobs (2018) Astro-tourism as a catalyst for rural route development. PhD Dissertation, University of Pretoria: South Africa.

Technical design of an insect friendly road light – from theory to practice

Theme: Technology and Design

Andreas Jechow,[1,*] Birte Saathoff,[2] Stephan Völker,[2] Franz Hölker, [3] and Sibylle Schroer[3]

[1] Brandenburg University of Applied Sciences, Brandenburg an der Havel, Germany
[2] Technische Universität Berlin, Berlin, Germany
[3] Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
andreas.jechow@th-brandenburg.de
[*] presenting author

Public outdoor lighting is a major contributor to light pollution (Riegel 1973) and therefore among the drivers of insect decline (Grubisic et al. 2019, Owens et al. 2020). There exist several approaches towards so called "insect friendly lighting" including dimming, spectral tuning and spatial confinement, often simply termed "shielding". Surprisingly, the latter has seen less attention although it seems very effective, particularly because it most often harmonizes human needs, and reduced ecological impact. Owens et al. (2024) conclude that the effects of spectral tuning and dimming are often ambiguous and frequently negligible and they point out that relative to its potential, shielding has attracted strikingly little scientific attention.

We have recently developed tailored and shielded LED road lighting that only directs light to the target area. This is achieved in two steps: i) via a tailored spatial light distribution realized by optics and ii) additional shielding of the high radiance/luminance at the exit point of the

Fig. 1: Frontal view comparing emission from a conventional LED luminaire (left) to our newly developed tailored and shielded LED luminaire (right) at one municipal site, both producing the same illuminance at the target area. (Images: A. Jechow)

luminaire (Schroer et al. 2021, Dietenberger et al. 2024). Particularly the latter renders the luminaire nearly invisible beyond the lit area (Fig. 1), while most conventional luminaires can be seen as point sources from large distances (Fig. 2). These tailored and shielded luminaires were effective in reducing insect attraction drastically while producing the same illuminance distribution on the ground at the target area as conventional lighting (Dietenberger et al. 2024). Results were obtained at multiple municipal sites across a gradient in skyglow and urbanization, as well as on a controlled field site. In this presentation, we will provide insights to the technological design process of the luminaires. This is a complex task as the luminaires were customized for the specific lighting situation at each site (here footway, cycle way, road with low traffic volume).

We will provide a wide variety of before-after comparisons including goniometer measurements and field measurements of the luminaires in the laboratory and outdoors as well as the design approach and modelling results. Additionally, different aesthetic requirements had to be met following the needs of a total of 7 municipalities. As a result, a modern flat road luminaire (TAL-shield, Selux GmbH, Berlin) and a version with classical luminaire appeal (based on BETA, Selux, GmbH, Berlin) were realized. Further, we will present the lessons learned from the two large projects that in total covered a period of 5 years. Working with different stakeholders, decision makers and logistics (within a pandemic) caused several unexpected obstacles that had to be resolved. Furthermore, strong customization of the spatial distribution also raised requirements on the precision of the lighting installations. A brief summary on recent, yet unpublished, results on insect monitoring will also be given.

Fig. 2: View of the road illumination (same site as in Fig 1) comparing a conventional LED luminaire (left) to our newly developed tailored and shielded LED luminaire (right). (Images: A. Jechow)

Acknowledgement

This work is the achievement of the large team of the AUBE and NaturLicht projects and we want to thank Manuel Dietenberger, Stefan Heller, Sophia Johannisson (Dehn), Gregor Kalinkat, Sarah Kiefer, Sophia Kimmig, Juliane Körner, Johanna Oldenburg (Reinhard), Daniel Raddatz, Bjarne Riesbeck, Heike Schumancher and Charis Wuthenow. We also want to thank Selux GmbH for their patient cooperation as well as the involved municipalities.

References

Dietenberger, M., Jechow, A., Kalinkat, G., Schroer, S., Saathoff, B., & Hölker, F. (2024). Reducing the fatal attraction of nocturnal insects using tailored and shielded road lights. Communications Biology, 7(1), 671.

Grubisic, M., van Grunsven, R. H., Kyba, C. C., Manfrin, A., & Hölker, F. (2018). Insect declines and agroecosystems: does light pollution matter? Annals of Applied Biology, 173(2), 180-189.

Owens, A. C., Cochard, P., Durrant, J., Farnworth, B., Perkin, E. K., & Seymoure, B. (2020). Light pollution is a driver of insect declines. Biological Conservation, 241, 108259.

Owens, A. C., Pocock, M. J., & Seymoure, B. M. (2024). Current evidence in support of insect-friendly lighting practices. Current Opinion in Insect Science, 66, 101276.

Riegel, K. W. (1973). Light Pollution: Outdoor lighting is a growing threat to astronomy. Science, 179(4080), 1285-1291.

Schroer, S., Austen, K., Moczek, N., Kalinkat, G., Jechow, A., Heller, S. & Hölker, F. (2021). Towards insect-friendly road lighting—a transdisciplinary multi-stakeholder approach involving citizen scientists. Insects, 12(12), 1117.

Monitoring Artificial Sky Radiance at major Astronomical Observatories in Chile

Theme: Measurement and Modeling

Andreas Kaufer,[1,*] Angel Otárola,[1] Alain Smette,[1] and Martin Aubé[2]

[1] European Southern Observatory, Santiago, Chile
[2] Université de Sherbrooke, Quebec, Canada
akaufer@eso.org
[*] presenting author

Abstract

All major professional astronomical observatories in the North of Chile benefit from low levels of artificial light pollution with increases in zenith radiance over the assumed natural levels clearly below one percent to a few percent (Falchi et al. 2023).

We have studied the evolution of the artificial sky radiance applying state-of-the-art radiation transfer models (ILLUMINA, Aubé & Simoneau 2018) to Visible Infrared Imaging Radiometer Suite (VIIRS) satellite radiance data from 2012 to 2024 at the current and future sites of several major astronomical observatories in operation and construction.

We find that the artificial sky radiance has substantially increased over the last decade at all observatory sites. In particular the almost pristine skies above the Paranal and Armazones observatory sites of the European Southern Observatory (ESO) have suffered and artificial sky brightness at zenith in V band has typically doubled (and tripled at 45 degrees elevation).

We have used our ILLUMINA models to identify the main contributors to the increased sky radiance around every observatory site and estimate the impact of possible mitigation measures to recover the pristine skies. The work shows that targeted mitigation measures based on thorough model evaluations could provide substantial improvements of the sky darkness without necessarily demanding global changes to existing installations.

We have further used our ILLUMINA models to quantitatively assess the impact on the sky brightness of new installations planned nearby the observatory sites as part of their environmental evaluation process. The high flexibility of ILLUMINA to add individual luminaries of any kind at any location to study their impact has proven to be of utmost importance for a quantitative assessment. Further, the possibility to consider realistic observing conditions like the presence of thin cirrus clouds that act like mirrors for nearby artificial light sources provides important insight for the impact studies.

In our presentation we will introduce our modelling approach and illustrate our findings with examples from different astronomical observatories in the North of Chile.

References

Aubé M, Simoneau A, (2018) New Features to the Night Sky Radiance Model Illumina: Hyperspectral Support, Improved Obstacles and Cloud Reflection, Journal of Quantitative Spectroscopy and Radiative Transfer 211: 25-34

Falchi F, Ramos F, Bará S, et al. (2023) Light pollution indicators for all the major astronomical observatories. Mon Not R Astron Soc 519: 26-33

Turning sky quality measurements into art and public outreach

Theme: Social Sciences & Humanities

Zoltán Kolláth[1,*]

[1]*Eszterházy Károly Catholic University, Department of Physics, Eger, Hungary*
kollath.zoltan.samuel@uni-eszterhazy.hu
[*] *presenting author*

We developed a photography-based sky quality measurement tool and obtained dozens of high-resolution all-sky mosaics during the last few years. When I realized the beauty of natural variations in sky colour (Kolláth & Jechow 2023), I turned my measurement data into a photography exhibition and a fulldome (planetarium) film. The high-resolution images allowed for huge (1mx1m) prints, a nice tool for presenting light pollution-related information to the general public. The exhibition has been displayed in several locations in Hungary over the past two years.

The next step was to develop a fulldome film for immersive entertainment. The film shows the results of our study on the quality and the variation of the colours of the night sky. We cannot see the night sky's colours, but spectra taken under the pristine sky can tell us precisely the actual colour of the night sky. The planetarium show demonstrates the natural beauty of the natural night. The film premiered at the Fulldome Festival Brno 2024, winning the Best Short Award. The jury emphasised the following:

"The film effectively deconstructs the misconception that the night sky is dark blue or colourless by sharing the results of recent research, revealing some surprising sources of night-time colour. It is a good demonstration of how scientific research can be communicated in planetariums, and we thought the circular transitions were a nice way to demonstrate the different colours of the sky."

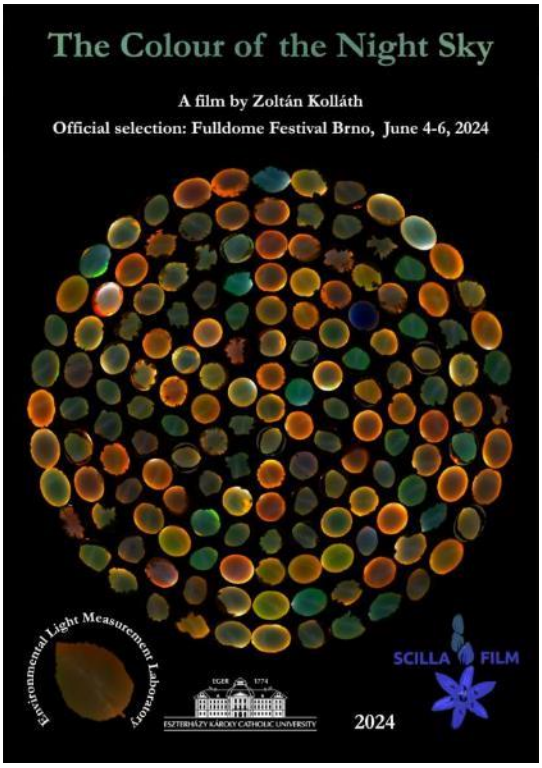


Fig. 1: The poster of the film: The Colour of the Night Sky

During my presentation, I will describe how the film was made and propose a wider collaboration to extend it with photos taken by researchers at different locations.

Acknowledgments

This research was supported by the Hungarian Scientific Research Fund (OTKA K143376)

References

Kolláth, Z., & Jechow, A. (2023). Natural variation of the colour and spectrum of the night sky observed at a potential European reference site for dark skies. Journal of Quantitative Spectroscopy and Radiative Transfer, 303, 108592

Representing and interpreting digital camera-based sky quality measurements

Theme: Measurement and Modeling

Zoltán Kolláth,[1,*] János Sztakovics,[1] and Tamás Hajdu[1]

[1] *Eszterházy Károly Catholic University, Department of Physics, Eger, Hungary*
kollath.zoltan.samuel@uni-eszterhazy.hu
[*] *presenting author*

We started using digital cameras to measure the night sky quality in 2008 when we launched the first dark-sky park in Hungary and Europe. Over the past 17 years, the methods have been continuously improved, and the quality of the cameras has improved in parallel. Over the last five years, we have collected high-resolution and high-precision data at locations where light pollution levels are minimal (Kolláth & Jechow 2023).

Based on our spectral measurements, it is possible to convert the RGB images to different units. Then, a primary representation of the photos is a radiance map on a colour scale. Correlated colour temperature (CCT) is frequently used as an additional quality indicator. However, different colours may result in similar CCT. We recommend using a 2D colour diagram or our False Colour Enhancement (FCE) method (Kolláth et al. 2020).

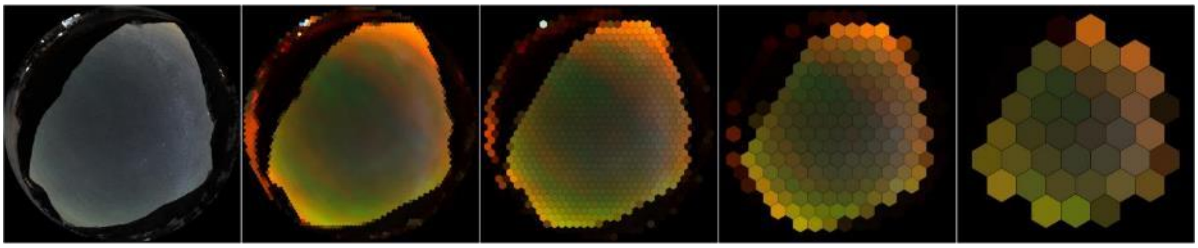


Fig. 1: Whole-sky image and its representation with False Colour Enhancement at different hexagonal meshes.

Intensive surveys of sky quality measurements may result in massive databases. Therefore, generating reduced-size data can be essential to keeping vital measurement information. We use a hexagonal grid on the whole-sky images. The values of each hexagon are given by mean values, omitting the stars (bright spots) and dark spots due to obscured regions or pixel errors.

Figure 1 displays the different resolutions of the hexagonal mesh with varying grid sizes. Please note that the usually used photo processing does not clearly show the colour variation in the images. The structure in the photo can be interpreted as thin clouds. However, the FCE colouring clearly indicates the variation in airglow. In the given example, it is a mixture of green oxygen and orange sodium airglow.

At dark locations, the variation of airglow results in a significant variation in sky radiance. Therefore, it is essential to use an indicator of the possible airglow, i.e. the actual colour of the sky. Figure 2 demonstrates this effect with our recommended representation of measurements. The photos were taken at the exact location (Sölktäler Naturpark, Austria) on different dates. The radiance map shows a substantial variation in sky brightness, which can only be interpreted correctly if we add the FCE maps. The radiance map is given for the Bessel V band magnitude. We observed an extreme sodium event (2nd column), a night with intense red airglow (630 nm oxygen) and the most frequently intense green (558 nm oxygen) airglow.

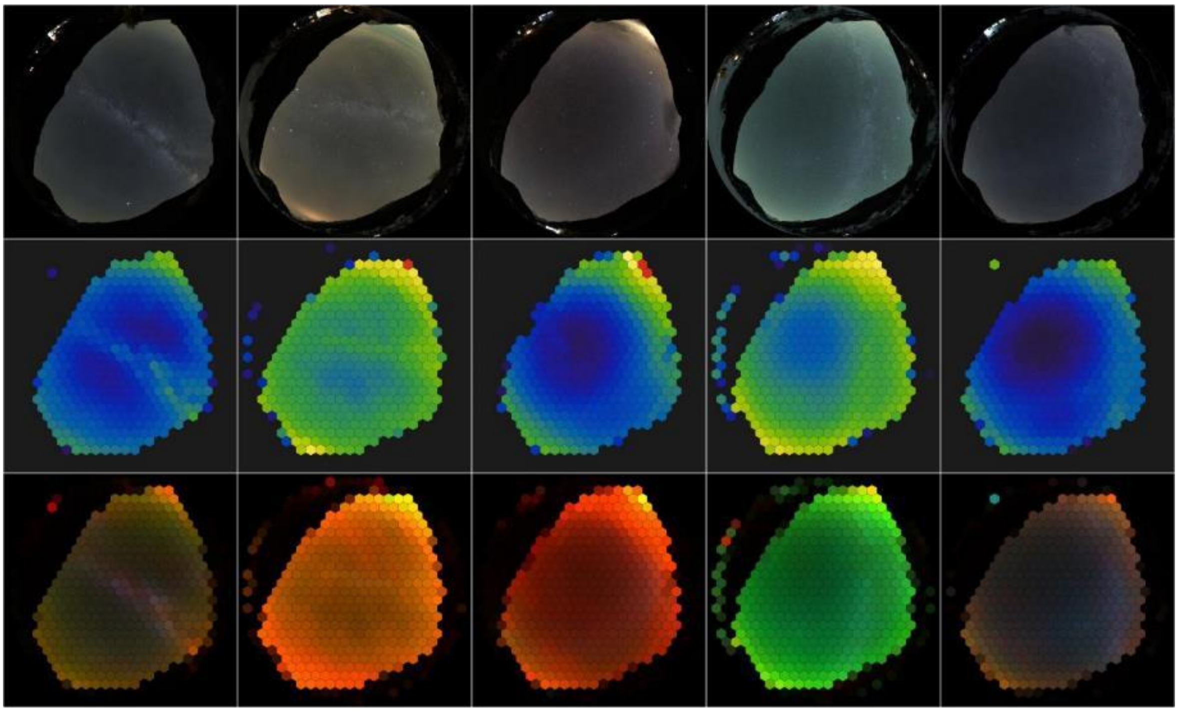


Fig. 2: Variations of the natural sky with different kind and strength of airglow. Top row: Photos with slightly bluish processing; middle row: colour scale radiance map; bottom row: FCE colouring clearly shows the variation of airglow.

Acknowledgments

This research was supported by the Hungarian Scientific Research Fund (OTKA K143376)

References

Kolláth, Z., & Jechow, A. (2023). Natural variation of the colour and spectrum of the night sky observed at a potential European reference site for dark skies. Journal of Quantitative Spectroscopy and Radiative Transfer, 303, 108592

Kolláth, Z., Száz, D., Tong, K. P., & Kolláth, K. (2020). The Colour of the Night Sky. Journal of Imaging, 6(9), 90, 6090090

Light Pollution Source Detection - Validation of Airborne Methods for Quantification and Identification of Light Pollution Sources

Theme: Measurement and Modeling

Iván Kopaitic,[1,*] Sebastián Fingerhuth[2], Javier González[2], Ignacio Stuardo[2] and Federico Toson[3]

[1] Laboratorio de Fotometría, Escuela de Ingeniería Eléctrica, Valparaíso, Chile.
[2] LabSens, Escuela de Ingeniería Eléctrica, Valparaíso, Chile.
[3]Department of Industrial Engineering, University of Padova, Padova, Italy
ivan.kopaitic@pucv.cl
[*]presenting author

Introduction

Light pollution is a growing environmental problem that affects astronomical observation, ecosystems and human health. In Chile, light pollution regulations have recently been updated to mitigate these impacts.

In this context, Vultur (see figure 1) has been developed, a system designed to capture aerial images with the purpose of detecting light emission sources that do not comply with the regulations. This system is designed to be mounted on various platforms, such as drones, helium balloons and helicopters.


Fig. 1: Vultur device and three mounting accessories for platforms

Methods and Results

The system uses two cameras with monochromatic sensors selected because of their higher sensitivity in low light conditions and their ability to capture images with better signal-to-noise ratio compared to color sensors. One of them is equipped with a blue band-pass filter. This allows spectral analysis of the images, focusing on the amount of blue light emitted by luminaires, a key factor in light pollution, which Chilean regulations restrict to 1% in astronomical or biodiversity zones and 7% in the rest of the territory. The Basler cameras used have a 3840 × 2160 pixel Sony IMX334 CMOS sensor. In addition, the system incorporates a GPS/RTK Here 3 module, which allows highly accurate georeferencing of the images and precise localization of light sources outside the established margins.

The system is managed by a Raspberry Pi 4B, configured to operate autonomously using software optimized for nighttime image capture. This microcomputer also collects data from various sensors during flight, such as inclination, GPS position and altitude.

To ensure measurement accuracy, the system was calibrated under controlled laboratory conditions. Spectral response tests were performed using light sources with known spectra, allowing the exposure and sensitivity parameters of the cameras to be adjusted to optimize luminaire detection, and the results of these calibrations are presented in this paper. The first analyses of images obtained from drones, helium balloons and helicopters are also presented.

To evaluate the performance of the system, night-time measurement campaigns were carried out in Valparaíso and Viña del Mar, using the three aerial platforms (see figure 2).

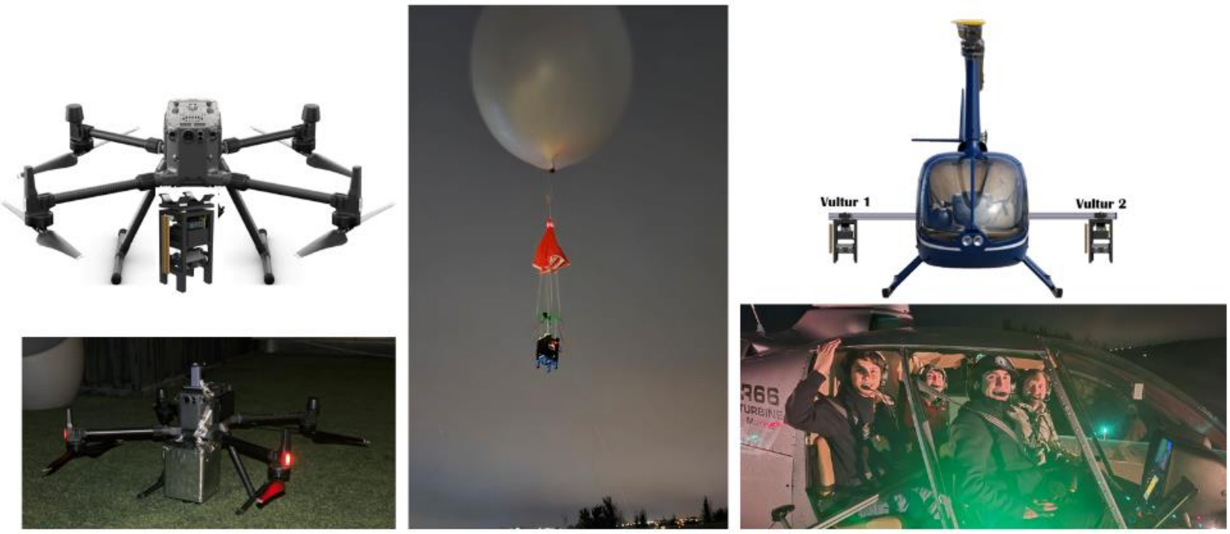


Fig. 2: testing Vultur on three airborne platforms

Conclusions

The results obtained show the capabilities of each method, highlighting their advantages and disadvantages in the detection and analysis of light pollution sources. Drones offer flexibility and precision in low altitude flights, but have limitations in flight autonomy. Helium balloons allow prolonged observation, but are sensitive to wind conditions. Helicopters, in contrast, can cover large areas, but require greater investment and logistical planning. Vultur represents an innovative and useful tool for the Superintendencia del Medio Ambiente, the national authority in charge of controlling compliance with light standards, by providing objective and georeferenced data that facilitates the control and enforcement of current regulations. The data generated by Vultur, in addition to being useful for environmental control, is also useful for the design of sustainable lighting strategies, optimization of public lighting and evaluation of the impact of new lighting technologies on light pollution.

References

P. Fiorentin, C. Bettanini, E. Lorenzini, A. Aboudan, G. Colombatti, S. Ortolani, y A. Bertolo, “MINLU: An instrumental suite for monitoring light pollution from drones or airballoons,” en 2018 5th IEEE International Workshop on Metrology for AeroSpace (MetroAeroSpace), pp. 274–278, ISSN: 2575-7490. [En línea]. Disponible en: https://ieeexplore.ieee.org/abstract/document/8453573

Ken Walczak Geza Gyuk, Jesus Garcia, y Cynthia Tarr, “Light pollution mapping from a stratospheric high-altitude balloon platform | international journal of sustainable lighting,” en *International Journal of Sustainable Lighting*, pp. 20–32. [En linea]. Disponible en: https://lightingjournal.org/index.php/path/article/view/106

Pietro Fiorentin, Carlo Bettanini, y Damiano Bogoni, “Sensors | calibration of an autonomous instrument for monitoring light pollution from drones,” en Sensors | Optical Sensors. [En línea]. Disponible en: https://www.mdpi.com/1424-8220/19/23/5091

C. Bettanini,M. Bartolomei, A. Aboudan, G. Colombatti, y L. Olivieri, “Flight test of an autonomous payload for measuring sky brightness and ground light pollution using a stratospheric sounding balloon,” en Acta Astronautica, vol. 191, pp. 11–21. [En línea]. Disponible en: https://www.sciencedirect.com/science/article/pii/S0094576521005907

The updated lighting standard EN 12464-2: Adaptations concerning light pollution

Theme: Technology & Design

Dr. David M. Kretzer[1,*]

[1] Federal Office for the Environment, Bern, Switzerland
corresdavid.kretzer@bafu.admin.ch
[*] presenting author

Introduction

The updated version of the lighting standard EN 12464-2 *'Light and lighting. Lighting of work places - Outdoor work places'* was released at the end of 2024. It replaces the former version of this standard from 2014. The standard addresses the lighting conditions of a variety of outdoor workplaces such as building sites, industrial sites and outdoor storage areas. Moreover, it defines the lighting requirements for outdoor areas of certain transport infrastructures – such as railway stations and airports.

As Kretzer and Reichenbach (2023) illustrate, standards are not legally binding and they do not contain criteria for whether or not an area needs to be lit. However, they (ibid.) argue that the existence of normative specifications for the lighting of a particular outdoor area increases the likelihood that this area will be illuminated. Moreover, they (ibid.) conclude that the requirements of the outdoor lighting standards have a significant influence on the extent of light pollution – which applies to both normative minimum and maximum requirements.

Method

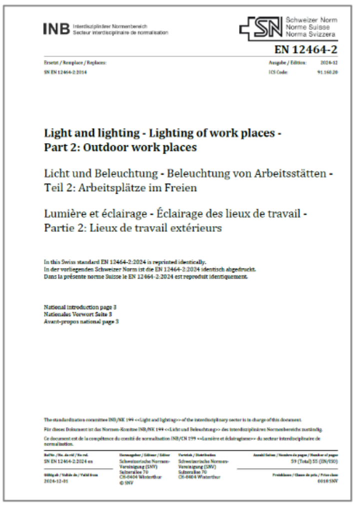
This paper analyses what consequences the adaptations in the new version of the standard are likely to have regarding light emissions. Therefore, the updated standard was examined for both aspects that support light pollution and for those that reduce light pollution. Based on the findings, it was anticipated what effects the standard's adaptations could have on future lighting design schemes.

Conclusions

The analysis of the updated lighting standard SN EN 12464-2 (Schweizerische Normen-Vereinigung, 2024) revealed that the standard's adaptions are likely to have both positive and negative consequences regarding light pollution.

The positive aspects concern especially the possibility of applying lower maintained illuminance values in some situations compared to the standard's version from 2014 (Schweizerische Normen-Vereinigung, 2014), a greater consideration of environmentally sensitive area, the introduction of an additional environmental zone, the lowering of the permitted upward light ratios and the explicit introduction of adaptive lighting.

On the other hand, the so-called 'modified maintained illuminance' was introduced as part of the lighting requirements tables – which offers the possibility of increasing the maintained



INB Interdisziplinärer Normenbereich
Secteur interdisciplinaire de normalisation

SN Schweizer Norm
Norme Suisse
Norma Svizzera

EN 12464-2

Ersetzt / Remplace / Replaces: SN EN 12464-2:2014

Ausgabe / Edition: 2024-12

ICS Code: 91.160.20

Light and lighting - Lighting of work places -
Part 2: Outdoor work places

Licht und Beleuchtung - Beleuchtung von Arbeitsstätten -
Teil 2: Arbeitsplätze im Freien

Lumière et éclairage - Éclairage des lieux de travail -
Partie 2: Lieux de travail extérieurs

In this Swiss standard EN 12464-2:2024 is reprinted identically.
In der vorliegenden Schweizer Norm ist die EN 12464-2:2024 identisch abgedruckt.
Dans la présente norme Suisse le EN 12464-2:2024 est reproduit identiquement.

National introduction page 3
Nationales Vorwort Seite 3
Avant-propos national page 3

SN EN 12464-2:2024 en

Schweizerische Normen-Vereinigung (SNV)
Sulzerallee 70
CH-8404 Winterthur
© SNV

2024-12-01

Fig. 6: The updated lighting standard SN EN

illuminance based on different context modifiers. Moreover, new lighting recommendations were made for areas that had not been addressed before by the standard. Furthermore, lighting is sometimes required by the standard even when the area is not occupied.

It will be concluded by arguing that it appears difficult to determine whether the new adaptions to the standard, viewed as a whole, are better or worse for the environment: The adaptations differ in nature and application and therefore cannot be directly compared or weighted against each other. However, it is crucial that lighting designers, lighting operators and public authorities know about these changes in the updated standard as well as about their possible impact on the environment – in order to enable them to make informed decisions when applying this standard to new lighting installations.

References

Kretzer, D. M., & Reichenbach, A. (2023). Zur Bedeutung von Außenbeleuchtungsnormen als wesentliche Stellschraube bei der Reduzierung von Lichtverschmutzung. In Lichttechnische Gesellschaft Österreichs (Hrsg.), *LICHT 2023: 25. Europäischer Lichttechnischer Kongress (Tagungsband)*, (S. 367-380). Salzburg.

Schweizerische Normen-Vereinigung. (2014). *SN EN 12464-2:2014: Light and lighting - Lighting of work places - Part 2: Outdoor work places.* Winterthur: SNV.

Schweizerische Normen-Vereinigung. (2024). *SN EN 12464-2:2024: Light and lighting - Lighting of work places - Part 2: Outdoor work places.* Winterthur: SNV.

Journey through the bright night – A board game on light pollution

Theme: Social Sciences & Humanities

Annette Krop-Benesch*, Benjamin Krop, and Viviane Krop

Nachhaltig Beleuchten, Seeheim-Jugenheim, Germany
info@nachhaltig-beleuchten.de
* *presenting author*

Introduction

A general problem with the acceptance of light pollution mitigation and regulation is a lack of knowledge about the consequences of artificial light at night. Today, people experience an overflow of information. The willingness to read long, complex texts is low. It is therefore necessary to find ways to provide information that is not perceived as dry education, but includes a fun factor, especially for children and young people.

This is not only the experience of adults, but also of children who try to explain environmental problems to peers. To show people how bad the amount of ALAN is, we have designed an easy board game, in which the players can experience different ecological consequences of ALAN and natural darkness. The driving force behind this game were two primary school students, Benjamin, 10 years, and Viviane, 9 years.

The game follows a simple structure of a ladder game with one dice. On each event field, the player takes the role of an animal, a person, or in one case a plant. A short text informs them about the effect of ALAN and the player either has to wait, advance, make a detour, or take a shortcut.

There is an additional booklet with the rules and more information about light pollution in general, the individual event fields, and ways to reduce light pollution.

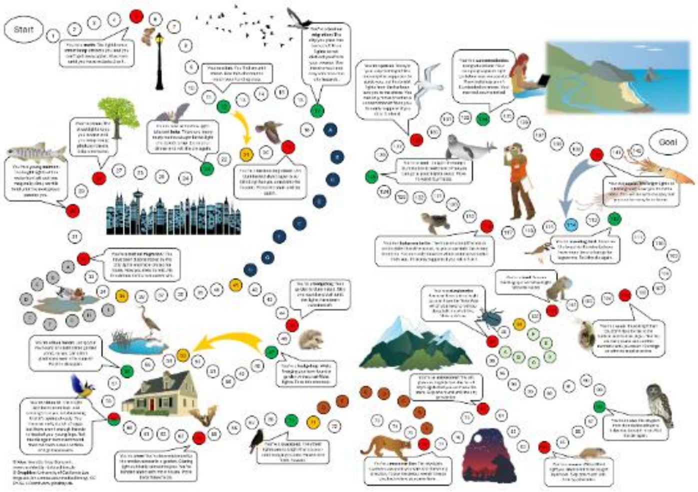


Fig. 1: Gameboard of Journey through the bright night.

The game is designed either as print-out for four DIN A 4 pages or one DIN A 2 page. It can be downloaded for free from this website: https://nachhaltig-beleuchten.de/blog/en/board-game-on-light-pollution/ . It is allowed to copy and distribute the game for free with credit to the authors. The game is used by a couple of groups to raise awareness for light pollution.

Thanks to a number of enthusiastic volunteers from all over the world, the game is available in German, English, French, Italian, Spanish, Dutch, Portuguese, Hebrew, Romanian, Catalan, Galician, and Esperanto. Many thanks to Amir Weinstein, Andreea Nasturel, Chiara Carucci, Daniel Gliedner, Daniela Gonzàlez, Enric Marco, Frank Vohla, H. G. Kaiser, Heike Roloff, Luciana Alanis, Martin Pawley, Raul Cerveira Lima, Rosa Magraner, and Theo Jurriens for their support and to Felicitas and Henning Stummer, Karin Dörpmund, Peter Stumpf, Sabine Frank and the Ravens from Seeheim primary school for testing.

Towards a European nighttime light observing satellite

Theme: Measurement and Modeling

Christopher C. M. Kyba[1,*]

[1] *Helmholtz Centre for Geosciences, Potsdam, Germany*
kyba@gfz.de
[*] *presenting author*

Satellite observations provide extremely useful information about the Earth system, both at day and at night. The American DMSP-OLS and VIIRS-DNB missions have so far provided the only nightly and global views of Earth in the visible band at night. While China's SDGSat-1 doesn't provide a global view, it is being increasingly used thanks to its improved resolution and spectral information. Despite its overall leadership in Earth observation through the Copernicus program, Europe has not yet launched a dedicated space-based and radiometrically calibrated instrument for observing nighttime lights. This presentation seeks to explain why nighttime lights are not yet a part of Europe's observing program, and how the ALAN community could potentially help to change this in the future.

At present, the European Space Agency's (ESA) Earth observation fleet (Figure 1) is divided into three groups: Science, Copernicus, and Meteorology. This division is both thematic and related to the different funding sources for the missions. Copernicus missions are "operational", meaning that they are designed to provide long-term monitoring of well-defined environmental parameters. In contrast, Science missions are one-off instruments that are intended to considerably advance understanding of one or more aspects of the Earth system. Science missions are currently mainly funded by the Earth Explorer and Scout funding lines. The success of a science mission (or even a convincing mission concept) can lead to the eventual incorporation of an Earth system variable into the Copernicus monitoring program.

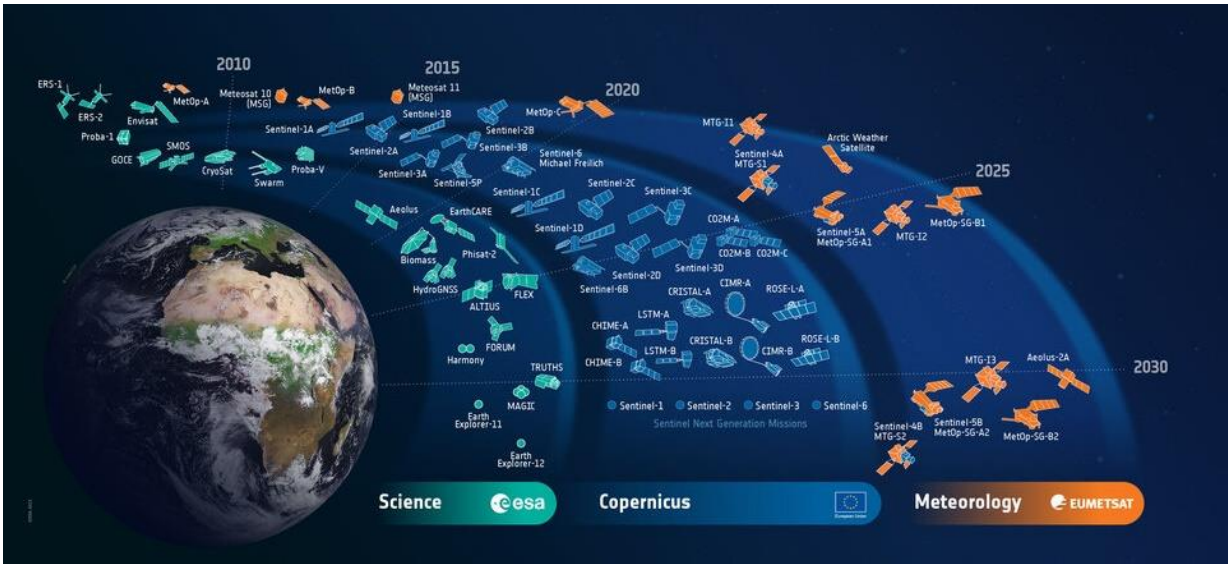


Figure 1: ESA's historical and planned Earth observation missions. Figure ©ESA, reproduced with permission for the purposes of this ALAN abstract, but not released under a CC-BY License. (https://www.esa.int/ESA_Multimedia/Terms_and_conditions_of_use_of_images_and_videos_available_on_the_esa_website)

A key task for the ALAN community is therefore to communicate both the needs and benefits of nighttime light observation to ESA, its member states, and their national space agencies.

But what exactly are our needs? Satellite mission design inevitably involves tradeoffs between different parameters, such as spatial resolution vs. spatial coverage (Figure 2). The VIIRS-DNB is only able to image the entire Earth each night thanks to its relatively low spatial resolution. Satellite instruments observing at higher resolution, such as SDGSat-1, are able to observe only specific targets on each overpass, which leads to much larger gaps in the time of observations, and potentially areas of Earth that are never imaged (e.g. oceans). For the ALAN community as a whole, which is more important, coverage and frequency of observation, or spatial resolution and sensitivity? And which aspects of ALAN would make the most convincing case for inclusion in the Earth Explorer or Scout programs?

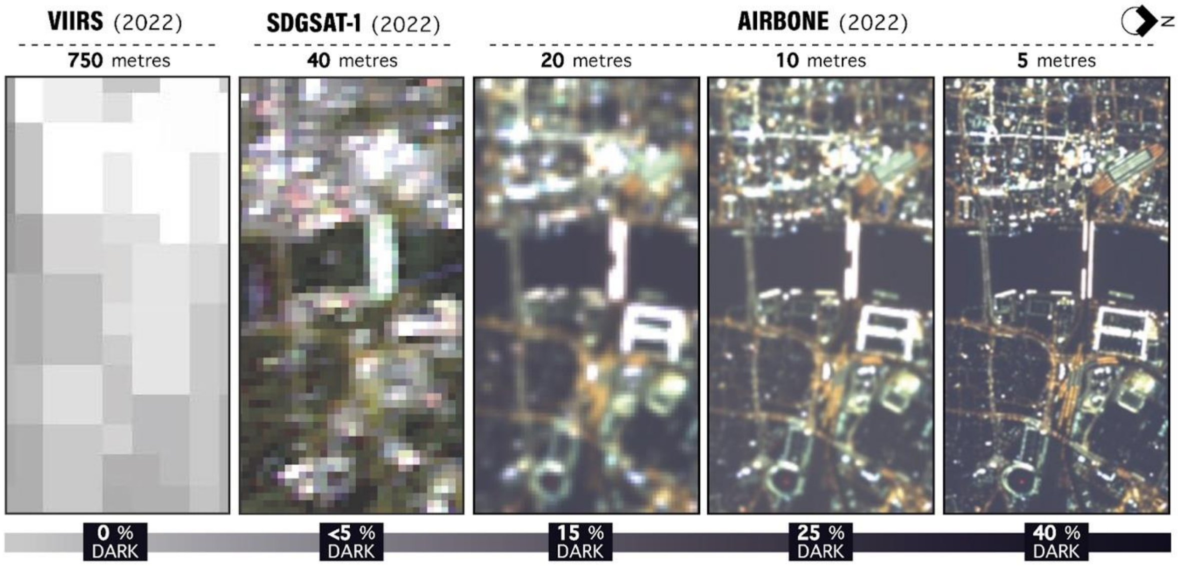


Figure 2: Cologne, Germany, imaged at different spatial resolutions from three different sensors. The airborne data was taken with a resolution of ~1 meter, and then modified to show the impact of reduced resolution. Image reproduced from Kyba et al. (2024), licensed under CC BY 4.0.

The aims of this presentation are to familiarize the ALAN community with the nature of known tradeoffs, to highlight the preparatory work that has already been done in the N8, Night Watch, and EULE mission proposals, to present the planned aims of our next Earth Explorer proposal, and to invite the ALAN community to constructively criticize these plans.

References

Kyba, C., Arroyo, H. L., Degen, T., Abascal, A., Simoneau, A., Kuffer, M. ... & Gyuk, G. (2024). Night Watch Mission Description Document.

A Global Assessment of Nighttime Emissions from Major Roads Outside of Urban Areas

Theme: Measurements & Modeling

Camille Labrousse,[1*] Carynelisa Haspel,[1] and Noam Levin[1,2]

[1] The Hebrew University of Jerusalem, Jerusalem, Israel
[2] The University of Queensland, Brisbane, Australia
camille.m.labrousse@gmail.com
[*] presenting author

Introduction

Artificial Light At Night (ALAN) is a form of pollution with significant environmental and health impacts. While urban streetlighting is a known contributor, the extent and impact of lighting along major roads outside of urban areas remain largely unquantified. This study presents the first global analysis to identify and quantify lit roads in non-urban areas, exploring the socio-economic, environmental, and governance factors that explain cross-country variations. We hypothesized that wealthier countries, particularly those with significant fossil fuel industries, would exhibit more extensive road illumination along major inter-city roads, whereas countries with strong environmental policies would show the opposite trend.

Methods

We combined global datasets to analyze major road lighting outside of urban areas. Major road networks were extracted from OpenStreetMap and nighttime radiance from VIIRS annual 2023 composite. Urban areas were masked using the World Settlement Footprint 3D and OSM residential data, and gas flares were excluded with the VIIRS night fire dataset. SDGSAT-1 night time lights imagery was used for validation (Figure 1). We then applied multivariate and spatial econometric models to relate lit road patterns to an ensemble of 18 national socio-economic, energy, and environmental indicators.

Discussion and Conclusions

Our results showed that most major roads outside urban areas remained unlit worldwide. Yet, in 27 countries, more than 2% of the road network outside of urban areas was illuminated, contributing up to 5.3% of national nighttime radiance (in the United Arab Emirates (UAE)). Hierarchical clustering revealed four groups of countries. The most brightly lit rural major roads occurred in oil- and gas-producing nations of the Middle East with high GDP per capita (e.g., Kuwait, UAE, Qatar) and in highly urbanized, wealthy Asian regions (e.g., Hong Kong, Singapore). By contrast, nations with strong environmental governance, renewable energy uptake, and carbon-pricing mechanisms (e.g., Scandinavian countries) maintained less lit major roads outside of urban areas. Road illumination was closely linked to fossil fuel dependence, urban radiance levels, and the number of environmental policies, aligning with our hypotheses.

To our knowledge, this study provides the first global assessment of nighttime emissions from major roads outside of urban areas, highlighting major disparities in lighting practices. It shows how national energy strategies, urbanization patterns, and policy frameworks shape the use of road lighting, with consequences for energy demand and light pollution at the global scale.

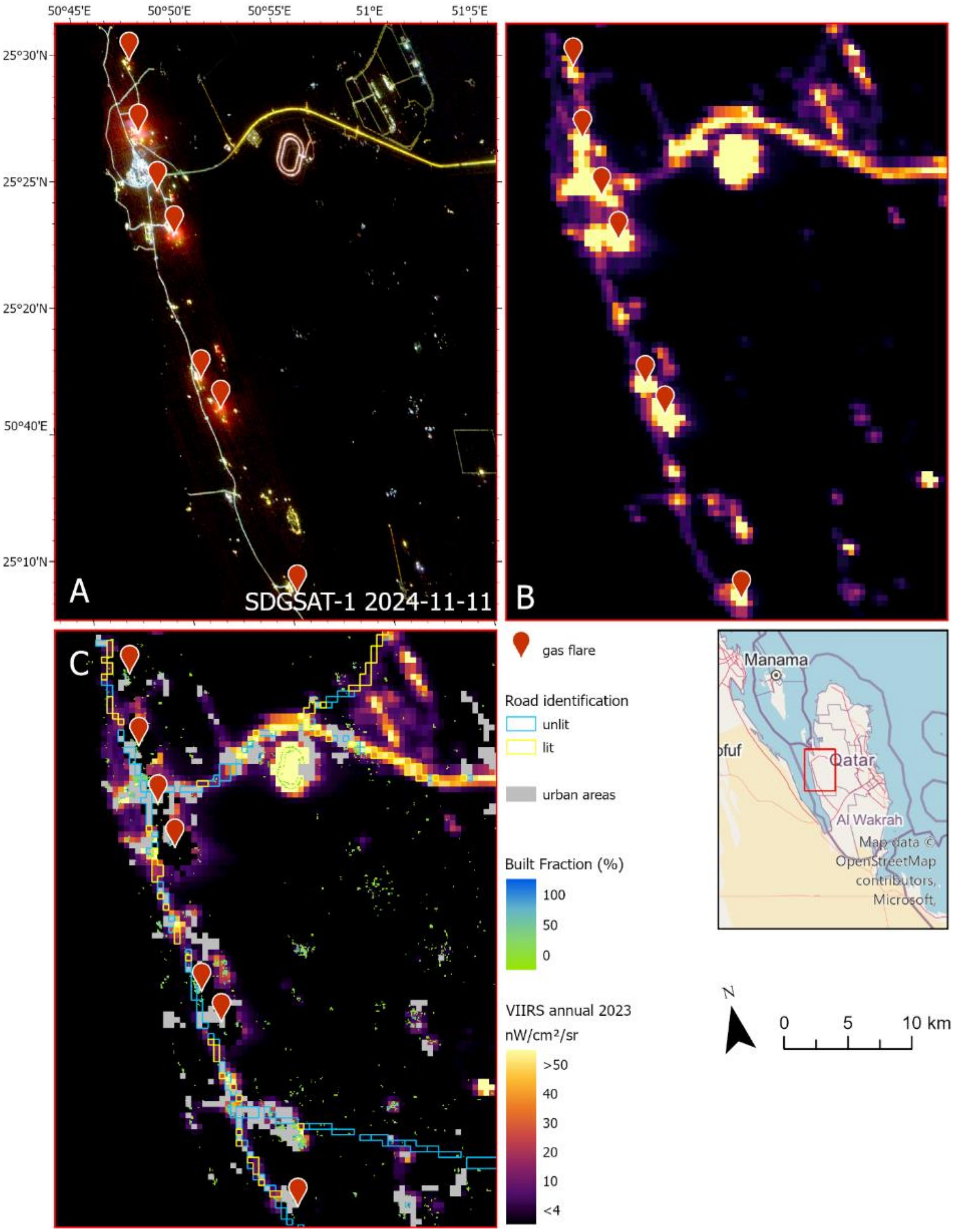


*Figure 7: **Gas flare and urban area exclusions in western Qatar**. A) SDGSAT-1 image acquired on 2024-11-11. B) VIIRS 2023 annual composite. C) VIIRS 2023 annual composite with circular masks applied around identified gas flare locations and exclusion of urban areas (shown in grey). Road identification (inter-city major roads only): Lit = roads with detected streetlighting outside urban areas; Unlit = roads with no detected streetlighting, or roads affected by gas flares, or roads with streetlighting located within excluded urban areas.*

Flexible, low-cost laboratory setup with digital LEDs for assessing effects of multiple light regimes

Theme: Technology and Design

Sandra R. Lang,[1,*] Manfred W. Lang,[1] Rabea Schweiger,[1] and Caroline Müller[1]

[1]Department of Chemical Ecology, Bielefeld University, Universitätsstr. 25, 33615 Bielefeld, Germany
caroline.mueller@uni-bielefeld.de
[*]presenting author

Introduction

Artificial light at night (ALAN) is a widespread component of global change of increasing importance (Kyba et al., 2017). Nevertheless, research on effects of this factor on species and ecosystems has only accelerated in the past decade (Davies & Smyth, 2018). Several empirical studies revealed detrimental effects of ALAN on physiological parameters, activity and life history traits of different animal species (Sanders et al., 2021). Most previous studies focused on comparing effects on organisms in the presence versus the absence of ALAN (Gaston et al., 2014), without considering the complex nature of ALAN at temporal and spatial levels. Thus, empirical research considering this complexity is needed (Bará & Falchi, 2023).

Several recent laboratory studies assessing effects of ALAN used some form of light-emitting diodes (LEDs) (Desouhant et al., 2019), which can be dimmed to low illuminance levels (Chinchero et al., 2020) to mimic realistic ALAN intensities. We aimed to provide more flexibility in adjusting different ALAN properties, allowing for simultaneous testing of different ALAN light intensities and durations (e.g., part-night lighting) with several biological replicates per treatment group. Thus, we manufactured a novel, low-cost, flexible experimental setup for research on ALAN, which may ultimately help to decipher mechanisms that underlie effects of ALAN on organisms (Gaston et al., 2014).

Methods

Our setup design implements digital LEDs mounted above compartments, each housing one individual of the study species under investigation (Fig. 1A-B). The LEDs are individually controlled by a microcontroller, allowing to set light treatments in randomized block designs. Open-source software is used to set light programs that can easily be adjusted in a flexible manner. Each LED can be set to a specific light color and brightness at any given time. This enables the programming of simulated complex light regimes including smooth transitions between day and night light settings as well as different ALAN regimes (Fig. 1A-B). We assessed the functionality of the setup by determining the homogeneity of illuminance across all individual LEDs. Furthermore, we tested the longevity of this technical approach for a continuous running time of

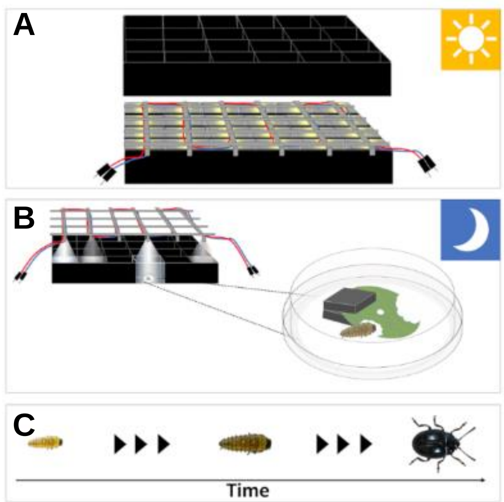


Fig. 1: The ALAN setup with digital LEDs used for mimicking sunlight (A) and different regimes of ALAN (B). In our experiment, we exposed individuals of the leaf beetle species *Phaedon cochleariae* in Petri dishes (B) to ALAN for their whole life span, from larvae to adulthood (C).

5.5 months, in which we conducted three experiments of several weeks each. One of these experiments focused on determining effects of different ALAN intensities (low versus high ALAN) and durations (continuous versus part-night lighting) on the herbivorous leaf beetle *Phaedon cochleariae* (Fig. 1B-C). Several life history and reproductive traits of this species were investigated. Here, we show some results of this experiment.

Conclusions

By illuminating individual compartments with one digital LEDs each, our setup enables the parallel testing of impacts of different light colors, intensities and durations on small organisms such as insects in randomized block designs (Fig. 1B). We highlight possibilities to adjust the design to fit various research questions related to light. For example, by increasing the number of LEDs and the size of the compartments, the setup can be adjusted for investigations with larger study species.

When measuring the light intensities of the LEDs at the same program level along the string of LEDs, we found highly homogenous illuminance patterns, indicating that voltage drops within the setup were neglectable. With this high level of homogeneity, we aim to increase the level of repeatability of research results. Our experiment with *P. cochleariae* revealed prolonged developmental times until adult eclosion under high continuous ALAN compared to the other light regimes. All other assessed life history traits were not affected by ALAN. This experiment and the general flexibility of the setup highlight the potential of our experimental design for various future in-depth ecological research studies on the consequences of ALAN for various species.

References

Bará S, Falchi F (2023) Artificial light at night: a global disruptor of the night-time environment. Phil Trans R Soc B, 378(1892), 20220352

Chinchero HF, Alonso JM, Ortiz TH (2020) LED lighting systems for smart buildings: a review. IET Smart Cities, 2(3), 126-134

Davies TW, Smyth T (2018) Why artificial light at night should be a focus for global change research in the 21st century. Glob Change Biol, 24(3), 872-882

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

Gaston KJ, Duffy JP, Gaston S, Bennie J, Davies TW (2014) Human alteration of natural light cycles: causes and ecological consequences. Oecologia, 176(4), 917-931

Kyba CCM, Kuester T, Sánchez de Miguel A, Baugh K, Jechow A, Hölker F, . . . Guanter L (2017) Artificially lit surface of Earth at night increasing in radiance and extent. Sci Adv, 3(11), e1701528

Sanders D, Frago E, Kehoe R, Patterson C, Gaston KJ (2021) A meta-analysis of biological impacts of artificial light at night. Nat Ecol Evol, 5(1), 74-81

Is Chile turning off its stars?
The national challenges of artificial light for astronomy

Theme: Governance & Regulation

Gabriela López[1,*]

[1] *Oficina de Protección de la Calidad del Cielo del Norte de Chile,* NSF's NOIRLab, La Serena, Chile
Gabriela.lopez@noirlab.edu
[*] *presenting author*

Introduction

Northern Chile is globally recognized for offering the darkest and clearest skies in the southern hemisphere, making it a key destination for astronomical observation. Chile concentrates 40% of the world's astronomical observation capacity and it is expected that by the end of this decade this number will reach 70% with the start of operations of three astronomical megaprojects currently under construction, reaffirming its position as a leader in the investigation of the universe.

Light pollution (LP) poses a growing challenge to astronomical observation, environmental health, and public awareness. It disrupts ecosystems, diminishes human connection to the night sky, and undermines scientific research in astronomy.

The main objective of the Office for Protection of the Quality of the Sky in Northern Chile (OPCC) is to promote protection of the dark skies for astronomy and to support the technical implementation of light pollution regulations in Chile. For this purpose, the OPCC conducted an analysis to answer the question: What are the conditions that put astronomical research in Chile at risk?

Methods

To obtain in-depth knowledge of the problem of light pollution, its gaps and challenges, and to identify the actors of the ecosystem, 19 stakeholders from different public institutions, municipalities, universities and astronomical observatories were interviewed.

Also, a problem tree analysis was made and a stakeholder map was developed to comprehend the dynamics of the actors involved in the light pollution problem. A problem tree analysis is a visual tool to explore and understand a problem by mapping its causes and effects. This method helps uncover root causes, prioritize areas for intervention, and foster collaboration among stakeholders, providing a solid foundation for developing effective solutions.

Finally, there were identified areas that can be intervened to lower the risk of affecting the astronomical observatories' productivity and the natural heritage of dark skies.

Conclusions

In this case the main problem to be address was defined as "Light pollution affects astronomical observation" (Fig. 1).

Six main causes of the problem were identified:

1. Increased level of artificial sky brightness
2. Lack of territorial diagnostics and studies of light pollution
3. Insufficient public awareness of the impact of light pollution and light regulation
4. Limited capabilities and knowledge in lighting design
5. Low control and inspection to comply with the current regulation
6. Market does not offer adequate light technologies that complies with regulation

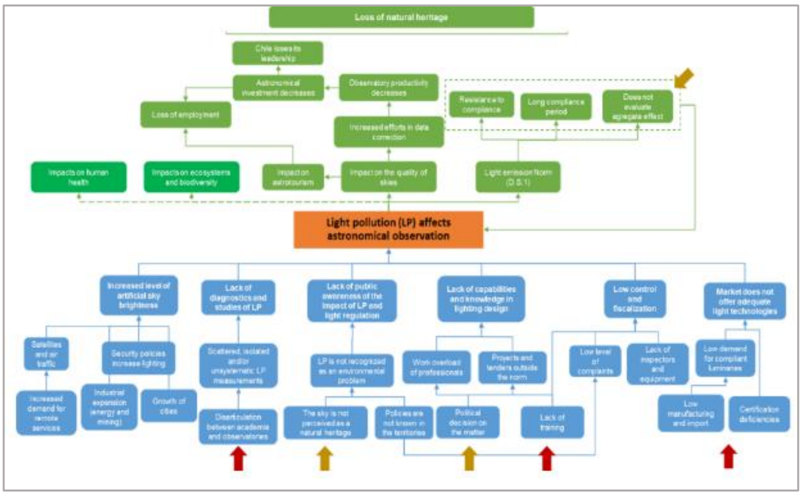


Fig. 1: Light pollution for astronomy problem tree

The main impact of the problem is the decrease in the sky quality that generates a greater effort in the correction of astronomical data, which could cause a decrease in astronomical investment in Chile, thus losing the country's leadership. Also has an impact on the astrotourism activities and may affect local employability.

The problem of light pollution has led to the development of a new lighting norm. Although the norm is demanding with respect to emission levels, the compliance periods are long and the net light pollution will not necessarily be reduced because the norm is an emission standard and does not evaluate the aggregate or cumulative effect of multiple light sources in the same territory. Also, it has provoked resistance from some institutions, like municipalities.

The impacts of light pollution on biodiversity, natural ecosystems and human health are also considered. These effects are not the focus of the OPCC, but serve as a lever to reach out to citizens and local institutions.

The analysis shows that the elements that can be intervened are: the lack of coordination in the light measurements and studies carried out by observatories and academia; the lack of capacities for the lighting design of projects and control procedures; and the low supply of luminaire technologies offered by the market. The variables identified that need to be addressed, but are far from astronomy are: the lack of recognition of the sky as a heritage of all people and of light pollution as an environmental problem; the political decision of institutions (especially municipalities) to deal with the problem; and the need for a secondary lighting norm that allows the aggregate effect of light sources to be evaluated.

These areas of intervention respond to the needs of the actors involved in the governance of dark skies, such as municipalities, astronomical observatories, Ministry of Environment and academia. It also seeks to respond to the gaps identified in technical knowledge on the part of municipal teams, professionals who develop environmental baselines and implementers of lighting projects.

The growth of cities and the development of the mining and energy industries pose a real threat to the operation of astronomical observatories, and although they are still not sufficient, Chile has made progress in policies that seek to harmonize the different activities and vocations in the territories of the Atacama Desert.

BALIN – Insect conservation at railway stations through more insect-friendly lighting

Theme: Biology and Ecology

Carmen Ludreschl[1,*], Daniel Rutte[2], Frederick Bott[3], Peter Siemt[3], Marianne Espeland[1], David Ott[1], and Christoph Scherber[1]

[1] Leibniz Institute for the Analysis of Biodiversity Change – Museum Koenig, Bonn, Germany
[2] German Centre for Rail Traffic Research at the Federal Railway Authority, Bonn, Germany
[3] DB InfraGO AG, Frankfurt, Germany
c.ludreschl@leibniz-lib.de
[*] presenting author

Introduction

Artificial light at night (ALAN) is considered to be one of the major threats to insects by attracting and dislocating them from their natural habitat (Owens & Lewis, 2018; Owens et al., 2019). In Germany, 5400 railway stations and a total of 1900 km of track are regularly illuminated at night by DB InfraGO AG for operational and traffic safety reasons. Although DB InfraGO AG's station lighting is subject to strict requirements, potential effects on insect diversity have hardly been taken into account so far. The research project "BALIN - Insect conservation at railway stations through more insect-friendly lighting" (2021 – 2025) provides the scientific background for updating the guidelines and integrating insect conservation into the lighting concept of DB InfraGO AG by analyzing the pull effect of three alternative platform lighting systems on flying insects (Fig. 1).

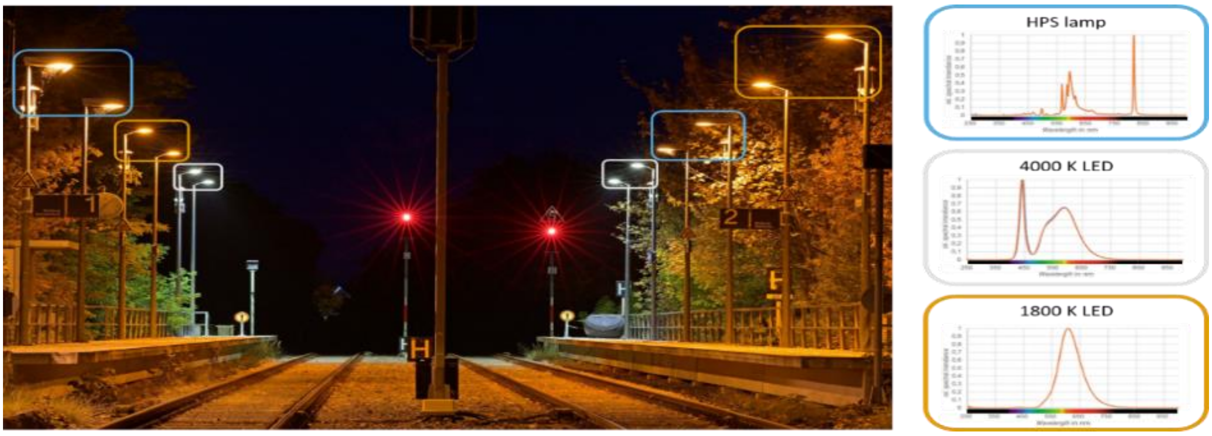


Fig. 1: Alternative platform lighting at the study railway station Pritzerbe, Germany (left; © Christian Bedeschinski) and their corresponding emission spectra (right; HPS: high-pressure sodium lamp)

Methods

The three alternative light sources (4000 K LED, 1800 K LED, high-pressure sodium lamps (2300 K)) differ in light colour and emission spectrum. While high-pressure sodium lamps represent the old stock at most German railway stations, 4000 K LEDs are being used in new buildings and renovations for energy reasons. The 1800 K LED was newly developed as part of the research project and is therefore not yet installed as standard by DB InfraGO AG. Due to the filtered out short-wavelength light, the newly developed 1800 K LED is assumed to be less attractive to flying insects than the other two alternative light sources tested. All three alternative light sources have been installed simultaneously at six semi-natural railway stations in the Westhavelland Nature Park (dark sky reserve in Brandenburg, Germany) to monitor their pull effect on flying insects using time-controlled air-eclector traps. Insect species affected by light pollution are assessed using destructive metabarcoding, while quantitative parameters are recorded by biomass measurements and image-based individual counting.

Results

Preliminary results from biomass measurements of 2023 (Fig. 2) suggest a significantly reduced pull effect of 1800 K LED on flying insects ($p < 0.001$) and could therefore substantially contribute to insect conservation in rail transport. Despite large differences in light colour, 4000 K LED and high-pressure sodium lamps do not appear to differ in their pull effect on flying insects ($p = 0.115$). The strong pull effect observed for high-pressure sodium lamps with a comparatively low average light colour of 2300 K could be due to their diffuse emission spectrum and greater heat development. Simply reducing the average light colour does not therefore appear to be a sufficient criterion for more insect-friendly lighting. Preliminary results from biomass measurements of 2023 will be further verified by count data, metabarcoding species lists and the sample set of 2024.

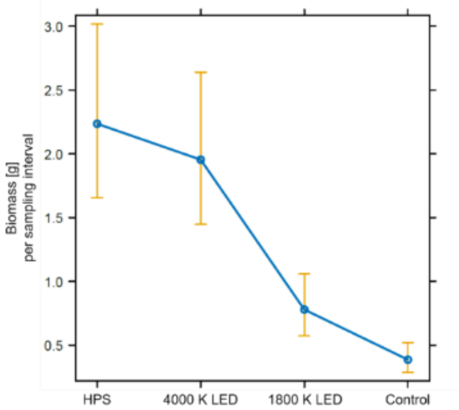


Fig. 2: Preliminary results of mean insect biomass per sampling interval and air-eclector trap with 95% confidence intervals in 2023 (tweedie distribution; HPS: high-pressure sodium lamp; *n(light source)* = 80; *n(control)* = 120).

To our knowledge, the BALIN project is one of the first scientific studies to analyze the pull effect of station lighting on insects in real rail operations and represents a stakeholder for other public and industrial entities on national and international level.

References

Owens, A. C. S., & 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. https://doi.org/10.1002/ece3.4557

Owens, A. C. S., Cochard, P., Durrant, J., Farnworth, B., Perkin, E. K., Seymoure, B. (2020). Light pollution is a driver of insect declines. Biological Conservation, 241. https://doi.org/10.1016/j.biocon.2019.108259

Night Vision: Navigating a pathway to policy for protecting Irish nightscapes through Partnerships & Collaboration

Theme: Governance & Regulation

G. MacMillan,[1,*] T. Conway,[1] and M. Mahon[1]

[1] University of Galway, Galway, Ireland

Corresponding author: g.macmillan1@universityofgalway.ie
[*] presenting author

Introduction:

Ireland is one of few EU Member States without legislation or national policy to protect dark sky places and mitigate light pollution (Widmer and Marnane 2022), despite being home to three officially recognised dark sky places; Kerry International Dark Sky Reserve with Gold Tier, Mayo International Dark Sky Park with Gold Tier (known as Mayo Dark Sky Park) at Wild Nephin National Park, and OM Dark Sky Park in Northern Ireland. However, the pervasive growth of light pollution across Ireland, particularly in the last two decades, has left the country with degraded night skies, and light polluted ecological corridors. The rapid development and implementation of Light Emitting Diodes (LEDs) has transformed the use of artificial light at night in the public realm. Whilst LEDs have brought significant benefits in energy efficiency and ease of control; their widespread installation has triggered growing concerns as to the impacts on the natural world (Gaston and Sánchez de Miguel 2022)1. Specifically, LEDs emitting blue-white light are known to scatter light more widely into the atmosphere, exacerbating light pollution and disrupting the natural day/night cycles of ecosystems, impacting biodiversity and human health. This increase in lighting emissions is now a critical issue as light pollution continues to spread into the remaining areas of natural darkness across Ireland and is likely to be accelerated as renewable power sources increase, making artificial light cheaper to run and therefore used more abundantly (Lyytimäki 2025). Therefore the implementation of mitigation strategies to control light emissions, not just to make energy more accessible, is in urgent need.

In 2021 the need to develop a national strategy for dark skies was acknowledged in Ireland's Rural Tourism development policy although agency responsibility for the delivery of the strategy was unclear and to date, it has not been completed. Identifying and empowering the most appropriate agency to develop policy on dark sky protection is a common challenge facing policy makers (Yakushina 2025). However, in January 2025 the newly formed Government of Ireland presented its new "Programme for Government", which for the first time included a government commitment to promote and encourage an expansion of Dark Sky Ireland national parks and reserves. The commitment positioned dark skies within the realm of "Protecting Heritage and Nature"; the remit of Ireland's National Parks & Wildlife Service (NPWS). Concurrently, NPWS also has responsibility to develop Ireland's Nature Restoration Plan (NRP) for Ireland by 2026 through a programme of co-creation with a wide network of stakeholders. This may be a timely opportunity to pave the way for appropriate regulation on light pollution in Ireland following the EU's call on Member States to consider measures to "stop, reduce or remediate light pollution in all ecosystems" within their NRPs.

This poster explores a vision of Ireland's pathway to future policy, supporting government commitment to protect and expand dark sky places. It builds on the existing knowledge and experience of dark sky places and NGOs (including Dark Sky Ireland) and considers the role of multi stakeholder networks, partnerships and collaborations in supporting the multi-tiered work required from government departments, agencies, NGOs and local stakeholders. Furthermore, it presents a framework for protecting Irish nightscapes in the long term.

References:

Gaston, K. J. and Sánchez de Miguel, A. (2022) Environmental Impacts of Artificial Light at Night. Annual Review of Environment and Resources, 47(Volume 47, 2022), pp. 373-398.

Lyytimäki, J. (2025) Sustainable Development Goals relighted: light pollution management as a novel lens to SDG achievement. Discover Sustainability, 6(1).

Widmer, K., Beloconi, A., Marnane, I., Vounatsou, P., (2022). Review and Assessment of Available Information on Light Pollution in Europe (Eionet Report – _ETC HE 2022/8), ISBN 978-82-93970-08-8, ETC HE c/o NILU, Kjeller, Norway.

Yakushina, Y. (2025) Light pollution regulations and where to find them. Journal of Environmental Management, 373, pp. 123757.

Artificial light at night and invasive crayfish drive cross-ecosystem effects on riparian spiders

Theme: Biology and Ecology

A. Manfrin[1, *], J. Schirmel[1, 2], M. Arias[1, 3], M. H. Entling[1], M. Huszarik[1, 4], S. Kolb[1], A. Schrimpf[1], T. Schmidt[1, 2], M. Bundschuh[1, 5], R. Schulz[1, 2]

[1] iES Landau, Institute for Environmental Sciences, RPTU Kaiserslautern-Landau, Landau, Germany
[2] Eusserthal Ecosystem Research Station (EERES), RPTU Kaiserslautern-Landau, Landau, Germany
[3] Instituto de Limnología "Dr. Raúl A. Ringuelet" (ILPLA), UNLP-CONICET-FCNyM, La Plata, Argentina
[4] Field Station Fabrikschleichach, Chair of Conservation Biology and Forest Ecology, Biocenter, University of Würzburg, Rauhenebrach, Germany
[5] Department of Aquatic Sciences and Assessment, Swedish University of Agricultural Sciences, Uppsala, Sweden

Corresponding author: a.manfrin@rptu.de
** presenting author*

Ecosystems are increasingly exposed to multiple anthropogenic stressors, both abiotic and biotic, which can interact across ecosystem boundaries (Ormerod et al., 2010; Birk et al., 2020). In coupled meta-ecosystems, these stressors can extend beyond ecosystem boundaries. For instance, reduced emergence of aquatic insects from streams can influence terrestrial predators and their trophic interactions (e.g. Krell et al., 2015; Graf et al., 2019). Two major threats to freshwater biodiversity in Europe are artificial light at night (ALAN) (e.g. Gaston et al., 2015; Hölker et al., 2021) and invasive species, such as the signal crayfish (*Pacifastacus leniusculus*) (Vaeßen and Hollert 2015).

We investigated how ALAN, signal crayfish, and their interaction affect riparian spiders by altering aquatic insect emergence. Using a field mesocosm facility with 16 replicated units, each consisting of a 15-meter artificial flume fed by river water and adjacent terrestrial habitat, we conducted a fully crossed experiment under near-natural conditions. Crayfish presence led to a 35% reduction in insect emergence within the first week, while ALAN had no significant effect. Spider abundance correlated positively with insect emergence, particularly for riparian Tetragnathidae species (*Pachygnatha degeeri* and *Tetragnatha extensa*), indicating indirect negative effects of the signal crayfish. During the first week of our experiment, spider numbers increased by 22% in pitfall traps exposed to ALAN, but decreased by 25% in suction samples. This difference is likely driven by differences in species composition between the two sampling methods. While the effects of crayfish and ALAN varied by taxon and time, no significant interactive effects were detected.

Our findings demonstrate that invasive signal crayfish can reduce insect emergence, triggering cascading effects on riparian spider communities and suggests that the effects of crayfish invasion and ALAN are largely independent. This highlights how biological invasions can extend beyond aquatic ecosystems, impacting terrestrial food webs. Understanding such cross-boundary stressor effects is essential for conserving aquatic-terrestrial ecotones in the face of global changes.

References

Birk S, Chapman D, Carvalho L, Spears BM, Andersen HE, Argillier C, Auer S, Baattrup-Pedersen A, Banin L, Beklioğlu M., Bondar-Kunze E (2020) Impacts of multiple stressors on freshwater biota across spatial scales and ecosystems. Nat Ecol Evol 4: 1060-1068

Graf N, Battes KP, Cimpean M, Dittrich P, Entling MH, Link M, Scharmüller A, Schreiner VC, Szöcs E, Schäfer RB (2019) Do agricultural pesticides in streams influence riparian spiders? Sci Total Environ 660: 126-135

Krell B, Röder N, Link M, Gergs R, Entling MH, Schäfer RB (2015). Aquatic prey subsidies to riparian spiders in a stream with different land use types. Limnologica 51: 1-7

Ormerod SJ, Dobson M, Hildrew AG, Townsend C (2010). Multiple stressors in freshwater ecosystems. Freshw Biol 55: 1-4

Vaeßen S, Hollert H (2015). Impacts of the North American signal crayfish (*Pacifastacus leniusculus*) on European ecosystems. Environ Sci Eur27: 1-6

Does more light make us safer?

Theme: Governance and Regulation

P. R. Marchant [1,*]

[1] *Formerly of Leeds Beckett University & The University of Leeds, Leeds, UK*
p.marchant@lightupevidence.com
[*] *presenting author*

Abstract

Safety is often given as a justification for increasing lighting. Whilst we need some light at night to avoid obstacles, we should all ask, 'What is the trustworthy evidence for the suggestion that increasing lighting reduces crime and road collisions?'. Perhaps the idea of a safety benefit from lighting stems from the unease humans feel about darkness at night, because we are a daytime species. After all, the question arises in regard to crime, 'Who does lighting help most, the law abiding citizen, seeing potential risks, or the criminal in highlighting targets and opportunities?'. In regard to road safety perhaps, lighting just encourages riskier road-user behaviour, through giving a seemingly safer environment.

Over the years I have found that studies used to promote the public safety claim are of very poor quality, so the claim is untrustworthy. I have written critiques of some of this pro-lighting work, Marchant (2004, 2017, 2022, 2024).

More recently I have been involved in studying the effect of relighting a whole city (Leeds UK), from predominately orange light to white, see Marchant and Norman (2023, 2025). It was claimed the relighting would make a substantial improvement to public safety, justifying the cost. The studies used a multilevel approach to model the change in the adverse events due to the new lighting. There were 19,000+ road collisions and 471,000+ useable police recorded crimes during 456 weeks in the 107 areas comprising the whole city as the nearly 80,000 replacement white lamps were installed. The method separates the effect of lighting from the underlying trends in the rate of events of interest that is independent of the build-up of white lighting.

Null results were found for both road collisions and crime with a narrow confidence interval for the latter. Null results were also obtained by an independent large scale study funded by the UK National Institute for Health and Care Research, see Steinbach et al (2015).

The presentation will briefly outline the deficiencies in the poor quality work that gives rise to dubious claims of large lighting benefit and then explains how the multilevel method works and overcomes weaknesses of the substandard studies. It is hoped that others will also investigate, using sound methods, what the effects of other lighting changes are.

References

Marchant PR (2004) A Demonstration That the Claim That Brighter Lighting Reduces Crime Is Unfounded. British Journal of Criminology 44(3): 441–447 https://doi.org/10.1093/bjc/azh009

Marchant PR (2017) Why Lighting Claims Might Well Be Wrong. International Journal of Sustainable Lighting. 19(1): 69-74 DOI: 10.26607/ijsl.v19i1.71

https://www.lightingjournal.org/index.php/path/article/view/71/79

Marchant PR (2022) Reprint of Bad Science: Comments on the paper ‘Quantifying the impact of road lighting on road safety — A New Zealand Study’ by Jackett & Frith. Radical Statistics, 131, 1-19 https://www.radstats.org.uk/no131/Marchant131.pdf

Marchant PR (2024) Comment on: Does darkness increase the risk of certain types of crime? A registered report protocol, by Jim Uttley et al. PLOS One https://journals.plos.org/plosone/article/comment?id=10.1371/annotation/a9922815-21db-4353-89c7-3d83e8a1fa53

Marchant PR, Norman PD (2023) In the best light? Road safety and public spending. Significance, 20(3): 30-31, https://doi.org/10.1093/jrssig/qmad046

Marchant PR, Norman PD (2025) To determine if changing to white light street lamps reduces crime: A multilevel longitudinal analysis of crime occurrence during the relighting of Leeds, a UK city, In Press

Steinbach R, Perkins C, Tompson L, Johnson S, Armstrong B, Green J, Grundy C, Wilkinson P, Edwards P (2015) The effect of reduced street lighting on road casualties and crime in England and Wales: controlled interrupted time series analysis. J Epidemiology and Community Health 69: 1118–1124. doi:10.1136/jech-2015-206012 https://jech.bmj.com/content/jech/69/11/1118.full.pdf

Understanding urban beaches users' preferences for light mitigation measures in Chile

Theme: Social Sciences & Humanities

Océane Marcone[1,*] and Olivia Rendon[1]

[1] *Plymouth Marine Laboratory, Plymouth, England*
ocm@pml.ac.uk
[*] *presenting author*

Introduction

In 2023, Chile adopted a law setting new standards for nation-wide regulations on light-emitting sources. The law focuses on the night sky for astronomical observations but also the protection of biodiversity and human health. It tackles all sources of lighting (both new and existing ones, including pedestrian lighting) and sets limits on luminous intensity, emission per reflection, restrictions on the emission of blue light. Implementing changes in public lighting is key to reduce the impact of ALAN on the biodiversity including the increasingly evidenced impacts on coastal and marine ecosystems (Davies et al., 2014). However, lights also play a role in people's feeling of safety. Few studies focused on population's preferences regarding light mitigation measures (Beaudet et al., 2022) and results are mixed. Some studies found a negative impact of reducing light intensity on the feeling of safety (e.g. Vrij & Winkel, 1991). Other studies focusing on light colour found a positive impact of white colour lights on the feeling of safety (e.g. Knight, 2010) but other found the opposite (e.g. Portnov et al., 2020). Implementing ALAN mitigation measures calls for a better understanding of users' preferences. Focusing on two urban beaches in Chile, our work aims at identifying users' preferences regarding various ALAN mitigation options.

Methods

Visual Q-method was used to understand the different social perspectives of beach users in two Chilean coastal cities regarding different urban light mitigation measures. Q-method supports the collection of individual perspectives and the measure and mapping of their variations across individuals (Kuipers et al., 2022). It uncovers different perspectives existing on an environmental topic or issue by identifying cluster of opinions (Webler et al., 2009). Q-method supports the collection of both quantitative and qualitative data and provides powerful results even with small sample as it builds on standard factor analysis.

Users of urban beaches in La Serena (a beach attracting international tourists, n=13) and Concepcion (a beach mainly used by locals, n=15) were recruited (through local gatekeepers and snowballing) for an up to one-hour individual interview. Participants were first presented a carefully designed information sheet detailing the pros and cons of ALAN (including impacts on the coastal ecosystems and societal benefits of ALAN). The participants were then presented with 25 images presenting 25 different possible ALAN mitigation options (Fig. 1). The images were based on a picture of the case-study location edited to reflect the different mitigation options: difference in light intensity, light colour, height of the light

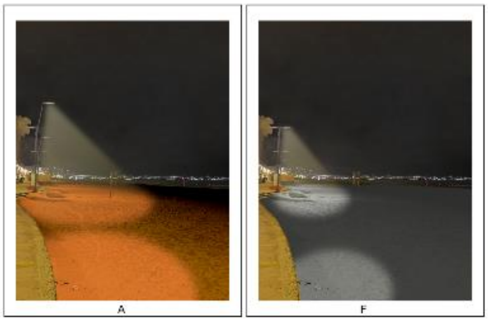


Fig. 1: Two examples of the pictures presented to participants in La Serena

pole, light switched-off. Participants were then asked to sort (i.e. organise) those images using a sorting grid (Fig. 2), and to explain the motivations behind their choices by "thinking aloud". Finally, participants filled a short questionnaire, to collect data about their uses of beaches, their values and socio-demographic data.

The sorting-grids were analysed through factor analysis, using the R package "qmethod". The resulting factors were interpreted using the qualitative data collected during the sorting exercise.

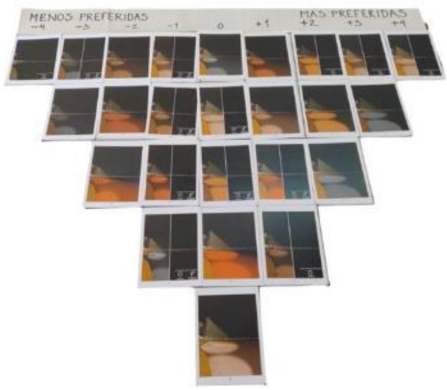


Fig. 2: Example of sorted images from one participant in the Q-method interview

Results and discussion

The analysis will identify different factors (i.e. perspectives, e.g. the "night lovers" or the "environmental impacts advocates") and in each factor, the most liked and disliked options. The rationales provided by the participants to explain their sorting (e.g. "light pollution attracts more pollution such as noise and rubbish", a participant in La Serena; "see stars, listen to the sound of the sea, tranquillity, all these helped me", a participant in Concepcion) will be used to analyse the salient features of each cluster. The responses to the questionnaire will be used to identify the characteristics of the participants in each factor. The analysis will also identify the "consensus" images (i.e. images that are liked or disliked across the different factors).

Identifying the beach users' viewpoints can support the development of ALAN mitigation measures that lower the resistance and/or impacts on users. The results are being used to develop a quantitative, nation-wide survey. They also inform Chile national policy and more broadly upcoming ALAN regulations globally through the identification of bottleneck and resistance as well as low-hanging fruit for mitigating ALAN.

References

Beaudet, C., Tardieu, L., & David, M. (2022). Are citizens willing to accept changes in public lighting for biodiversity conservation? Ecological Economics, 200, 107527. https://doi.org/10.1016/j.ecolecon.2022.107527

Davies, T. W., Duffy, J. P., Bennie, J., & Gaston, K. J. (2014). The nature, extent, and ecological implications of marine light pollution. Frontiers in Ecology and the Environment, 12(6), 347–355. https://doi.org/10.1890/130281

Knight, C. (2010). Field surveys of the effect of lamp spectrum on the perception of safety and comfort at night. Lighting Research & Technology, 42(3), 313–329. https://doi.org/10.1177/1477153510376794

Kuipers, G., Sezneva, O., & Halauniova, A. (2022). Culture beyond words: Using visual Q-methodology to study aesthetic meaning-making. Poetics, 91, 101655. https://doi.org/10.1016/j.poetic.2022.101655

Portnov, B. A., Saad, R., Trop, T., Kliger, D., & Svechkina, A. (2020). Linking nighttime outdoor lighting attributes to pedestrians' feeling of safety: An interactive survey approach. PLOS ONE, 15(11), e0242172. https://doi.org/10.1371/journal.pone.0242172

Vrij, A., & Winkel, F. W. (1991). Characteristics of the built environment and fear of crime: A research note on interventions in unsafe locations. Deviant Behavior, 12(2), 203–215. https://doi.org/10.1080/01639625.1991.9967873

Webler, T., Danielson, S., & Tuler, S. (2009). Using Q method to reveal social perspectives in environmental research. Social and Environmental Research Institute.

The effect of ALAN combined with other abiotic stresses on the photosynthetic pigments, soluble carbohydrates, metabolic profile, and antioxidant capacity in vascular and bryophyte model plants

Theme: Biology & Ecology

Marianna Marschall,[1,*] Szabolcs B. Tóth,[1] Erika Pénzes-Kónya,[1] and Zoltán Kolláth[2]

[1]Department of Botany and Plant Physiology, [2]Department of Physics
Eszterházy Károly Catholic University, Eger Hungary
marschall.marianna@uni-eszterhazy.hu
[*] presenting author

Introduction

Natural photoperiod is a reliable signal for plants to keep the timing of their physiological activity, metabolism, and whole life cycle. Photosynthetic pigment systems absorb certain light spectrum wavelengths, and various photoreceptors sense light for the circadian regulation of ontogenesis. Continuous artificial light at night disrupts the plants' perception of photoperiod. The absence of a continuous dark period at night, the light perceived by phytochromes at night, disrupts the evaluation and signaling of light-based information and provides misleading signals to plant functions, leading to significant physiological changes in plants. These alterations include reduced photosynthetic efficiency, impaired chlorophyll synthesis, oxidative stress, and changes in carbohydrate metabolism. The extent of these effects varies depending on the light spectrum and plant species, highlighting the need for species-specific assessments when considering the ecological impacts of ALAN. In natural plant populations, different abiotic stresses do not act in isolation. The main aim of this study is to obtain new data on physiological activity under different spectra of continuous light combined with other abiotic stresses (e.g. water stress, cold stress) in vascular and bryophyte model plants.

Methods

Pelargonium zonale was cultivated in the department. *Porella platyphylla* (L.) Pfeiff. was collected from the Bükk Mountains and dehardened and hardened (cold adaptation or desiccation) before using in tests (Table 1). *Pelargonium* leaves were detached and put into Hoagland solution containing 21% PEG (6000) (only Hoagland in controls). Experiments were carried out in 3 climate chambers (3050K full, 2950K warm, 6550K cold light spectrum) (Fig. 1) at a photosynthetic photon flux density (PPFD) of 200 µmol m^{-2} s^{-1}, at 18˚C for 1 week. A 14-hour light/10-hour dark cycle was applied in the full-spectrum climate chamber, and constant lighting was used in both the warm and cold light chambers. Physiological parameters were measured in plants (n=3 in 3 independent setups) at the beginning of the experiments and after 1 week. Photosynthetic

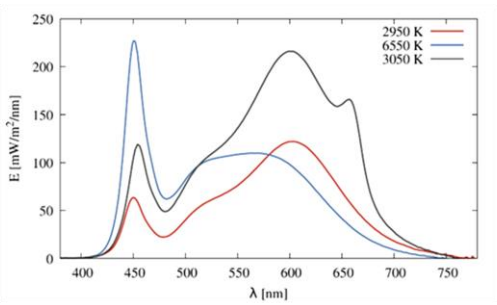


Fig. 1. Comparison of the light spectra of the applied three climate chamber lighting technologies: 3050 K Led (black) / 6550 K Led (blue) / 2950 K Led (red).

Experimental design and plant materials		Change in % compared to controls		
Porella platyphylla	pretreatment	chl_a/chl_b	chls/cars	total chls
darkness for 1 week at 18˚C	cold stress for 6 months	-40	+66	-30
	desiccation for 6 months	-19	+27	-80
14h light/10h dark cycle at 18˚C for 1 week	cold stress for 6 months	+4	+37	+51
	desiccation for 6 months	-6	+3	-73
continuous WARM light at 18˚C for 1 week	cold stress for 6 months	+15	+30	+102
	desiccation for 6 months	-22	+27	+67
continuous COLD light at 18˚C for 1 week	cold stress for 6 months	-13	+49	+91
	desiccation for 6 months	-22	+29	-20
Pelargonium zonale				
21% PEG & 14h light/10h dark cycle at 18˚C for 1 week		+0.3	-1	+18
21% PEG & continuous WARM light at 18˚C for 1 week		+0.2	+1	+15
21% PEG & continuous COLD light at 18˚C for 1 week		-0.1	-3	+11

Table 1. Experimental design, treatments. Photosynthetic pigment change in %. *P. platyphylla* and *Pelargonium zonale* were kept under 14h light/ 10h dark cycle at full spectrum, and continuous warm and cold lights at 18˚C for 1 week combining the effect of water stress and previous hardening as cold and desiccation.

pigment content analyses followed Lichtenthaler and Wellburn (1983) using 96% (v/v) ethanolic extraction and reading absorbance at 470, 649, and 665 nm on a spectrophotometer (Varian Cary 3E). Antioxidant capacity was determined by the DPPH test from the 96% (v/v) ethanolic extracts (Marschall *et al.* 2024). Total soluble sugars and fructans in *P. platyphylla* were quantified using 80% (v/v) ethanolic extracts followed by Marschall *et al*. 1998. The metabolic profile of the plant extracts was measured by GC-MS analysis (Marschall *et al.* 2024).

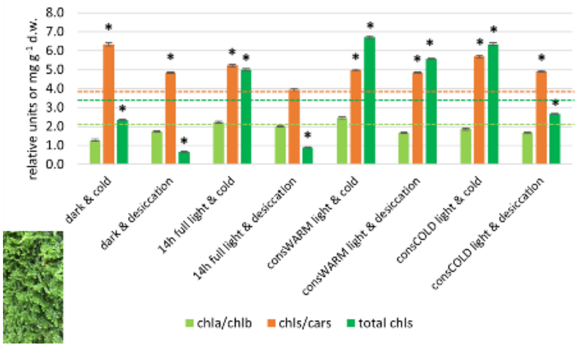


Fig. 2. Photosynthetic pigments in cold or desiccation hardened (dotted lines=unhardened controls) *P. platyphylla* after 1 week of dark, continuous warm (2950 K) or cold (6550 K) led lighting. Control plants were kept at a 14-hour light/10-hour dark cycle having the full-spectrum (3050 K) of light. *= Statistically significant (p<0.05). Error bars are STDs, where n=3.

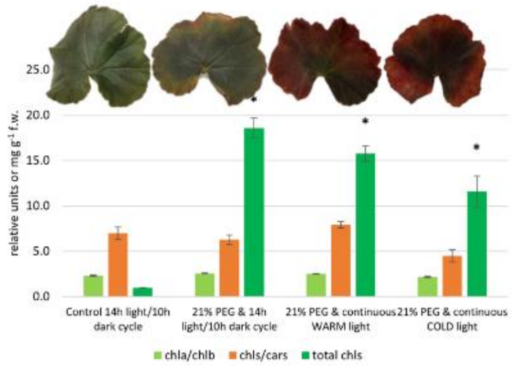


Fig. 3. Photosynthetic pigments in *Pelargonium zonale* after 1 week of using continuous warm (2950 K) or cold (6550 K) led lighting and combined 21% PEG treatment. Control plants were kept at a 14-hour light/10-hour dark cycle having the full-spectrum (3050 K) of light. *= Statistically significant (p<0.05). Error bars are STDs, where n=3.

Conclusions

ALAN affecting alone or interacting with the water deficit of cells can alter photosynthetic (Table 1, Fig. 2, 3) and non-photosynthetic pigment composition, the quality and the quantity of the storage carbohydrates, metabolic profile, and the antioxidant capacity of the whole plant. The specific effects vary among species, highlighting the importance of considering individual plant responses when assessing the impact of artificial lighting on plant physiology.

References

Lichtenthaler H, Wellburn AR (1983) Determination of total carotenoids and chlorophyll a and b of leaf extracts in different solvents. *Biochem Soc Trans* 603: 591–593.

Marschall M, B Tóth Sz, Novák B (2024) Antioxidant capacity and membrane permeability under rewetting recovery of *Porella platyphylla*, a desiccation-tolerant liverwort. *Acta Biol Plant Agr* 12(1): 75–95.

Marschall M, Proctor MCF, Smirnoff N (1998) Carbohydrate composition and invertase activity of the leafy liverwort *Porella platyphylla. New Phytol* 138: 343-353.

Kickstarting a Quebec strategic network on nocturnal studies

Theme: Measurement and Modeling

Alex Mavrovic[1, 2, *], Martin Aubé[1, 3, 4], Johanne Roby[1]

[1] Cégep de Sherbrooke, Sherbrooke, Canada
[2] Centre for Northern Studies, Québec, Canada
[3] Université de Sherbrooke, Sherbrooke, Canada
[4] Bishop's University, Sherbrooke, Canada
alex.mavrovic@cegepsherbrooke.qc.ca
[*] presenting author

At any given moment, half of the Earth is illuminated by the Sun, while the other half is embraced by the night. Although the nighttime environment has a significant impact on the human circadian cycle and ecosystems, Earth's night remains considerably less studied than daytime. Yet, several environmental disturbances, including light pollution, noise pollution, and air pollution, follow a diurnal cycle in which the darkness period plays a critical role in the impact of these pollutants. Nighttime is half of life!

In Quebec, an increasing number of specialists are focusing on the nighttime environment due to its effects on human and ecosystem health, astronomical observations, and energy consumption. Notably, light pollution is gaining attention in the media, legislation, and scientific research in Quebec. The newly formed **Catalyst for Innovation in Night Studies** is a strategic network on nocturnal studies regrouping researchers and specialists from academia, government agencies and private sector. The network brings together Quebec experts in nocturnal environments, covering areas such as light pollution, noise pollution, air pollution, human health, epidemiology, ecology, geomatics, and environmental sciences. The funding of this network is a statement from the Quebec government that night studies are of importance for the Quebec society.

The Catalyst for Innovation in Night Studies is structured around four main research themes that reflect its members' interests and fields of expertise:

1. **Instrumentation and monitoring of the nighttime environment**
2. **Modeling of physical processes**
3. **Impact on human health, wildlife, flora, and ecosystems**
4. **Awareness and outreach regarding issues and solutions**

The Catalyst for Innovation in Night Studies leads an innovative, unifying research project with four key objectives that bridge scientific research on light pollution with practical applications:

1. **Case studies of two isolated northern villages** as an outdoor laboratory to support modeling and understanding of light pollution propagation in the environment.
2. **Development of an instrument** to measure aerosols and greenhouse gases at night, as these significantly impact air quality and the spread of light pollution in the atmosphere.

3. **Support for maintaining and promoting Quebec's nocturnal environment protection initiatives**, including the very International Dark Sky Reserves of Mont-Mégantic (Canada) and the Urban Night Sky Place of Mont-Bellevue (Canada).
4. **Analysis of the inequities in nighttime environmental quality among socio-demographic groups** (environmental justice) and an **epidemiological study on the role of light exposure in prostate cancer incidence**.

As of March 2025, there are 21 researchers from academia, 7 applied field specialists, 5 universities, 5 colleges and 6 applied field organizations that are parts of the Catalyst for Innovation in Night Studies. With several research funding projects starting, the Quebec strategic network welcomes international collaborations.

Regulation of Light Pollution in Indian Environmental Law: A Comparative Study

Theme: Governance and Regulation

Swati K. Mawandiya,[1,*]

[1] *Institute of Law, Nirma University, Ahmedabad, India*
[*] *presenting author*

Introduction

Light Pollution basically refers to the excessive, misdirected and obtrusive use of exterior lighting at night-time which has the effect of over-illuminating the atmosphere. Unlike the other forms of pollution recognised, Light Pollution is a relatively unrecognised form in India which has otherwise gained global acceptance. It has not received its due attention as it is present mostly in urban areas alone. India, as a developing nation, has its focus on rural electrification and with this need for lighting, the negatives have been side-lined. Also, with major and urgent environmental concerns like climate change at hand, light pollution seems ignorable. However, it is submitted that it is better to prevent a concern before it becomes a menace.

Light Pollution: A Rising Concern for India

India is developing and urbanising at a very fast pace and the urban cities are facing a number of environmental issues due to unregulated urbanisation processes. There is no such environmental problem that the developed countries face and India does not. The globe is common for all and India, sooner or later, will find itself submerged in light and will need to take steps to undo something that could have easily been prevented. India can choose to adopt energy efficient and proper lighting installations to prevent light pollution from rising. With this approach, India will not only prevent the menace of excessive lighting but also save the economy.

Legal Setting in India

The Indian experience shows the active role played by both civil and criminal law in terms of preventing and abating nuisance before the specific environmental legislations were enacted. The tool of nuisance law has been successfully applied for relief by higher judiciary for cases of pollution and contamination of environment even before dedicated laws were in place. The author thus first enquires whether the common law tool of nuisance can be applied and used for the purpose of light pollution. Also, it examines whether this tool can act as the appropriate remedy to deal with light pollution. The environmental law in India is not a stand-alone legislation. It is rather a development of a set of legislations, rules and by laws through adoption of the international principles and national constitutional mandate of environmental protection and improvement. The bulk of environmental legislations in India address some or the other specific environmental concern along with an umbrella legislation.

Comparative Study of Legislative Approach in UK and USA

The developed countries have long been facing the menace of light pollution and have taken legislative measures to combat and mitigate it. While developed countries like UK and USA have recognised and established a legal mechanism to abate light pollution, there are inherent limitations to each of these legal systems. The legal mechanism in India is very similar to that of these countries and drawing on their experiences can contribute to better solutions. This research work aims to find the best possible approach to abate light pollution as suited to the Indian legal mechanism. In order to do that, it follows a comparative study of legal instruments existing in these developed countries to arrive at an appropriate remedy.

Contextualizing in Indian Environmental Law

As for the legislative approach to curb light pollution, the concept of light pollution is contextualized in light of the environmental jurisprudence of India. While the environmental legislations in India follow a command-and-control method and would appear anthropocentric, the constitutional mandate is eco-centric. Being party to all major international conventions, India has accepted the long-term goal of sustainable development. In order to trace a remedy for light pollution, it is pertinent to understand the delicate intricacies of India's own environmental jurisprudence. This paper entails an in-depth discussion about the environmental jurisprudence of India with help of analysis of various principles and landmark cases. This paper then interlinks the concept of light pollution under each specific head of international principles, constitutional mandate and specific legislations.

Conclusion

The crux of this entire research is to find the most appropriate legal remedy for light pollution in India in accordance with the Indian environmental jurisprudence. The author analyses and draws comparison of existing models of regulations to recommend legal measures to improve the scope of legal regulation of light pollution.

References

Barentine, J. C. (2020). Who speaks for the night? The regulation of light pollution in the 'Rights of Nature'legal framework. *International Journal of Sustainable Lighting*, *22*(2), 28-36.

Bedi, T. K., Puntambekar, K., & Singh, S. (2021). Light pollution in India: appraisal of artificial night sky brightness of cities. *Environment, Development and Sustainability*, 1-16.

Bogard, P. (2013). Bringing back the night: a fight against light pollution. *Yale Environment*, *360*.

Crawford, D. L. (1996). Light pollution: the problem and the potential solutions. *Open Astronomy*, *5*(2), 263-270.

Degen, T., Kolláth, Z., & Degen, J. (2022). X, Y, and Z: A bird's eye view on light pollution. *Ecology and Evolution*, *12*(12), e9608..

Kundu, D., & Pandey, A. (2021). Sustainable urbanisation in India and Delhi: challenges and way forward. *Background paper for 23rd ASEF Summer University ASEF Education Department.*

https://www.academia.edu/76927683/Sustainable_Urbanisation_in_India_and_Delhi_Challenges_and_Way_Forward_Background_Paper_23rd_ASEF_Summer_University_ASEF_Education_Department. *Last accessed*, *15*.[1]

Kaushik, K., Nair, S., & Ahamad, A. (2022). Studying light pollution as an emerging environmental concern in India. *Journal of Urban Management*, *11*(3), 392-405.

Latham, M., Schwartz, V. E., & Appel, C. E. (2011). The Intersection of Tort and Environment Law: Where the Twains Should Meet and Depart. *Fordham L. Rev.*, *80*, 737.

Longcore, T., & Rich, C. (2004). Ecological light pollution. *Frontiers in Ecology and the Environment*, *2*(4), 191-198.

Nhalur, S., Josey, A., & Mandal, M. (2018). Rural electrification in India. *Economic & Political Weekly*, *53*(45), 31-38.

ALAN decreases daytime locomotor activity and circulating melatonin levels in wild pigeons

Theme: Biology & Ecology

Stan Moaraf [1, 2, *], Nareed Hashem [3], Inon Scharf [1], Abraham Hefetz [1], Monika Okuliarová [4], Michal Zeman [4], Anna Zamansky[3], Anat Barnea [2]

[1] School of Zoology, Tel-Aviv University, Tel-Aviv, Israel
[2] Department of Natural Sciences, The Open University of Israel, Ra'anana, Israel
[3]Department of Information Systems, Haifa University, Haifa, Israel
[4] Department of Animal Physiology and Ethology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovak Republic.

stanmoaraf@mail.tau.ac.il
** Presenting author*

The introduction of artificial light at night (ALAN) from various sources (e.g. street, domestic, or industrial sources) disrupts the daily cycle of light, has vast biological impacts on all organisms, from the molecular to the ecosystem levels, and is associated with physical and mental health problems. In birds, ALAN affects various aspects, such as reproductive behavior (Dominoni et al., 2013) and sleep control (Raap et al., 2016). However, there is little information regarding the effects of ALAN on daytime and night-time locomotion activity of wild birds, although the importance of such studies has been emphasized.

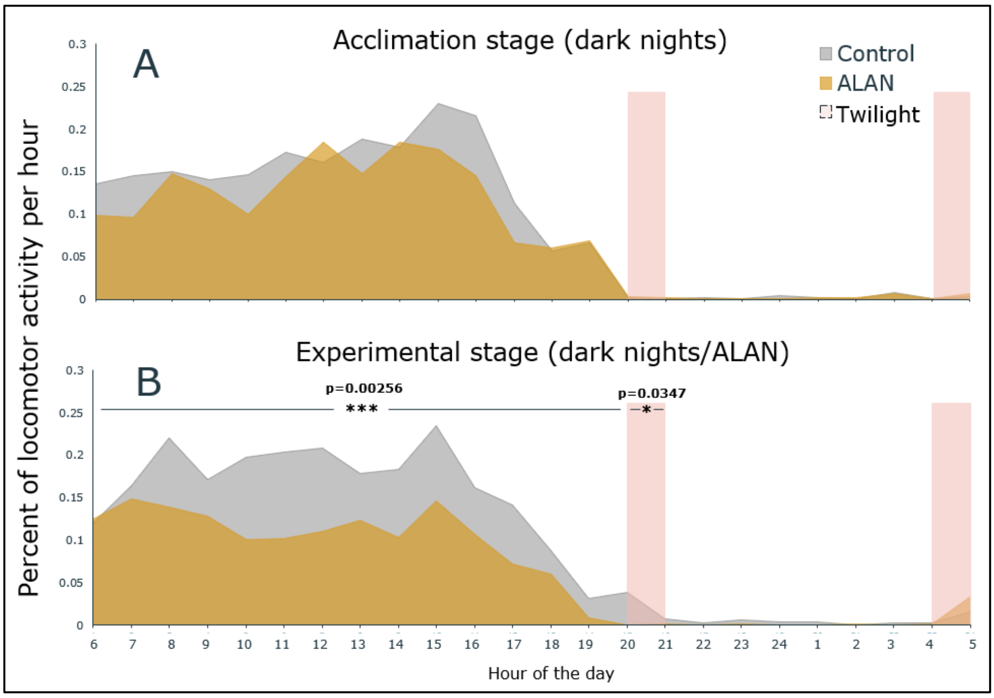


Figure. 1: Night and day locomotor activity during 24-hour detection period (percent of locomotor activity per hour) in the Control and ALAN groups during acclimation (A) and experimental (B) stages of the experiment. N = 16 birds / group. The two groups differed significantly ($F_{(1,32)} = 9.33$; $P = 0.0058$).

In our study we captured 32 wild adult male and female pigeons *(Columba livia domestica)* and randomly divided them into two groups – CONT and ALAN (16 birds / group), which were housed in eight identical big (6X2X2 m) outdoor aviaries (4 aviaries / group; 4 birds / aviary). The study consisted of two stages, acclimation and experimental, which lasted 6 weeks each. During the acclimation stage, both groups were exposed to day-time natural light intensity and complete darkness during the nights. During the experimental stage, both groups remained under the same daytime conditions, however during the nights CONT were still exposed to darkness, while the ALAN group was exposed to 5 lux illumination. Mid-day and midnight plasma melatonin levels were measured by sensitive radioimmunoassay at the end of the acclimation and experimental stages. We also reordered the locomotor activity of the pigeons, with an infrared camera continuously for 48-hours at the end of each of these stages. All video recordings were automatically analysed using an algorithm based on custom trained Yolo8 model, detecting individual birds, quantifying their movement and calculating the percent of their movement / hr.

During the acclimation stage (Fig. 1A), both groups exhibited similar levels of locomotor activity during day-, twilight-, and night-times, as expected, because during this stage they were kept under identical conditions. The pattern of this activity was high levels during the day, a decline towards the twilight time, and very low activity at night, when both groups where exposed to darkness. Plasma melatonin levels were also similar in both groups during this stage. However, during the experimental stage (Fig. 1B), the ALAN group exhibited significantly less locomotor activity during the day- and twilight- times compared to CONT, even though during these hours both groups were exposed to the same illumination. Surprisingly, during the nights no difference was detected between the two groups, despite the fact that the experimental group was exposed to ALAN, while the CONT was exposed to dark nights. In addition, during this experimental stage, pigeons in the CONT gradually decreased their locomotor activity during twilight time, while the ALAN birds stopped their activity earlier and more sharply. Finally, during this stage, there was also a significant decrease in night-time plasma melatonin levels in the ALAN group compared to CONT.

Taken together, we hypothesize the reduced night-time plasma melatonin levels under ALAN disrupted sleep, leading to increased daytime tiredness in the pigeons. Consequently, this may have resulted in decreased daytime locomotor activity compared to CONT. However, this possible sleep disruption was not reflected by an increase in night-time activity, as we recently found in zebra finches (*Taeniopygia guttata*), in which ALAN exposure increased nocturnal activity while maintaining similar daytime levels in both ALAN and CONT (Moaraf et al., under revision). These contrasting behavioral responses to ALAN suggest possible species-specific differences and/or differences between wild and captive birds. Further research is needed to test these possibilities. Overall, our study contributes to the growing body of evidence that ALAN disrupts the natural plasma melatonin rhythm and natural sleep-wake cycle in birds, which, in turn, may impact their behaviour, and hence their fitness and survival. Our findings contribute to the understanding of the broader ecological consequences of ALAN.

References

Dominoni D, Quetting M, Partecke J (2013) Artificial light at night advances avian reproductive physiology. Proc Biol Sci 280, 20123017

Raap T, Pinxten R, & Eens M (2016) Artificial light at night disrupts sleep in female great tits (*Parus major*) during the nestling period and is followed by a sleep rebound. Environ Poll 215: 125-134.

Moaraf S, Heiblum R, Scharf I, Hefetz A, Okuliarová M, Zeman M, and Barnea A (under revision) Counteracting the Effects of Artificial Light at Night: The Role of Melatonin in Brain Plasticity and Nighttime Activity in Songbirds. Sci Total Environ

Enacting darkness: A relational more-than-human approach to participatory lighting planning

Theme: Social Sciences & Humanities

Anna C. Mosler,[1 *] Carolin Liedtke,[1] Roland Greule[1]

[1] University of Applied Sciences Hamburg, Germany
anna.mosler@haw-hamburg.de
[*] presenting author

The Interreg North Sea project DARKER SKY aims to mitigate light pollution and enhance biodiversity in the North Sea Area. To pursue this objective, among other strategies, municipalities and ports are equipped with co-design methodologies to develop innovative approaches for reducing light pollution. At the pilot sites in Hamburg, Germany, a series of participatory workshops were conducted to engage local stakeholders in the planning process utilizing extended reality (XR) technologies. Our workshop methodology recognizes that stakeholders extend beyond human participants to include the *more-than-human*[2] world. We aim to develop a relational framework that surpasses dualistic notions, such as human/environment and nature/culture, by conceptualizing humans as participants within a broader ecosystem. This approach sharply contrasts with the prevailing practices in contemporary lighting planning, which focus on a human-centered approach that emphasizes human requirements.

Fig. 1: The pilot site as a more-than-human space
Image credit: Anna Carena Mosler

The human-centered perspective is rooted in the following assumptions:

1. Human exceptionalism paradigm (humans are superior to all other species)
2. Human/nature dichotomy (humans are distinct from and independently of the natural environment)

These beliefs conceptualize humans as "users" of an environment intended as a resource to meet human needs. The consequences are extensive and result in environmental destruction, including the consequent loss of biodiversity and climate change.

Nocturnal environments are also substantially destructed by anthropocentric behavior such as artificial light at night (ALAN). The extensive use of ALAN is largely driven by the objective of enhancing perceived personal safety. In Western cultural contexts, light is typically perceived as a symbol of safety and positivity, whereas darkness is associated with danger and

[22] In his book "The Spell of the Sensuous: Perception and Language in a More-than-human World," Abram (1996) introduced the notion of *more-than-human*. *More-than-human design* is an interdisciplinary field that critiques the traditional human-centered design paradigm by extending the scope of consideration beyond human beings (e.g., Akama et al., 2020).

negativity. The concept of dualism is reflected in the portrayal of light and darkness as opposing entities. However, in actual experience, as Morris puts it, “True darkness is a rare occurrence. In reality, one’s perception shuttles between extremes of light and dark. Darkness is situated, partial and relational.” (Morris, 2011, p.317)

This contribution explores the conceptualization of urban darkness as a space for relational dynamics by drawing on concepts from the enactive approach to cognitive science. The enactive approach posits that cognition emerges dynamically through interactions with the environment. The relationship between organisms and their environments is characterized by mutual dependence, in a manner that transcends a dualistic subject/object framework (e.g., Varela et al., 1991; Di Paolo et al., 2018; Thompson, 2007).

We propose that conceptualizing darkness through an enactive framework allows for the understanding of darkness not as an absence of light, but as an environment in itself. Consequently, this perspective enables the recognition of the intrinsic value of darkness and the necessity of its preservation.

References

Abram, D. (2017). *The spell of the sensuous: Perception and language in a more-than-human world*. Vintage Books.

Akama, Y., Light, A., & Kamihira, T. (2020). Expanding Participation to Design with More-Than-Human Concerns. *Proceedings of the 16th Participatory Design Conference 2020 - Participation(s) Otherwise - Volume 1*, 1–11.

Di Paolo, E. A., Cuffari, E. C., & De Jaegher, H. (2018). *Linguistic Bodies: The Continuity between Life and Language*. The MIT Press.

Morris, N. (2011). Night walking: Darkness and sensory perception in a night-time landscape installation. *Cultural Geographies - CULT GEOGR*, *18*, 315–342.

Thompson, E. (2007). *Mind in life: Biology, phenomenology, and the sciences of mind* (S. xiv, 543). Belknap Press/Harvard University Press.

Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience* (S. xx, 308). The MIT Press.

Acknowledgements

DARKER SKY is co-financed by the European Union under the Interreg North Sea program.

Optimization of public lighting using multi-sensor satellite observation and ground data

Theme: Measurement and Modeling

Aurélien Mure[1,*], Florian Greffier[1], Emma Bousquet Borrut[1], Sébastien Castets[1], Samuel Busson[1], Jean-François Bretaud[1], Romuald Jobert[1], Bastien Nguyen Duy[2], Tom Brunelle[2], Camille Lhenry[2], Vincent Delbar[2], Julie Chaurand[2], Sarah Potin[2], Anne Gizard[3], Fannie Veuillot[3], and Marie-Odile Marche[4]

[1] *Cerema Occitanie, Toulouse, Angers, Nantes, Aix-en-Provence, L'Isle-d'Abeau, France*
[2] *La TeleScop, Montpellier, France*
[3] *Syane, Annecy, France*
[4] *Centre National d'Etudes Spatiales, Toulouse, France*
aurelien.mure@cerema.fr
[*] *presenting author*

Introduction

Light pollution is known to disrupt ecosystems, affect human health, and obscure our view of celestial objects. This phenomenon primarily results from poorly designed lighting fixtures, over-illumination, and the widespread use of artificial lights in urban areas. At the global scale, light pollution has been increasing by approximately 10% per year since 2011 (Kyba et al., 2023). A large part of public lighting could be optimized in order to save energy and public funds, and to reduce greenhouse gas emissions and light pollution. Nevertheless, urban planners often lack of knowledge regarding the possible location and measures to implement.

The ORENOS project (Orientation of nighttime lighting renovation by satellite observation) aims to develop an artificial light at night (ALAN) quality indicator using satellite imagery over the French departments of Haute-Savoie and Maine-et-Loire. This indicator will enable local decision-makers to prioritize actions for public lighting adaptation, renovation, or extinction, with the goal of promoting more efficient, better-adapted lighting with a lower impact on biodiversity.

To develop the ALAN quality indicator, nighttime radiance measurement and modeling will be compared. High resolution nighttime radiance measurement from the SDGSAT-1 satellite will be considered. In parallel, a model of expected radiance will be created based on local and national land cover datasets, and in situ and satellite measurements of albedo. The discrepancies could indicate possible adjustments of public lighting. It will be done with a close look at the ground optical properties and its impact on the light reflection. A second indicator will be computed to assess the impact of ALAN on biodiversity, considering local and national databases of wildlife location.

The ORENOS project is funded by the Space for Climate Observatory (https://www.spaceclimateobservatory.org/fr/orenos) and led by Cerema, LaTeleScop and the Haute-Savoie energy union (Syane). The project started at the end of 2024 and will last 18 months.

Methods

The reflectivity of a surface, called albedo, represent a significant influencing factor of radiance observed through satellite imagery. Indeed, at constant lighting levels, various radiance values can be observed from the sky depending on surface albedo. However, few scientific studies aimed at modeling light pollution consider the influence of albedo.

Over the cities of Annecy and Angers, albedo measurements obtained from daytime satellite imagery at 10 meters resolution (Sentinel-2) will be compared with field measurements of albedo, using a reference albedometer. The study will focus on albedo variations depending on surface types, and will be used as an input for expected radiance simulations. A second methodology will be developed for estimating albedo using very high resolution (1.50 meters) daytime satellite data from SPOT-6 satellite.

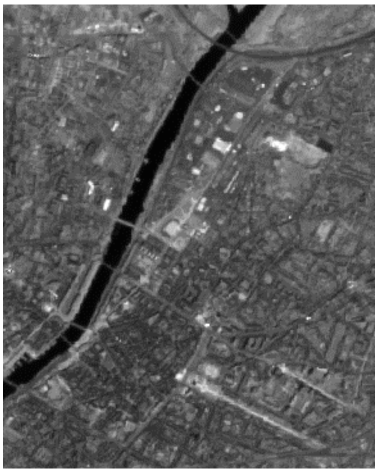


Fig. 1: Sentinel-2 albedo over the city of Angers.

The resulting albedo will then be used to model the expected nighttime radiance over Haute-Savoie, using the local public lighting database and the road type database. The masking of light by vegetation could also be modeled, using Copernicus (High Resolution Layers, Corinne Land Cover, Street tree Layer, etc.) or national datasets (OCS GE, CoSIA, BD TOPO, etc.) from the national geographic institute (IGN).

Finally, ALAN modeling will be compared with high resolution (10 meters) nighttime radiance measurement from SDGSAT-1 GLI satellite data, provided by the CBAS (International Research Center of Big Data for Sustainable Development Goals, China). The differences resulting from the comparison will indicate whether groups of lighting meets standards, has malfunctions, is overlit, or if the road surface is unsuitable.

Supplementary indicators, regarding the expected lamp type and the level of impact on biodiversity, will also be computed based on seasonal SGDSAT-1 nighttime data and local and national databases of wildlife location.

Conclusions

The confrontation of nighttime SDGSAT-1 satellite data with modeled radiance data could enable to detect maladjusted public lighting and to help local decision-makers to prioritize actions for public lighting adaptation, including more efficient and directed lighting. This project is developed over two French cities, but could be replicated to other areas. At the global scale, these actions would have a significant impact on energy saving and biodiversity preservation.

References

Kyba, C C, Altıntaş, Y Ö, Walker, C E, Newhouse, M (2023) Citizen scientists report global rapid reductions in the visibility of stars from 2011 to 2022. Science, 379(6629), 265-268

Light at night interferes with energy balance during acute inflammatory response

Theme: Health

Monika Okuliarova,[1,*] Beata Benedikova,[1] Viera Sebenova Jerigova,[1] and Michal Zeman[1]

[1] *Department of Animal Physiology and Ethology, Faculty of Natural Sciences,*
Comenius University, Bratislava, Slovakia
monika.okuliarova@uniba.sk
[*] *presenting author*

Introduction

Energy requirements markedly increase during infection or tissue injury to effectively supply the immune defence mechanisms, which involve energetically costly processes. Therefore, energy balance must be tightly regulated to redistribute the energy and nutrients between the activated immune system and other vital body functions. This is associated with metabolic adaptations that occur at both the cellular and systemic levels (Lercher et al. 2020). For example, the acute inflammatory response is characterised by a metabolic switch from glucose to lipid oxidation and sickness symptoms, including anorectic behaviour, lethargy and locomotor inactivity.

Research studies have shown that many metabolic and immune parameters exhibit daily rhythms that are controlled by the circadian clock and synchronised with external environmental cycles, primarily the light/dark (L/D) cycle. Artificial light at night (ALAN) directly disturbs the natural L/D cycles, under which all life has evolved, compromising information for the circadian clock. Indeed, in our studies in rats, we found that an exposure to dim ALAN of 2 lx profoundly suppressed the daily rhythms of clock and clock-controlled genes in the central oscillator in the hypothalamus (Okuliarova et al. 2022) and impaired the daily rhythms of several endocrine, metabolic, behavioural (Okuliarova et al. 2022; Rumanova et al. 2022) and immune parameters (Okuliarova et al. 2021; Jerigova et al. 2023). In addition, we have shown chronodisruption of the acute inflammatory response after ALAN exposure (Jerigova et al. 2023), pointing out a potential explanatory mechanism, why disruption of circadian rhythms is a recognised risk factor for several lifestyle diseases. To further understand a link between ALAN and immune dysfunction, here, we focused on the metabolic response and changes of energetic metabolism during inflammation and whether they are dependent on the timing of immune stimulation.

Methods

In our experiments, we exposed adult male Wistar rats either to the L/D (12:12 h) regime with 0 lx during the night or to the ALAN regime with dim light (~2 lx) throughout the night. To elicit the acute inflammatory response, the rats were injected i.p. with lipopolysaccharide (LPS) either during the day (passive phase) or during the night (active phase). In experiment 1, rats were monitored in the metabolic cages (Panlab, Spain) to obtain data for locomotor activity, food and water intake, respiratory exchange ratio (RER) and energy expenditure (EE). Data were averaged in 1-hour intervals. Moreover, to monitor the daily rhythms of body temperature (BT) and febrile response after LPS stimulation, animals were implanted subcutaneously with temperature loggers. In experiment 2, rats were sacrificed 3 h after stimulation to collect plasma, liver and adipose tissue samples for gene expression analysis.

Results

The daily rhythm of BT was attenuated after 2 weeks on the ALAN regime, as shown by the reduced night/day difference. After 3 weeks of ALAN, we observed the recovery of the night/day difference, but daytime BT remained elevated compared to the LD regime. The response of BT to LPS had a typical pattern with initial hypothermia followed by pronounced hyperthermia, especially during the light phase. Interestingly, the hypothermic response was absent on the ALAN regime, regardless of the time of day the rats were challenged with LPS.

Next, LPS stimulation reduced RER and EE, in parallel with a reduction in locomotor activity. The RER is calculated as the ratio of CO_2 produced to O_2 consumed and illustrates the transition from carbohydrate to lipid utilisation. In the ALAN regime, daytime LPS challenge induced a lower RER response, indicating an impaired ability to switch to lipid metabolism during acute inflammation. These data on energetic metabolism were in line with molecular analysis of immune and metabolic pathways in the liver and adipose tissue. Interestingly, ALAN reduced fatty acid mobilisation after daytime LPS injection, particularly compromising the capacity to maintain FA metabolic adaptations during inflammation. This is consistent with our previous results, reporting that dim ALAN attenuated the anorectic response to endotoxin when rats were challenged during their early light phase (Jerigova et al. 2023).

Conclusions

Together, our results demonstrate important links between the circadian control of the inflammatory response and metabolism. Exposure to dim ALAN impaired energy balance and lipid metabolic adaptations during acute inflammation, which may cause immune dysfunction and limit immune defence mechanisms.

Study was supported by the Slovak Research and Development Agency APVV-21-0223 and VEGA 1/0565/22.

References

Jerigova V, Zeman M, Okuliarova M (2023). Chronodisruption of the acute inflammatory response by night lighting in rats. Sci Rep, 13(1), 14109

Lercher A, Baazim H, Bergthaler A (2020). Systemic immunometabolism: challenges and opportunities. Immunity, 53(3), 496-509

Okuliarova M, Dzirbikova Z, Rumanova VS, Foppen E, Kalsbeek A, Zeman M (2022) Disrupted circadian control of hormonal rhythms and anticipatory thirst by dim light at night. Neuroendocrinology, 112(11): 1116–1128

Okuliarova M, Mazgutova N, Majzunova M, Rumanova VS, Zeman M (2021) Dim light at night impairs daily variation of circulating immune cells and renal immune homeostasis. Front Immunol, 11(3548), 614960

Rumanova VS, Okuliarova M, Foppen E, Kalsbeek A, Zeman M (2022) Exposure to dim light at night alters daily rhythms of glucose and lipid metabolism in rats. Front Physiol, 13, 973461

Examining the Effects of LED Street Lighting on the Activity of Bat Species

Theme: Biology & Ecology

Kevin O'Reilly[1,*], and Niamh Roche [2]

[1] Ulster University, Coleraine, Northern Ireland
[2] Bat Conservation Ireland
caoimhino94@gmail.com
[*] presenting author

Introduction

The transition from traditional artificial lighting at night (ALAN) technologies to light-emitting diode (LED) street lighting is occurring on a global scale due to benefits such as increased energy efficiency and cost-effectiveness. However, the impact of this shift on nocturnal wildlife, particularly bats, remains understudied. Certain bat species react differently to the presence of ALAN with some exhibiting avoidant behaviour while others are generally considered more tolerant of ALAN (Mathews et al., 2015). Some bat species even use ALAN to their advantage for foraging (Stone et al., 2012).

Fig. 1: Map of transects chosen for spatial analysis.

Current lighting guidelines recommend the use of LED lighting under the assumption that it has reduced effects on bats compared to older lighting technologies (Institute of Lighting Professionals, 2023). This study utilizes data from Bat Conservation Ireland's (BCIreland) car-based bat monitoring scheme to investigate whether LED streetlights influence bat activity to the same degree as non-LED lighting, with a particular focus on more light-tolerant bat species.

Methods

Data was collected across Ireland using a network of 420 transects, each surveyed twice per year from 2020 to 2023. Bat activity was recorded using full-spectrum detectors and analysed using spatial and statistical modelling techniques. Streetlights were categorized into LED and non-LED types. Generalized Linear Mixed Modelling (GLMM) was employed to assess differences in bat activity relative to lighting type and other temporal and environmental factors. A subset of transects was chosen to carry out spatial analysis on clustering patterns of bat activity around light sources (Fig. 1).

Results

GLMM analysis revealed that *Nyctalus leisleri* exhibited increased activity along LED-lit transects compared to non-LED and unlit transects (estimate = 1.3, t-value = 5.617, $p < 0.05$). *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus* showed no significant relationship with lighting type, suggesting varied responses across species. Spatial analysis indicated that bat activity was clustered around both LED and non-LED streetlights, supporting the hypothesis that increased insect prey attraction near ALAN influences bat foraging behaviour irrespective of lighting type (Voigt & Kingston, 2016).

Conclusions

These findings challenge the prevailing assumption that the use of LED lighting as opposed to other lighting technologies mitigates the ecological impact of ALAN on bats. Instead, LED luminaires may exert similar or even greater influences on bat activity compared to traditional lighting technologies. Conservation strategies should prioritize species-specific mitigation measures, such as reduced-intensity lighting and adaptive lighting schemes, to minimize negative effects on bat populations (Kerbiriou et al., 2020; Heim et al., 2024). Further research is needed to explore the spectral composition of LED lighting and its ecological consequences on nocturnal species such as bats, and their invertebrate prey.

References

Heim O, Chávez F, Courtiol A, Paul F, Voigt CC (2024) Guild-specific response of bats to motion-triggered LED lighting of bicycle trails. Conservation Science and Practice, 6(4).

Institute of Lighting Professionals (2023) Guidance Note 08/23: Bats and Artificial Lighting at Night.

Kerbiriou C, Barré K, Mariton L, Pauwels J, Zissiz G, Robert A, Le Viol I (2020) Switching LPS to LED Streetlight May Dramatically Reduce Activity and Foraging of Bats. Diversity.

Mathews F, Roche N, Aughney T, Jones N, Day J, Baker J, Langton S (2015) Barriers and benefits: implications of artificial night-lighting for the distribution of common bats in Britain and Ireland. Biological Sciences.

Stone E, Jones G, Harris S (2012) Conserving energy at a cost to biodiversity? Impacts of LED lighting on bats. Global Change Biology, 18(8), pp. 2458 - 2465

Voigt C, Kingston T (2016) Bats in the Anthropocene: Conservation of Bats in a Changing World. s.l.:Springer Open.

A European Light Pollution Awareness Event

Theme: Social Science & Humanities

Stijn Vanderheiden[1,*] , Fleur De Nil, [1] and Friedel Pas[1]

[1] Leve(n)de Nacht vzw / Living Night, Boortmeerbeek, Belgium
friedel.pas@livingnight.org
[*] presenting author

Introduction

In Belgium there is a yearly Night of Darkness since 1996. Local governments and private

Organisations switch off a part or all their outdoor lighting. At the same time there are many local activities organised like star gazing, nightly nature walks, telling stories and concerts in the dark, …. Events where the public can experience different aspects of the night and enjoy darkness. Every year a lot of local and regional organizations are participating. They host between 15000 and 25000 visitors at the local events en let them experience the beauty of the night. The members of al those local organizations and those visitors, and also the diversity of those organizations increase seriously the critical mass of concern about light pollution what makes the subject getting on the agenda and make that politicians can not neglect anymore the topic.

In Europe there are several countries with a legislation on light pollution that does not seems to work, there are also countries that have lack of good legislation but good awareness where more positive changes are on light pollution and last but not least countries with as well good legislation and awareness. Legislation without awareness usually remains a dead letter because it is not supported enough and you have never enough man power to control the legislation. When there is awareness there is a need of a good guide for lighting in a proper way and legislation can be that guide. So awareness supports legislation and legislation supports the impact of awareness.

Purpose

Light pollution is in most countries seen as an environmental and ecological issue. In most countries the legislation about these subjects is just limited to what the EU obligates the states to do. That means that in those countries there will come changes to light pollution policy only when there is an EU policy.

The EU mentions light pollution as an important issue for the declination of biodiversity, but did not work out yet a clear policy to tackle that.

To get that changed it is important to show European politicians there is a broad awareness and support on reducing light and light pollution by a wide range of different organizations and a broad part of the public.

Because of that it would be powerful to have a month of activities throughout Europe in the context of light pollution that can be visited by the public - arranged not only by astronomical associations but also nature and cultural associations - to increase in that way our European critical mass. In several European countries, activities are already being held and most of them are currently happening in the month of October. We would like to call on these other organizations across Europe to also organize activities in their countries to highlight light pollution and bring them together under one European umbrella.

Plan for the future

In the Flemish, Walloon and North France region there exists already an awareness campaign on the second Saturday of October. We have submitted an INTERREG microproject to set up a first collaboration between these partners and to share our experience. The feedback and knowledge gained from this can be used after two years to roll out the collaboration across Europe. The project should be granted before the ALAN conference. When the project is not granted we still want to share information between these three regions, but the possibilities to do will be less then when the project is granted. It's still our goal to use that collaboration experience to result in a European event over the next years.

The Interreg partners are ASCEN and Leve(n)de Nacht / Living Night in Belgium and ANPCEN in France. The project should run for 18 months and will be called NIGHT-ELAN, **N**etwork **I**nitiatives **G**enerating a **H**alt **t**o **E**xcessive **L**ight **a**t **N**ight.

References:

Websites of events that could become part of the European awareness event:

BE: Nacht van de duisternis in Flanders: https://www.nachtvandeduisternis.be

BE : Nuit de l'obscurité in the Walloon region: http://www.ascen.be/no/

FR : Jour de la nuit in France: https://jourdelanuit.fr/

NL: Nacht van de nacht in the Netherlands: https://nachtvandenacht.nl/

IRL: Mayo Dark Sky Festival: https://www.mayodarkskyfestival.ie/

D&AUS: Paten Der Nacht & Earth Night : https://www.paten-der-nacht.de/ or https://www.earth-night.info/

One-year *in situ* study of ALAN's impacts on a worldwide coastal areas species, the oyster *Crassostrea gigas,* and the European native oyster *Ostrea edulis*.

Theme: Biology and Ecology

Laura Payton[1,*], Audrey Botté[1], Yannick Geerebaert[1], and Damien Tran[1]

[1]*Univ. Bordeaux, CNRS, Bordeaux INP, EPOC, UMR 5805, F-33120 Arcachon, France*
laura.payton@u-bordeaux.fr
[*]*presenting author*

Introduction

Coastal ecosystems are strongly exposed to ALAN with 1.6 million km^2 of the coastal seas affected by this phenomenon at 10-m depth (Smyth et al., 2021). The importance of studying ALAN's effects on coastal organisms has been addressed mainly recently (Marangoni et al., 2022). The Pacific oyster *C. gigas* is the world's most globalized marine invertebrate inhabiting coastal environments. Introduced from East Asia to over 50 countries for aquaculture, wild *C. gigas* has colonized these new environments and is often considered as an invasive species (King et al., 2021). On the opposite, its European native congener *O. edulis* is threatened with extinction (Pogoda et al., 2020). As sessile bivalve mollusks, oyster species are likely exposed to ALAN, which is suspected to disrupt their daily, lunar, and annual rhythms, synchronized with the natural cycles of the sun- and moonlight (Payton and Tran, 2019; Tran et al., 2020).

We showed in previous studies under laboratory-controlled conditions that the *C. gigas*' daily rhythm is disrupted by ALAN starting from of 0.1 lux (Botté et al., 2023a). This impact has also been shown to be wavelength-dependent and worsens when applying the part-night lighting mitigation strategy when the skyglow is maintained (Botté et al., 2023b, 2023c). Finally, we showed an impact on the daily shell growth and a gill microbiota dysbiosis, both directly correlated with the daily rhythm robustness decrease (Botté et al., *submitted*).

To go further, we have investigated ALAN's impacts under realistic conditions. For that, we performed a one-year field study under semi-controlled conditions mimicking skyglow just above the maximum moonlight intensity. We recorded throughout the year the effect of ALAN on valve behaviour, shell growth, dry weight, and gonadal development. ALAN's impacts on behavioural rhythms and growth were compared between *C. gigas* and *O. edulis*.

Methods

The study was performed at the "*île aux oiseaux*" island (Lat.: 44.7°; Long. -1.18°), the emerged site the least affected by ALAN in Arcachon Bay (France), from Dec. 2023 to Nov. 2024. The experimental platform consisted of two equipped oyster tables separated from each other by 18 meters, linked by underwater wires of power supply and transmission data to an emerging technical platform (Figure 1). The control

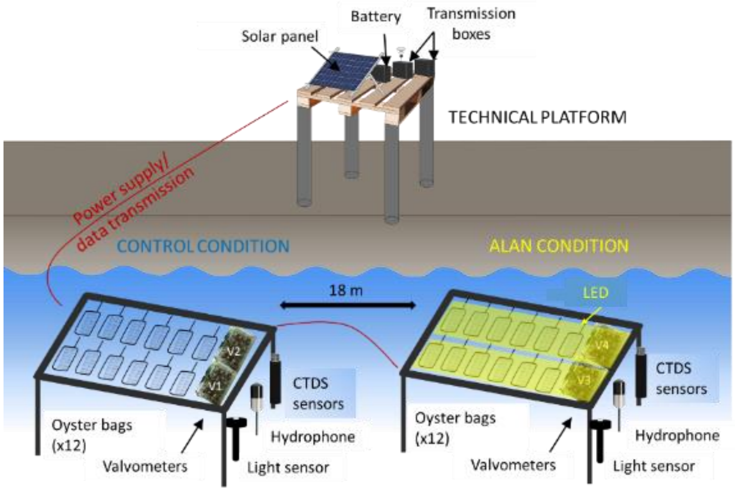


Figure 1: Experimental setup.

table was exposed to natural conditions, while the second table was exposed to a continuous low ALAN intensity (~10^{-6} µE/cm²/s; ~0.5 lx) using submersible LEDs. This semi-controlled experience allowed all oysters to be exposed to the same environmental conditions, except light intensity at night, in terms of physico-chemical, climatic, and biological conditions, to avoid multifactorial effects. For each table, the valve activity of 16 *C. gigas* and 16 *O. edulis* was continuously recorded using HFNI valvometers (Tran et al., 2020). Furthermore, 12 bags of 16 *C. gigas* were placed on each table and sampled monthly for biometric measurements (dry weight, Marteil index) and molecular analyses (real-time qPCR, RNA sequencing, *not presented here*). High-accuracy physicochemical sensors were also installed, recording underwater real-time and high-frequency, light irradiance, temperature, water level, salinity, turbidity, conductivity, and noise.

Conclusions

This study, part of the ANR LUCIOLE project (*Light pollution impacts on organisms living in coastal environments*), constitutes an innovative long-term field approach of ALAN impacts on coastal invertebrate species. Results show that ALAN, in a skyglow range intensity, impacts the physiology of both oyster species. ALAN strongly increases shell growth, with an earlier growth peak at the annual scale. An annual advance of phase is also observed in the gonadal development of *C. gigas*. Furthermore, ALAN's impacts on the behavior and the different biological rhythms studied (daily, tidal, lunar and annual) are analyzed for both species. Overall, *O. edulis* is more impacted than *C. gigas*, suggesting an highest sensitivity of the European native oyster to ALAN. These findings echo the *C. gigas* current expansion on the coastlines, on contrary to *O. edulis* which struggles to reintroduce, highlighting that ALAN should be considered as a relevant parameter potentially affecting nearshore native oyster restoration measures.

References

Botté A, Payton L, Tran D. 2023a. Artificial light at night at environmental intensities disrupts daily rhythm of the oyster *Crassostrea gigas*. Marine Pollution Bulletin 191:114850. doi:10.1016/j.marpolbul.2023.114850

Botté A, Payton L, Tran D. 2023b. The effects of artificial light at night on behavioral rhythm and related gene expression are wavelength dependent in the oyster *Crassostrea gigas*. Environ Sci Pollut Res. doi:10.1007/s11356-023-30793-1

Botté A, Payton L, Lefeuvre E, Tran D. 2023c. Is part-night lighting a suitable mitigation strategy to limit Artificial Light at Night effects on the biological rhythm at the behavioral and molecular scales of the oyster *Crassostrea gigas*? Science of The Total Environment 905:167052. doi:10.1016/j.scitotenv.2023.167052

King NG, Wilmes SB, Smyth D, Tinker J, Robins PE, Thorpe J, Jones L, Malham SK. 2021. Climate change accelerates range expansion of the invasive non-native species, the Pacific oyster, *Crassostrea gigas*. ICES Journal of Marine Science 78:70–81. doi:10.1093/icesjms/fsaa189

Marangoni LFB, Davies T, Smyth T, Rodríguez A, Hamann M, Duarte C, Pendoley K, Berge J, Maggi E, Levy O. 2022. Impacts of artificial light at night in marine ecosystems—A review. Global Change Biology 28:5346–5367. doi:10.1111/gcb.16264

Payton L, Tran D. 2019. Moonlight cycles synchronize oyster behaviour. Biology Letters 15:20180299. doi:10.1098/rsbl.2018.0299

Pogoda B, et al. 2020. NORA moving forward: Developing an oyster restoration network in Europe to support the Berlin Oyster Recommendation. Aquatic Conservation: Marine and Freshwater Ecosystems 30:2031–2037. doi:10.1002/aqc.3447

Smyth TJ, Wright AE, McKee D, Tidau S, Tamir R, Dubinsky Z, Iluz D, Davies TW. 2021. A global atlas of artificial light at night under the sea. Elementa: Science of the Anthropocene 9:00049. doi:10.1525/elementa.2021.00049

Tran D, Perrigault M, Ciret P, Payton L. 2020. Bivalve mollusc circadian clock genes can run at tidal frequency. Proceedings of the Royal Society B: Biological Sciences 287:20192440. doi:10.1098/rspb.2019.2440

Monitoring the Night Sky using Fish-eye Lenses- The KID-Darker Sky Monitoring Network

Theme: Measurements and Modeling

Reynier F. Peletier,[1,*] Dirk van der Geest,[1] Jake Noel-Storr[1], Alex Hin[1], Theo Jurriëns[1], Nynke Visser[1], Andreas Hänel[2], Shah, F.R.[1], and Björn Poppe[2]

[1] *University of Groningen, The Netherlands*
[2] *University of Oldenburg, Germany*
[*] *presenting author*

To keep dark sky places dark, automatic night sky monitoring is of utmost importance, to understand the sources of ALAN and their increase. In the INTERREG North Sea KID (Keep it Dark) project we have developed a night sky monitoring system in the Waddensea, a World Heritage Area, consisting of a network of 40 SQMs and about 10 DSLRs, placed in a number of Dark Sky areas and some brighter places. In the subsequent INTERREG Darker Sky project we are using this network for monitoring the night sky.

An analysis of the SQM brightness in 27 locations in the Netherlands and Northern Germany reveals that in the darkest areas, light pollution is increasing at a rate of 3-4 percent per year. Contrary to data from the SUOMI-VIIRS satellite, seasonal effects can be seen. In bright areas the analysis of SQMs is much more difficult, since large variations are seen, as a result of artificial light sources. The results have been submitted for publication (Shah et al. 2025). Here DSLRs provide much more useful information.

In this presentation, we discuss some results obtained with our system of Wide Angle DSLR Camera's. They consist of some SQCs from Andrej Molnar, and some other Canon RP camera's, for which we developed the software ourselves. We discuss monitoring in the harbor of Lauwersoog, one of the pilot harbours in the Darker Sky project, in which we are working with the local stake holders to reduce light pollution. We also discuss the results from analyzing the colors of the light. The introduction of LED light has caused bluing in many places, with its negative effects for biodiversity. We end discussing the advantages of having the camera's in the darker places, as opposed to SQMs.

The system of DSLRs produces images that are available to the public on-line. We will discuss the system, and the efforts required for maintaining it.

Reference:

Shah, F.R., Peletier, R.F., Noel-Storr, J., van der Geest, D., Jurriens, T., Hänel, A., Cordes, L., Hoffmann, T., Will, R., Rietze, A.S., Gehlen, M., Kjelden, H., Nazzari, C. and Björn Poppe, B., 2025, submitted to Monthly Notices of the Royal Astronomical Society.

Long-term effect of short light treatments in the case of annual plants: the comparison of growth and development of chamomile (*Matricaria chamomilla* L.) after different artificial light treatments of seedlings

Theme: Biology & Biology and Ecology

Erika Pénzes-Kónya,[1*] Marianna Marschall[1] and Zoltán Kolláth[2]

[1]Department of Botany and Plant Physiology, [2]Department of Physics
Eszterházy Károly Catholic University, Eger Hungary
konya.erika@uni-eszterhazy.hu
[*] presenting author

Introduction

Annual plants have high adaptive potential and their distribution is predicted to be higher and higher in certain areas on Earth (Poppenwimer et al. 2023). Short-lived vascular plant species like chamomile can be model organisms for testing the wide plasticity in responses to ALAN effects. Chamomile has a wide distribution range and it occurs naturally also it is cultivated in several countries (Chauhan et al. 2022). The main question of the experiments made in the laboratory, in the greenhouse, and botanical garden was simple: are flowering chamomile individuals different in dry phytomass values and flower numbers after a short light treatment effect in their germination period?

Methods

Fig. 1. Chamomile seedlings and seeds in distilled water during the experiment
Photo: Erika Pénzesné Kónya

Experiments were carried out at the Department of Botany and Plant Physiology in 2 Memmert climate chambers (2950K warm, 6550K cold light spectrum) at 18˚C and 21˚C for 4 weeks. A natural light/ dark cycle was applied to the control population and constant lighting was used in both the warm and cold light chambers. The method of germination experiments was unique but successful: seeds were placed into glass tubes filled with distilled water and no nutrients were added to the tubes during the light experiments (Fig. 1). After 4 weeks the plant individuals were planted into soil in the greenhouse of EKCU. The root-green shoot rate of the individual seedlings was measured under a stereo microscope at the Department of Botany and Plant Physiology of EKCU and dry phytomass was measured separately for roots, shoots, leaves, and flowers. The samples were collected from the chamomile cultivation grown in the Botanical Garden of EKCU.

Conclusions

The results indicate that the short light treatments significantly affect individuals throughout their entire life cycle, which is a novel finding for this plant species. The seedlings from the two light treatments, utilizing cold and warm LED light sources, exhibit healthy growth with distinct morphological features; however, all populations can produce viable seeds.

References

Poppenwimer T, Mayrose I & Demalach N (2023) Revising the global biogeography of annual and perennial plants. *Nature* 624: 109–114. https://doi.org/10.1038/s41586-023-06644-x

Chauhan R, Singh S, Kumar V, Kumar A, Kumari A, Rathore S, Kumar R, & Singh S (2022) A comprehensive review on biology, genetic improvement, agro and process technology of German chamomile (*Matricaria chamomilla* L.). Plants 11(1): 29. https://doi.org/10.3390/plants11010029

A National Milestone in Light Pollution Research: Uruguay's Interdisciplinary Approach to ALAN Mitigation

Theme: Biology & Biology and Ecology, Governance & Regulation

Florencia Reichmann [1*], Andrés Canavero [1], Andrés Olivera [2], Patricia González [3], Camila Gianotti [1], Andrés Fernández [4], Sheena Salvarrey [3], Santiago Roland [1], Valentina Pezano [1], Verónica Quirici [5], Alejandro Sánchez de Miguel [6], Emilio Falco [7], Rafael Bernardi [1] and Andrea Sosa [1]

[1]Centro Universitario Regional Este, Universidad de la República, Maldonado/Rocha, Uruguay
[2] Independent Researcher, Montevideo, Uruguay
[3] Facultad de Ciencias, Universidad de la República, Montevideo, Uruguay
[4] Sistema Nacional de Áreas Protegidas (SNAP), Uruguay
[5] Universidad Andrés Bello, Santiago de Chile, Chile
[6] Instituto de Astrofísica de Andalucía, Granada, Spain
[7] Southern Arizona Chapter of DarkSky International, Tucson, United States
florencia.reichmann@cure.edu.uy
[*] presenting author

Introduction

In 2025, Uruguay launched its first Research Group for Light Pollution Studies—a pioneering initiative in the Global South. Backed by Universidad de la República (Udelar), the group links researchers, institutions, and communities to address artificial light at night (ALAN) through science, education, and public policy. This work responds to growing concern over the environmental, cultural, and health impacts of light pollution.

Here we outline the group's integrated approach to ALAN mitigation, structured around: (1) ecological and night sky research, (2) community engagement and education, and (3) policy collaboration.

Methods

(1) Ecological and Night Sky Impact Research

- A master's thesis is assessing ALAN effects on ecological connectivity in South America using satellite data and network theory.
- A long-term monitoring program assesses the impact of LED transitions on night sky brightness, combining fixed SQM measurements in Montevideo (in collaboration with the Technical Unit of Public Lighting) and protected areas in Uruguay such as Ambá, Laguna Garzón, and Paso Centurión.
- Biodiversity surveys include insect sampling (glue and box traps) and acoustic monitoring to evaluate nocturnal activity under different lighting conditions.

(2) Community Engagement and Education

- Workshops, talks, and technical advice are delivered to communities and authorities in Rocha, Canelones, and Maldonado.
- A participatory process is advancing the designation of Ambá as Uruguay's first Dark Sky Park.
- Educational actions include courses and integration of light pollution content into university programs.

(3) Policy and Institutional Collaboration

- The group is co-developing Uruguay's first regulations on light pollution with the governments of Rocha and Montevideo.
- Continuous dialogue with decision-makers promotes the inclusion of ALAN in local environmental agendas.
- Work with neighbors, private actors, and authorities helps quantify lighting changes and demonstrate measurable improvements in night sky quality.

Conclusions

This interdisciplinary research initiative demonstrates how ALAN can be addressed through science-based action and collaborative governance. The group provides data, tools, and guidance to support evidence-informed decisions for light pollution mitigation. As a model rooted in the Global South, it helps protect the night as a shared ecological and cultural resource—while also drawing on the expertise of international collaborators and researchers from other world regions.

References

Universidad de la República. (n.d.). Núcleo interdisciplinario de estudios en contaminación lumínica: mitigación e implicancias sobre el cielo nocturno, los ecosistemas y la salud humana. https://www.ei.udelar.edu.uy/grupos-financiados/sigla-acronimo/nucleo-interdisciplinario-estudios-contaminacion-luminica-mitigacion-implicancias-sobre-cielo

Deploying dense ALAN monitoring networks for territorial actions:

the cases of Réunion Island and La Brière region, France

Theme: Measurement and Modeling

Matthieu Renaud,[1,9,*] Samuel Challéat,[2,9] Sylvain Morvan,[2,9] Christian Brouat,[3,9] Mathieu Delsaut,[3,9] Kévin Barré,[4,9] Laurent Godet,[5,9] Johan Milian,[6,9] Béatrice Morel,[3,9] Martin Riethmuller,[7] Léo Chevillon,[7] Enora Péron[8]

[1] UAR 3365, OSU-Réunion, St-Denis de La Réunion, France
[2] UMR 5602, GEODE, Toulouse, France
[3] Université de La Réunion, UR ENERGY-Lab, Saint-Denis de La Réunion, France
[4] MNHN, UMR7204 CESCO, Concarneau, France
[5] UMR6554 LETG, Nantes, France
[6] Université Paris 8, UMR7533 LADYSS, Aubervilliers, France
[7] SEOR, Cambuston, Saint-André, La Réunion, France
[8] Brière Regional Nature Park, Saint-Joachim, France
[9] Nocturnal Environment Observatory & GDR2202 LUMEN (CNRS)
matthieu.renaud@cnrs.fr ([*] presenting author)

Introduction

Although artificial light at night (ALAN) is now recognized for its significant ecological, health, and cultural impacts, its measurement and monitoring remain challenging — let alone its governance in territories concerned with nocturnal preservation. Space-borne observations have proven useful for mapping large-scale patterns (Falchi et al., 2016; Levin et al., 2020), but they fall short in capturing the fine-grained spatiotemporal dynamics of ALAN. Ground-based approaches have emerged as a complement, involving both professional and citizen-science networks (Duriscoe et al., 2007; Hänel et al., 2018). Yet, most rely on sparse infrastructures — SQMs or all-sky cameras — limiting their spatial resolution and temporal continuity (Jechow et al., 2019; Kolláth & Dömény, 2020). In contrast, dense networks of photometric sensors represent a transformative approach, offering high-frequency, high-resolution data at unprecedented spatial scales. Such arrays detect lighting variations across minutes to years, enabling both short- and long-term assessments (Solano Lamphar & Kocifaj, 2013; Bará et al., 2019), while also enhancing skyglow and radiative transfer modeling (Pun et al., 2021; Ribas et al., 2022). Critically, they support fine-scale evaluation of lighting policies — such as LED transitions or dimming regulations — by tracking their effects on sky brightness (Hänel et al., 2021). These systems also enable near-continuous monitoring of ALAN changes with atmospheric conditions including aerosols and cloud cover (Jechow & Hölker, 2019; Aubé et al., 2020), and help validate satellite-derived products (Levin et al., 2020; Li et al., 2022) while informing ecological and health impact assessments.

Methods

In this contribution, we present high-resolution datasets from two dense TESS-W sensor networks deployed for long-term ALAN monitoring in: (1) Réunion Island, a French territory in the Indian Ocean with volcanic terrain, high biodiversity, and a rapidly urbanizing coast; and (2) the Brière region, a wetland near France's Atlantic coast, home to a regional nature park and sensitive nocturnal ecosystems. These networks provide continuous, multi-year measurements of night-sky brightness at fine spatial (~km) and temporal (~minute) scales.

Conclusions

We describe the network architecture, calibration procedures, data processing pipeline, and access details. By making these high-resolution ALAN datasets openly available, this work enhances our ability to monitor light pollution and evaluate the effectiveness of mitigation strategies. Designed as part of the *Observatoire de l'Environnement Nocturne* of the French National Centre for Scientific Research (CNRS), these datasets offer a robust empirical foundation for investigating the multifaceted dynamics of light pollution across ecological, atmospheric, sociocultural, and territorial contexts. They also contribute to public engagement and educational initiatives, fostering broader awareness and collective action toward preserving the nocturnal environment.

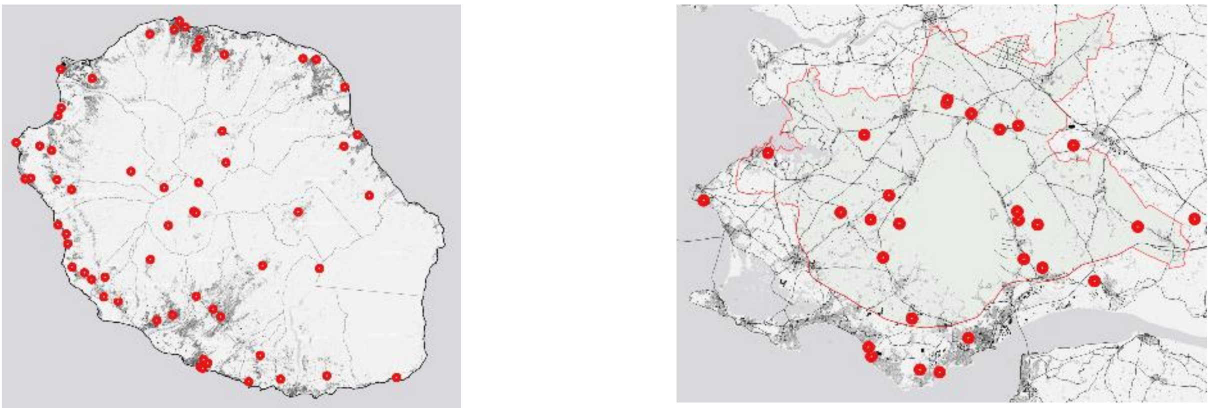


Fig.1: Maps of the TESS-W networks currently deployed in La Réunion *(left)* and in La Brière *(right)*

References

Falchi, F., Cinzano, P., Duriscoe, D., et al. (2016) The new world atlas of artificial night sky brightness. *Science Advances*, 2(6), e1600377
Levin, N., Kyba, C. C. M., Zhang, et al. (2020) Remote sensing of night lights: A review and an outlook for the future. *Remote Sensing of Environment*, 237, 111443
Duriscoe, D. M., Luginbuhl, C. B., & Moore, C. A. (2007) Measuring night-sky brightness with a wide-field CCD camera. *Publications of the Astronomical Society of the Pacific*, 119(852), 192-213
Hänel, A., Posch, T., Ribas, S. J., et al. (2018). Measuring night sky brightness: methods and challenges. *J. Quant. Spectrosc. Radiat. Transf.*, 205, 278-290
Jechow, A., Kolláth, Z., & Hölker, F. (2019). Variability of night sky brightness and cloud coverage near an urban area. *J. Quant. Spectrosc. Radiat. Transf.*, 235, 106162
Kolláth, Z., & Dömény, A. (2020). Introducing the dark sky unit for multi-spectral measurement of the night sky quality with commercial digital cameras. *J. Quant. Spectrosc. Radiat. Transf.*, 253, 107162
Solano Lamphar, H. A., & Kocifaj, M. (2013). Light pollution in ultraviolet and visible spectrum: Effect on different visual perceptions. *PLoS ONE*, 8(2), e56563
Bará, S., Lima, R. C., & Zamorano, J. (2019). Monitoring skyglow with astronomical all-sky cameras. *International Journal of Sustainable Lighting*, 21(1), 12-17
Pun, C. S. J., So, C. W., & Chung, F. T. W. (2021). A review of the state-of-the-art in skyglow modeling. *Remote Sensing*, 13(3), 461
Ribas, S. J., Aubé, M., & Bará, S. (2022). Light pollution monitoring using digital cameras: A case study in Montsec (Spain). *International Journal of Sustainable Lighting*, 24(1), 1-9
Hänel, A., Posch, T., & Ribas, S. J. (2021). The evolution of light pollution in German cities. *J. Quant. Spectrosc. Radiat. Transf.*, 256, 107283
Jechow, A., & Hölker, F. (2019). How dark is a river? Artificial light at night in aquatic systems and the need for comprehensive night-time light measurements. *Wiley Interdisciplinary Review: Water*, 6(6), e1388
Aubé, M., Roby, J., & Kocifaj, M. (2020). Evaluating potential spectral impacts of various artificial lights on melatonin suppression, photosynthesis, and star visibility. *PLoS ONE*, 15(10), e0239314
Li, X., Ma, R., & Zhang, Q. (2022). Anisotropic characteristics of artificial light at night: Implications for remote sensing of nighttime light. *Remote Sensing of Environment*, 268, 112760

Perceptions and knowledge of coastal Artificial Light at Night

Theme: Social Sciences and Humanity

Olivia R. Rendón[1,*], Andrew Edwards-Jones [1], Nicole Janhsen [2], Rodrigo Estevez Weinstein[3], Cristian Duarte Valenzuela[2]

[1] Plymouth Marine Laboratory, Plymouth, UK
[2] Universidad Andres Bello, Santiago, Chile
[3]Universidad Santo Tomas, Chile
**ore@pml.ac.uk*

Introduction

Artificial Light at Night (ALAN) is an important field of study with increasing attention from the academic and policy sectors (Davies and Smyth 2017), especially its impacts in the marine environment (e.g. Candolin 2024, Stanton and Cowart 2024). As our understanding of marine ALAN impacts rises, concerns and potentially new policies are likely to follow e.g. Chile's 2023 national law on lighting, EU Horizon funding for light pollution research. An area less studied is society's knowledge and perceptions on the existence of ALAN pollution and its potential impacts.

Most studies on societal ALAN impacts have focused on human health or on terrestrial ecosystems and species (e.g. La Sorte et al. 2022, Hansen 2017). This study aims to assess society's knowledge and perceptions of marine ALAN and their willingness to support (or not) the implementation of different mitigation measures (e.g. light colour change, lower post heights, reduced light intensity). Our results will help guide implementation of socially acceptable ALAN mitigation measures and highlight possible societal resistance.

Methods

Two coastal cities, Valparaiso and Vina del Mar, with some of the highest levels of ALAN in Chile were selected as case study sites. A Chilean recruitment company carried out a total of 100 pilot surveys and 754 final in-person household surveys in 2022. Surveys were done along transects radiating from the coast inland. The survey was designed to gather data on ocean connectedness, knowledge of ALAN, perceived human and marine life impacts of ALAN, exposure to ALAN problems, willingness to support different ALAN mitigation measures, management of ALAN, and sociodemographic information. Data was analysed using exploratory statistics to determine trends and multinomial logistic regressions to understand concern for ALAN and support for mitigation measures.


Fig 1. Example 1 of urban beach ALAN Chile (photo credit: A. Edwards-Jones)

Fig 2. Example 2 of urban beach ALAN in Chile in (photo credit: A. Edwards-Jones)

Conclusions

The study found extremely low awareness of marine ALAN pollution. The main benefits of ALAN were perceived personal safety, safer movement/transport, and property security. The main negative effects of ALAN were traffic accidents and loss of starry sky. ALAN mitigation measures had different levels of support, with the most support for reducing light intensity in protected areas, installing lights with movement sensors and reducing light glare (between 58-70%). While reducing light post height, changing white to yellow lights and turning off lights had the least support (28-42%).

Further, concern for coastal-marine ALAN pollution was found to be higher for office workers, with a strong ocean connectedness index, perceiving importance of marine ALAN impacts and those that have experienced a problem with ALAN near their home. There was less support for ALAN mitigation measures from women, those in mid to high socioeconomic status, non-professionals and those perceiving more negative impacts from ALAN.

There is a large part of society that has low awareness of ALAN, especially regarding the marine environment. This leads to a low concern for marine ALAN and its impacts. Thus, ALAN mitigation measures with high social acceptance need to be prioritised, but they need to consider the perceived/actual feeling of safety by women and create greater awareness of ALAN impacts.

References

Candolin U (2024) Coping with light pollution in urban environments: Patterns and challenges. iScience 27, 109244.

Davies TW, Smyth T (2017) Why artificial light at night should be a focus for global change research in the 21st century. Global Change Biology 24: 872-882.

Hansen J (2017) Night Shift Work and Risk of Breast Cancer. Curr Envir Health Rpt 4:325-339.

La Sorte FA, Lepczyk CA, Aronson MFJ (2022) Light pollution enhances ground-level exposure to airborne toxic chemicals for nocturnally migrating passerines. Global Change Ecology 00:1-12.

Stanton DL, Cowart JR (2024) The effects of artificial light at night (ALAN) on the circadian biology of marine animals. Frontiers in Marine Science 11, 1372889.

The importance of Night Sky Quality Certifications, a controversy is served.

Theme: Governance & Regulation

Salvador J. Ribas[1,*]

[1] Parc Astronòmic del Montsec – Ferrocarrils de la Generalitat de Catalunya, Àger, Spain
sjribas@parcastronomic.cat
[*] presenting author

In recent years there is a notable increase of natural areas and other kind of figures that apply to be certified with one or more of the Night Sky Quality Certifications available nowadays. There are probably many possibilities to be certified but mainly it could be divided in two blocs: national or regional laws with associated certification and independent private institutions certifications.

But these certifications are opening a kind of war to be certified and, specially from private certifications, there is a notable increase of demand to be certified. This peak is probably linked to the notable increase of astrotourism activities all around the world and the important economy associated with them.

But there are many controversies opened around the certifications:

- How is the evaluation of the quality of the night sky and other parameters in this certifications?
- Are the parameters to classify the quality used reasonable?
- Are the international certification really worldwide? Currently it seems any certifying institution has a “comfort” environment where it expands easily.
- Is the money to pay some certifications (or the expenses to prepare the proofs of requirements) crucial in the process?
- Are the response time to get certifications reasonable?
- Is it possible that a place get an international certification and not following on site laws or recommendations for protected areas?
- Is there a way to get an agreement with private certifying institutions to facilitate the multiple certification in less steps?

The aim of this talk is to open a discussion and not looking to another side on these controversies. Probably there is no real answer or solutions to some of the open questions but the role of professional researchers of ALAN different topics (Biology, Health, Regulation, … experts) it is more necessary than the usual participation of specialists on Measuring or Lighting Techniques.

So a proposal of independent working group of people of all of these topics will be also presented. This group could have as main aim getting more realistic and stable night sky quality certification recommendations and define some guidelines to be sure that a quality certification is really helping the night sky protection in a wide perspective and not only astronomical or economical promotion.

Setting up Light and Noise Maps to Define the Contours of a Reserve of Darkness and Silence in Sherbrooke, Québec, Canada

Theme: Social Sciences & Humanities or M&M

Johanne Roby,[1,*] Jérome Bisson,[1] Sabrina Côté[1], Henry Curry,[1] William Fauteux,[1] Jérémy Hatier,[1] Othman Labsir,[1] Léa Rivard,[1] Gaëlle Belleau-Magnat,[2] A. Guy[2], Olivier Robin,[2] and Philippe Apparicio[2]

[1] Cégep de Sherbrooke, Sherbrooke, Canada
[2] Université de Sherbrooke, Sherbrooke, Canada
johanne.roby@cegepsherbrooke.qc.ca
[*] presenting author

Introduction

Urban sprawl is bringing cities closer to natural areas, leading to challenges like light and noise pollution. These types of anthropogenic pollution are common in areas with human presence and significantly affect both wildlife and human well-being. While artificial light improves security and modernity, it disrupts the natural nightscape, harming biodiversity and human health. Similarly, noise pollution, especially from urbanization and traffic, disturbs wildlife behavior and causes environmental stress. Although the combined effects of light and noise pollution are not fully understood, both can occur together, varying in intensity. Preserving natural light and sound is vital for effective conservation, particularly in protected areas. This project aims to evaluate strategies to reduce light and noise pollution in Parc du Mont Bellevue, Canada's inaugural certified Urban Night Sky Place by Dark Sky. Through collaboration between college and university students, the project uses brightness and noise maps to define a dark and silent reserve for long-term conservation planning. It also encourages citizen participation in data collection.

Methods

The light and sound environments around the park were mostly mapped using two devices mounted on vehicles or bicycles: a multispectral and multidirectional brightness sensor (LAN3) and a sound level meter (SLM) (fig. 1b, c). Long-term and fixed-point light and noise measurements were conducted to develop the mobile measurement protocol (fig. 1a). Wind tunnel measurements in an anechoic chamber were also used to determine the effect of travel speed on measured noise levels,

Figure 1: A. Fixed-point light and noise measurement system at SIRENE (Interdisciplinary Research Site on the Outdoor Environment), in the parc du Mont-Bellevue - B. Installation of a LAN3 and anSLM on the roof of a car for a validation campaign - C. Installation of a LANcube and an SLM on a mechanically-decoupled pole at the rear of a bike (credit@JRoby).

showing that speeds of less than 15 km/h ensure unbiased acoustic measurements using a windscreen.

Results and conclusions

Effect of wind-speed on a mobile SLM

Since we considered cars and bikes to conduct our data collection, the anechoic wind tunnel at Université de Sherbrooke was used to understand better the impact of the vehicle's speed on data collection. Several orientations of the SLM were considered, as well as two windscreen sizes, to evaluate their effect of measured Leq in dB(A). It appeared that the effect brought by the dimension of the windscreen could lead to a difference of several dB. However, the main driving parameter is the wind speed, which will inescapably increase the measured sound pressure level as soon as it goes above 15 km/h.

Light and noise maps

After a post-processing step, the team was able to propose a first combined brightness and noise map of a neighborhood east of parc du Mont-Bellevue from data collected on November 16, 2023, between 9 pm and 11:30 pm with the LAN3 and the SLM devices mounted on vehicles. The light map (Fig. 2A) distinguishes between the brightest (yellow) and darkest (purple) areas. The noise map (Fig. 2B) distinguishes between the largest (purple) and lowest (green) sound pressure levels.

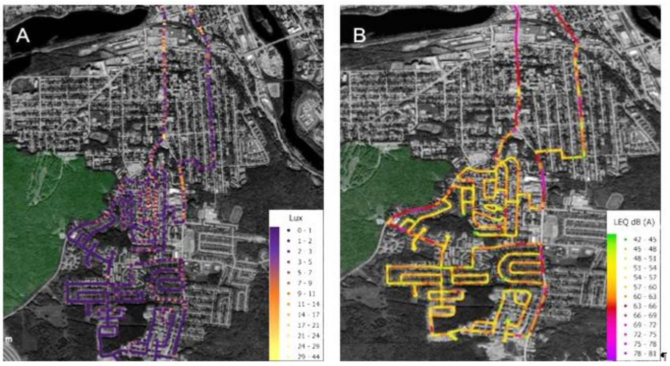


Figure 2: Preliminary results, data collected using a car - A. Light pollution map - B. Noise pollution map.

When we analyzed the noise pollution data, we found that the noise caused by the car was not constant enough to be subtracted from the values we had recorded. Indeed, every time the vehicle slowed down or accelerated, the background noise decreased or increased significantly (Fig. 2B). To overcome this problem, we are developing a methodology that allows us to cycle through the area (Fig. 1C). We are currently analyzing preliminary data which will be presented at the conference.

Additionally, our research team is currently testing and optimizing methodologies that will enable the production of noise and light maps according to specific periods (morning, noon, evening, and night). We hope that instrumented bicycles will allow this active and participatory data collection in order to properly map the area. The analysis of these maps will enable us to verify, for example, if there are connections between light pollution and noise pollution. These maps are essential for engaging with the public and decision-makers to propose solutions for reducing these types of pollution in critical areas.

Finally, to fully understand the origins of light and noise pollution and to define the limits of a reserve of silence and darkness, it is essential to develop a thorough knowledge of one's environment. It's equally important to involve students, citizens and researchers, so that everyone can contribute to the development of new knowledge while providing solutions to critical environmental problems.

The value of preserving the darkness through Agri-Climate Rural Environmental Scheme - Rural Restorative Lighting

Theme: Governance and Regulation

Elizabeth Ryder[1,*], Georgia MacMillan[2], Kerem Asfuroglu[3], John Walsh[4], Brian Espey[5] Louise Duignan[1], Mary McAndrew[1], Aileen Flynn[6], Patrick Crushell[1].

[1] ACRES West Connacht, Westport, Co. Mayo, Ireland.
[2] University of Galway, Galway, Ireland/Mayo Dark Sky Park, National Park & Wildlife Service, Ballycroy, Co. Mayo, Ireland.
[3] Dark-Source Limited, Wexford, Ireland.
[4]CT Electrical, Castlebar, Co. Mayo, Ireland.
[5]Trinity College, Dublin, Ireland.
[5]Department of Agriculture, Food and the Marine, Johnstown, Co. Wexford, Ireland.
***Corresponding author**: elizabethryder2010@gmail.com*
[*] **Presenting author.**

Introduction

In the 1990s, the Common Agricultural Policy (CAP) introduced mandatory agri-environmental schemes across all European Union member states as a measure to combat biodiversity loss. These schemes provided a structured plan for sustainable agricultural practices and funding to farmers for implementing nature conservation measures. After thirty years of agri-environmental schemes, their effectiveness is unclear (Tsakiridis et al. 2022, O'Rourke et al. 2020), and there remains a decline in habitats, biodiversity and water quality.

In Ireland to acknowledge the continued environmental and nocturnal habitat decline, there was a policy shift for a better alignment of the objectives of the CAP with European and National policies such as the Biodiversity Action Plan, the Water Framework Directive, the River Basin Management Plans, Bird and Habitat Directives and the Prioritised Action Framework for NATURA areas. As a result, the national Agri-Climate Rural Environmental Scheme (ACRES), a results-based agri-environmental model was developed and launched in 2023. This ambitious scheme strives to work directly with farmers and advisors, where farmers' payments are based on the quality of their farmland habitats and incentivised improvement to their habitats is available through appropriate targeted voluntary actions such as Non-Productive Investment and Landscape Actions.

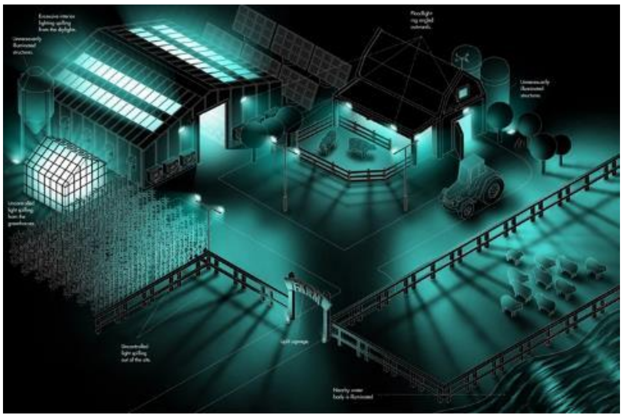
The ACRES Cooperation scheme provides opportunities to collaborate alongside regional stakeholders in the development of a Local Action Plan incorporating specalised management landscape actions. One innovative Landscape Action under ACRES is the Rural Restorative Lighting initiative, developed in collaboration with local stakeholders, including landowners, Mayo Dark Sky Park, Dark Sky Ireland, lighting experts, academics and the Department of Agriculture, Food and the Marine. This action recognises darkness as a critical habitat for nocturnal species and offers financial support, training and practical solutions for farmers to retrofit or install sustainable external lighting infrastructure on farm buildings in priority areas.

Method

By integrating restorative lighting into regional Local Action Plans as a special management landscape action, it contributes and is complementary to the broader ACRES environmental and conservation goals such as protecting watercourses, enhancing habitat connectivity, continued protection of archaeological sites, NATURA 2000 sites, annex habitats and species.

The recommended lighting infrastructure aims to protect our dark sky and nocturnal biodiversity through the:

1. Reduction of over lighting areas: ensuring that lighting is used only where necessary.
2. Choosing the right location for lighting and avoiding unnecessary lighting spillage.
3. Shielding lighting spill, preventing lighting from spreading beyond its intended area.
4. Promoting lighting at the right time through the use of timers and sensors to minimise nighttime illumination.
5. Using lower-spectrum lighting, that is energy efficient and cost effective, capable of providing visibility and safety for farmyard activities, while contributing to environmental sustainability.



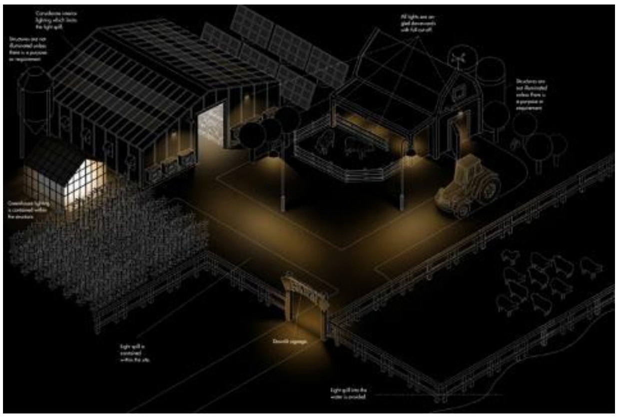


Figure 8: Example farmyard before and after implementation of lighting management. The ACRES Landscape Action - Rural Restorative Lighting is an action for external farmyard lighting and replacement only. (Graphic Kerem Asfuroglu).

References

Tsakiridis, A., O'Donoghue, C., Ryan, M., Cullen, P., Ó hUallacháin, D., Sheridan, H., and Stout, J. Examining the relationship between farmer participation in an agri-environment scheme and the quantity and quality of semi-natural habitats on Irish farms. Land Use Policy, Volume 120, 2022, https://doi.org/10.1016/j.landusepol.2022.106284.

O'Rourke, E. and Finn, J. A., eds. (2020) Farming for Nature: The Role of Results-Based Payments, Dublin: Teagasc and National Parks and Wildlife Service (NPWS). isbn: 978-1-84170-663-4

Navigating the dark:
New international guidance to mitigate light pollution for migratory species

Theme: Governance & Regulation

Cesar F. San Miguel[1,2,*] Laetitia Nunny,[2] and Narelle Montgomery[1,2]

[1] Australian Department of Climate Change, Energy, the Environment and Water, Canberra, Australia
[2] Wild Animal Welfare, La Garriga, Spain
[3] Convention on Migratory Species, Platz der Vereinten Nationen 1, 53113 Bonn, Germany
Cesar.sanmiguel@dcceew.gov.au
[*] presenting author

Artificial light at night can disrupt critical behaviours in wildlife. Where this occurs in threatened species, artificial light has the potential to stall the recovery of populations. Where it occurs in migratory species, the impact of light may compromise an animal's ability to undertake long distance migrations integral to their life cycle. For example, hatchling marine turtles may not be able to find the ocean when beaches are lit, and fledgling seabirds may not take their first flight or become grounded if their nesting habitats never become dark.

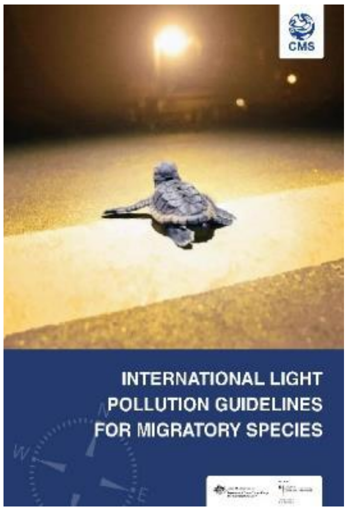


Fig. 1: CMS International Light Pollution Guidelines for Migratory Species Cover

To address the conservation challenge migratory species face, the Convention on the Conservation of Migratory Species of Wild Animals (CMS) developed *International Light Pollution Guidelines for Migratory Species* (the Guidelines). Finalised in late 2024, the Guidelines are now available for use. The Guidelines raise awareness about the impacts of artificial light on migratory species and provide a framework for assessing and adaptively managing these impacts. The Guidelines also provide six best practice principles for reducing light pollution and taxa-specific advice for marine turtles, seabirds, migratory shorebirds, migratory landbirds and bats. Critically, if countries do not have their own framework for managing light pollution, the Guidelines are applicable to any jurisdiction and context.

CMS has steadily progressed efforts to address light pollution for migratory species over the past 5 years. At the 13th Conference of Parties (COP) in 2020, CMS adopted Australia's National Light Pollution Guidelines for Wildlife and agreed to prepare international Guidelines for adoption by the 14th COP. Building on Australia's foundational work, CMS, in consultation with the CMS Scientific Council, drafted the International Light Pollution Guidelines for Migratory Species which were adopted at COP14 by 133 parties.

However, there are two overarching barriers to mitigating light pollution for migratory species—awareness and implementation. Awareness raising among different jurisdictional scales (sub-national, national, international) is still needed. Many communities and institutions remain unaware of the impacts of light pollution on wildlife and do not have policies or frameworks for managing impacts. There is also a need to enhance uptake and implementation of the Guidelines, and any other relevant mitigation guidance, by various stakeholders to ensure light pollution is managed globally for both migratory species and the environment more broadly. The CMS Scientific Council is continually progressing pathways to help mitigate light pollution for migratory species to address this complex, multi-scalar environmental challenge.

References

CMS (2024) CMS International Light Pollution Guidelines for Migratory Species. CMS Secretariat

European Union Atlas of the Real Artificial Light at Night (RALAN) with SDGSAT-1

Spectral classification and cloud detection

Theme: Measurements and Modeling

Alejandro Sánchez de Miguel,[1,2,3,*] Sam Morrel,[3,4]

1. *Instituto de Astrofísica de Andalucía (IAA-CSIC), Granada, Spain*
2. *Departamento de Física de la Tierra y Astrofísica, Instituto de Física de Partículas y del Cosmos (IPARCOS), Universidad Complutense de Madrid, Madrid, Spain*
3. *Environment and Sustainability Institute, University of Exeter, Penryn, Cornwall, United Kingdom*
4. *Department of Physics and Astronomy, University of Exeter, Exeter, United Kingdom*

**Presenting author. Corresponding author: asanchez@iaa.es*

Introduction

Artificial light at night (ALAN) is a widespread anthropogenic pressure that disrupts natural light cycles and affects a wide range of ecological and human systems. Satellite-based observations have been instrumental in monitoring ALAN, especially the VIIRS-DNB sensor aboard the SUOMI-NPP and NOAA-20 satellites. However, VIIRS lacks spectral resolution and operates at coarse spatial scales (740 m), which limits its usefulness for detecting different lighting technologies and understanding ecological impacts at the local level. The recent launch of the SDGSAT-1 satellite by the United Nations, with RGB nighttime imaging capabilities at 40 m resolution, offers a transformative opportunity to characterize ALAN with high spatial and spectral detail.

Methods

We generated the first multi-colour nighttime raster map of the entire European Union and the United Kingdom using SDGSAT-1 Level 4A products. These images were pre-processed through atmospheric correction—accounting for Rayleigh scattering, ozone and aerosol absorption—and radiometric calibration using coefficients derived from reference sites in China. To construct a homogeneous mosaic, panchromatic bands (10 m) were downsampled and integrated with the RGB bands. We applied a median mosaicking approach to reduce noise and ensure consistency across swaths.

To ensure data quality, we implemented a supervised machine learning approach for cloud and noise masking, using Random Forest classifiers trained with manually labelled examples from Spain. Input features included SDGSAT-1 band ratios (e.g., B/G), spatial entropy, blurred image features, and contextual data such as VIIRS-DNB maximum median composites, CORINE land use classes, and building height rasters from the Global Human Settlement Layer. For spectral classification, we trained another Random Forest model to distinguish between various lighting technologies based on correlated colour temperature (CCT), including high-CCT LEDs, high-pressure sodium lamps, and intermediate/low-CCT sources. Ground-truth training regions were selected in Madrid and Andalusia, where the lighting inventories are known.

Fig 1. Preview on an EU map using SDGSAT-1

Conclusions

The resulting dataset provides a pan-European, high-resolution map of ALAN that distinguishes lamp types using their spectral signatures. We show that the prevalence of different lighting technologies varies considerably between countries and correlates with existing national and regional policies on light pollution. For example, countries with early or strict legislation, such as France and Malta, show higher retention of sodium lighting or adoption of lower-CCT LEDs, while others, such as Italy, have a high proportion of high-CCT LED sources. Our results highlight both the potential and the complexity of policy influence in the landscape of ALAN.

This work demonstrates how SDGSAT-1 enables operational, scalable, and reproducible monitoring of ALAN at ecologically meaningful resolutions. The data and methods we present are suitable for supporting urban planning, biodiversity protection, and environmental regulation. The full map and classification results are available via an online web application: https://pmisson.users.earthengine.app/view/sdgsat-eu-visual.

References

Sánchez de Miguel, A., et al. (2021). Colour remote sensing of artificial light at night. *Remote Sensing*, 13(13), 2583.
Elvidge, C.D., et al. (2021). Annual time series of global VIIRS nighttime lights derived from monthly averages. *Remote Sensing*, 13(5), 922.
Guo, H., et al. (2023). SDGSAT-1: A scientific satellite mission for sustainable development goals. *Nature Communications*, 14, 1719.
Lv, C., et al. (2024). Urban lighting classification using SDGSAT-1 data. *Remote Sensing of Environment*, 300, 113738.

Sensory governance: Regaining awareness for invisible lighting infrastructure

Theme: Governance & Regulation

Nona Schulte-Römer, ERC-project WAVEMATTERS

Humboldt University Berlin, Institute for European Ethnology
nona.schulte-roemer@hu-berlin.de
[*] *presenting author*

Lighting infrastructure can be paradoxically invisible. It illuminates the urban environment, yet most people pay little attention to the technology that produces artificial light at night. The normalcy of light and the inattention to bad solution make it difficult to tackle excessive lighting. ‘Education' is the most common response to this problem. In this paper, however, I outline a more systemic perspective based on the idea of 'sensory governance'. I propose this concept to explain how lighting infrastructure became invisible in the first place (Schulte-Römer 2023). In particular, I outline the historical, a pragmatic and political dimension of sensory governance.

Historically, lighting infrastructure became standard with the widespread electrification in industrialised countries. As urban lighting became taken for granted, lighting infrastructure 'faded into the background' of public attention (Star and Griesemer 1989). Pragmatically, this inattention to lighting infrastructure – and the public's oblivion of the possibility of darkness – was facilitated by the simultaneous development of light engineering expertise (Jakle 2001; Isenstadt 2019). Lighting engineers took care of urban lighting and developed standards for increasing visibility and reducing glare, especially for motorised traffic, aiming for homogeneous light levels and unobtrusive lighting infrastructure. This delegation of lighting to experts also has a political dimension. To paraphrase the sociologist and philosopher Bruno Latour (2005), lighting ceased to be a matter of public concern and became a matter of fact – an infrastructural service that no longer required public debate or democratic deliberation.

In the 21st century, however, lighting infrastructure seems to be re-emerging in the context of research and public concern about the negative ecological effects and potential health risks of artificial light at night (ALAN 2025). Accordingly, I conclude with a reflection on how twentieth-century 'sensory governance' might be challenged and reversed to systemically promote more sustainable lighting infrastructure.

Empirically, this analysis draws on historical accounts by Jane Brox, John Jakle, Sandy Isenstadt, David Nye and Wolfgang Schivelbusch as well as on my own ethnographic and participatory social research on urban lighting and light pollution in several research projects: the current ERC-project WAVEMATTERS (2021-2026, with Prof. Dr. Ignacio Farías), the Nachtlicht BüHNE project (2019 – ongoing, with Prof. (?) Dr. Christopher Kyba), the project Light Pollution – A Global Discussion (2018 – with Dr. Josiane Meier and Etta Dannemann) and my doctoral thesis project “Innovating in Public – the introduction of LED lighting in Berlin and Lyon” (2015).

Night Sky Brightness Caused by Orbital Reflectors. Part 2: Cloudy Sky

Theme: Measurement and Modelling

Erkin Sidick *, Ben Nowack, and Tristan Semmelhack
Reflect Orbital, 12727 S Van Ness Ave, Hawthorne, CA 90250
erkin@reflectorbital.com
* *Presenting author*

We are in the process of developing a system which redirects the incoming sunlight to a stationary ground target after sunset and before sunrise. The purpose of the system is to (1) generate electricity by illuminating solar-power farms and extending their operating time-window after sunset and before sunrise, and (2) provide lighting for operations and industrial work, such as construction, mining, streetlighting, surveillance, and search and rescue missions. The system consists of multiple reflectors orbiting the Earth near the terminator-line, delivering sunlight to the ground through the atmosphere. So our system contributes to artificial light or light pollution at night in the vicinity of the illuminated area.

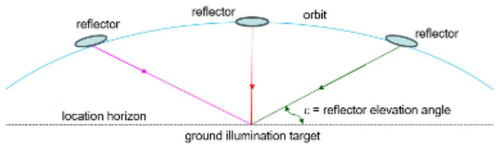


Fig. 1: Schematic diagram of sun beam coming from an orbital reflector. The three reflectors represent the same device at three different elevation angles. We will limit the value of reflector elevation angle to 30° ≤ ⍰ ≤ 150° in our studies.

The sunlight reflected from an orbit towards a ground target goes through several effects before and after illuminating a targeted area. The first is the reduction of its power-density. The Sun subtends an full-angle of ⍰ ≅ 0.5deg ≅ 0.0093 radians when looked at from the Earth. For that reason, the size of the solar image or sunspot on a ground target becomes much larger than the size of the orbital reflector that created the sunspot. For example, if the orbit height is h = 400km, the sun-image diameter becomes ~3.5km when the reflector is at the zenith. The second is the attenuation of sunlight by atmosphere, especially by clouds which weaken the sunlight by reflection, absorption and scattering before it reaches the ground. The third is the reflection of the sunlight by various surfaces on the ground.

The light pollution caused by an orbiting reflector has two parts. The first part is produced by the reflector's beam when it is propagating through the atmosphere to reach the ground target. This part is similar to the night sky brightness caused by moonlight, but with some differences: (1) The moonlight fills the whole space from the top of atmosphere to the ground, but an orbiting reflector produces a beam having a shape of a tapered cylinder which either illuminates a small patch of the atmosphere along the line of sight (LOS) of an observer on the ground or does not intersect the observer's LOS at all. (2) The intensity of the light coming from an orbiting reflector is much stronger than the intensity of moonlight. The second part is produced by the reflector's light that reached a ground target and reflected by it into the low-altitude atmosphere. This part of light pollution is similar to the night sky brightness caused by the artificial lights of a city at its center and outside the city at all zenith angle distances.

We have developed an optical model to predict the night sky brightness caused by the light coming from an orbital reflector. In a companion paper (Sidick *et al.* 2025) we reviewed some work done by others on the night sky brightness caused by artificial city lights (Garstang 1986) and moonlight (Krisciunas 1991) first, then presented our results of model predictions on light pollution caused by orbital reflectors, and showed how they compare with natural sky background, measured full-moon brightness, and some data measured on the night sky brightness in locations near a city or a campus under a clear sky condition. After that work we extended our study to cloudy sky. This paper summarizes our work on cloudy sky.

To address the problem of cloudy sky brightness, we need to consider the light components shown in Fig. 2. The radiative transfer of visible-band sunlight in clouds can be calculated using the Eddington radiative-transfer method while accounting for the effects of scattering and absorption. We developed a modeling tool for simulating radiative transfer of sunlight through a cloud layer by converting the Python codes reported by Korkin *et al*. (Korkin 2022) into MATLAB. Figure (3a) shows the variation of cloud-glow components as a function of cloud optical depth τ. As we can see, the diffuse and direct transmission dominates the cloud-glow when about $\tau \leq 4$, after that the diffuse transmission becomes the main contributor of the cloud-glow. Part (b) shows the total cloud-glow for three different values of orbit height. As expected, the cloud-glow strength increases when the orbit height is decreased.

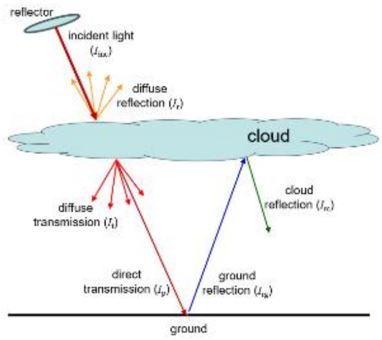


Fig. 2: Various light components produced by an orbiting reflector.

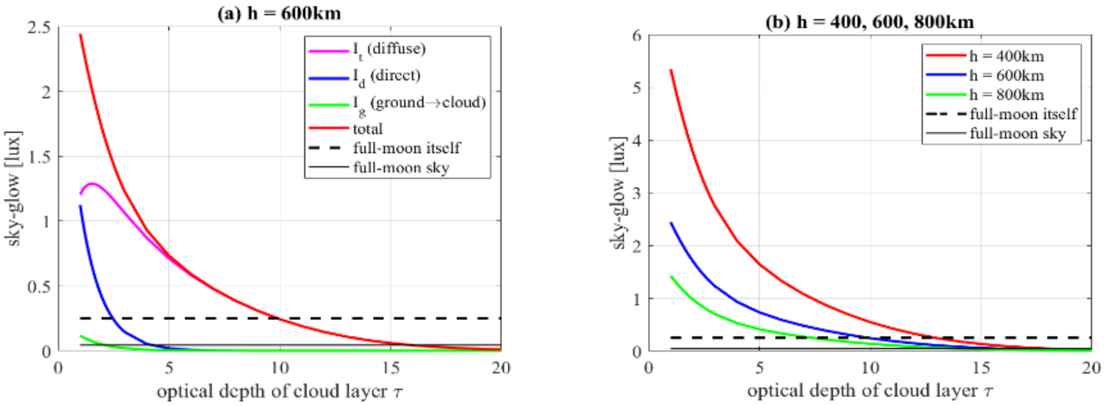


Figure 3. Variation of cloud-glow as a function of cloud optical depth τ when viewing angle $\theta = \mathrm{acos}\mu$ is the same as the light source polar angle $\theta_0 = \mathrm{acos}(\mu_0)$: $\mu = \mu_0 = 0.98$ (θ_0 =11.5°). The brightness of full-moon itself and its night sky at a viewing angle of 11.5° under a clear sky condition are also included as references. (a) Three components of cloud-glow when orbit height *h* = 600km: Diffuse (I_t) and direct (I_d) transmission, and "ground" (I_g) component, which includes the scattered light along the path from the bottom of the cloud layer to the ground, from the ground to the bottom of the cloud layer, and the light reflected by the cloud layer downward. (b) Total cloud-glow versus τ for orbit height values of *h* = 400, 600 and 800km, respectively.

References

Sidick E, Nowack B, Semmelhack T (2025) Night sky brightness caused by orbital reflectors. SmallSat Conf. 2025, Paper SSC25-P2-61, Salt Lake City, Utah, to be published.

Garstang R H (1986) Model for artificial night-sky illumination. Publ. Astron. Soc. Pacific 98: 364-375.

Krisciunas K, Schaefer B E (1991) A model of the brightness of moonlight. Astronomical Society of the Pacific, Publications 103: 1033-1039.

Korkin S, Sayer A M, Ibrahim A, Lyapustin A (2022) A practical guide to writing a radiative transfer code. Computer Physics Comm. 271: 108198.

The Impacts of light pollution on invertebrates; a comprehensive review informing advocacy and social change

Theme: Biology and Ecology

David A.J. Smith,[1,*] and Shreoshi. Das[1]

[1] Buglife, United Kingdom
david.smith@buglife.org.uk
[*] presenting author

The exponential increase in light pollution represents one of the most rapidly expanding forms of anthropogenic environmental change, yet it remains significantly under addressed in conservation policy and public awareness. Natural light-dark cycles have shaped ecosystems and species adaptations. However, the rapid spread of artificial light at night (ALAN) has fundamentally altered these patterns, creating challenges for biodiversity conservation, particularly for invertebrate populations that are already experiencing significant global declines (Sánchez-Bayo & Wyckhuys, 2019).

This presentation presents Buglife's 2025 review on the *Impacts of Light Pollution on Invertebrates*, bringing together current understanding of light pollution's impacts on invertebrate biodiversity and presents evidence-based policy recommendations developed through Buglife's ongoing advocacy initiatives. Our work builds upon our 2011 assessment of artificial light impacts on invertebrates (Bruce-White & Shardlow, 2011), updating this work with the substantial body of research that has emerged in the intervening years. The 2025 comprehensive review documents how light pollution affects invertebrates across multiple ecological dimensions and habitats, providing crucial evidence for informed policy development.

The ecological consequences of light pollution for invertebrates are both diverse and extensive. Nocturnal insects exhibiting positive phototaxis are drawn to artificial light sources, disrupting navigation systems that evolved to utilise natural celestial cues (Warrant & Dacke, 2016). This behavioural disruption increases predation vulnerability and interferes with essential activities including foraging, reproduction, and habitat selection (Owens & Lewis, 2018). Conversely, species exhibiting negative phototaxis may avoid illuminated areas entirely, effectively experiencing habitat loss through light-induced fragmentation (Manfrin et al., 2017). These behavioural alterations go beyond individual organisms to influence community composition and ecosystem functioning (Knop et al., 2017).

At the physiological level, light pollution exposure disrupts circadian rhythms through suppression of melatonin production, affecting sleep patterns and reproductive cycles. Research has documented these effects across diverse invertebrate taxa, including worms, butterflies, and flies. Additional physiological impacts include premature development, suppressed diapause initiation, and altered hormonal regulation, effects that manifest in both nocturnal and diurnal species. Importantly, these disruptions can translate to population-level consequences, potentially contributing to documented invertebrate declines.

Our review reveals that light pollution's impacts extend across terrestrial and aquatic ecosystems, with vulnerability observed in areas where artificial illumination overlaps with critical invertebrate habitats. The extent of these impacts is underscored by International Union for Conservation of Nature (IUCN) Red List assessments, which now recognise light pollution as a threat factor for 113 invertebrate species (IUCN, 2023). This figure likely represents a significant underestimation given limited assessment coverage for invertebrates globally.

Despite mounting evidence of ecological harm, current regulatory frameworks primarily address artificial lighting through the lens of energy efficiency and cost reduction rather than biodiversity conservation. This policy gap stems partly from the historical framing of light pollution as primarily an astronomical concern rather than an ecological imperative. Consequently, there exists a critical need for evidence-based policies that specifically address the biological impacts of artificial illumination.

This presentation will culminate in recommendations and next steps for integrating light pollution management into conservation planning and policy frameworks to protect and restore invertebrate populations. Specifically, it will cover Buglife's ongoing advocacy and social change campaigns, aimed at aimed at influencing legislation and policy and creating positive behavioural change and engagement with the nocturnal environment

By addressing the knowledge gap surrounding light pollution's ecological impacts, we can develop more comprehensive approaches to safeguarding invertebrate biodiversity and the essential ecosystem services they provide. The preservation of nocturnal environment represents not merely the absence of artificial light but rather the active conservation of ecological conditions necessary for the persistence of countless species that have evolved within the rhythms of day and night.

References

Bruce-White, C., & Shardlow, M. (2011). A review of the impact of artificial light on invertebrates. Buglife - The Invertebrate Conservation Trust.

IUCN. (2023). The IUCN Red List of Threatened Species. Version 2023-1. https://www.iucnredlist.org

Knop, E., Zoller, L., Ryser, R., Gerpe, C., Hörler, M., & Fontaine, C. (2017). Artificial light at night as a new threat to pollination. Nature, 548(7666), 206-209.

Manfrin, A., Singer, G., Larsen, S., Weiß, N., van Grunsven, R. H. A., Weiß, N. S., Wohlfahrt, S., Monaghan, M. T., & Hölker, F. (2017). Artificial light at night affects organism flux across ecosystem boundaries and drives community structure in the recipient ecosystem. Frontiers in Environmental Science, 5, 61.

Owens, A. C. S., & 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.

Sánchez-Bayo, F., & Wyckhuys, K. A. G. (2019). Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation, 232, 8-27.

Warrant, E., & Dacke, M. (2016). Visual navigation in nocturnal insects. Physiology, 31(3), 182-192.

Harnessing the Convention on Biological Diversity to mitigate light pollution and protect the nocturnal environment

Theme: Governance & Regulation

David A.J. Smith,[1,*] and Yana. Yakushina,[2]

[1] Buglife, United Kingdom
[2] University of Ghent, Belgium
david.smith@buglife.org.uk
[*] presenting author

Introduction

Light pollution, an anthropogenic disruption with widespread ecological, physiological, and astronomical consequences, has emerged as a significant yet underappreciated global challenge. The increasing pervasiveness of artificial light at night (ALAN) disrupts circadian rhythms, disorients migratory species, and threatens the integrity of nocturnal ecosystems. Recognising the profound implications of light pollution for biodiversity, the United Nations Convention on Biological Diversity (CBD) provides an opportunity as an important framework for international cooperation to mitigate its effects and establish global governance measures.

Despite the CBD's mandate to address threats to biodiversity, light pollution, and indeed the nocturnal environment has received limited attention within its deliberations. Nevertheless, the CBD in its recent Kunming-Montreal Global Biodiversity Framework (GBF) highlighted the need to reduce pollution from all sources. This presentation explores how the CBD can serve as a platform for advancing global efforts to curb light pollution and protect the nocturnal environment. It outlines key strategies how light pollution can be addressed within GBF and presents actionable steps for future Conference of the Parties (COP).

Integrating light pollution into the CBD Framework

The biological and ecological consequences of ALAN are well-documented. Disruptions to pollinators, turtle hatchlings, migratory birds, and nocturnal predators illustrate the profound impacts of artificial lighting on biodiversity. Additionally, excessive illumination contributes to habitat fragmentation, altering predator-prey dynamics and affecting species interactions. While these issues align with existing CBD 2050 goals, particularly Goal A: *Protect and Restore*, and Goal B: *Prosper with Nature*, light pollution remains an overlooked component of global biodiversity policy and is only featured in guidance notes under Target 7.

The CBD operates as a mechanism with near-universal participation for biodiversity protection, making it an ideal platform for embedding light pollution mitigation into global environmental governance. To ensure the protection of nocturnal ecosystems, light pollution mitigation should be incorporated into National Biodiversity Strategies and Action Plans (NBSAPs), encouraging Parties to recognise light pollution as a biodiversity threat and develop guidelines for reducing its impact at both national and subnational levels. Furthermore, light pollution should be explicitly included in the Kunming-Montreal Global Biodiversity Framework, with dedicated targets or indicators under Goal A (Ecosystem Integrity) and Goal B (Reducing Threats to Biodiversity), alongside measurable national commitments for reducing its ecological footprint. The Subsidiary Body on Scientific, Technical and

Technological Advice (SBSTTA) should be tasked with developing technical guidelines and best practices for light pollution control, while Parties should be encouraged to share innovations in lighting technology, zoning policies, and regulatory frameworks through a CBD clearing-house mechanism. Additionally, collaboration with other Multilateral Environmental Agreements (MEAs), such as the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and the Ramsar Convention, should be strengthened to address transboundary light pollution challenges. Partnerships through the United Nations Environment Programme (UNEP) and its conventions and other expert organisations should also be promoted to advocate for global responsible lighting standards. By embedding these measures and other measures, such as Environmental Impact Assessment (EIA) within the CBD framework, Parties can ensure that light pollution mitigation becomes a fundamental component of biodiversity conservation.

Pathway to COP Advancement

Attempts have been made to include light pollution into the CBD, notably at the most recent COPs, 15 (Montreal 2022) and 16 (Cali, 2024). The Expert Input to the draft Post-2020 GBF provided the grounds for light pollution to be addressed through the CBD. An amendment to the draft Post-2020 GBF to explicitly include light pollution were maintained until the final high-level negotiations and were supported by a Buglife and Dark Sky International led briefing to ministers. At COP16, a PLAN-B led application saw the first light (and noise) pollution focused side events take place at a CBD COP.

For future CBD COPs, several key steps should be prioritised to ensure meaningful progress in addressing light pollution. First, there must be formal recognition of light pollution as a biodiversity threat, which can be achieved through a COP Resolution that acknowledges ALAN’s role in biodiversity loss and lays the foundation for future policy interventions. The adoption of a voluntary action plan would also be instrumental, providing a structured framework for Parties to develop and share best practices in light pollution mitigation. Pilot projects in urban, coastal, and protected areas should be initiated to assess the effectiveness of light pollution control measures and generate empirical data to inform future policymaking. Additionally, financial resources need to be mobilised through mechanisms such as the Global Environment Facility (GEF) to support national initiatives aimed at mitigating light pollution impacts. Finally, broad public and stakeholder engagement is crucial to building a coalition of policymakers, urban planners, and conservation organisations that can advocate for integrating light pollution mitigation strategies into the CBD framework. By advancing these steps, the COP can catalyse international efforts to reduce ALAN’s ecological footprint and enhance the protection of nocturnal ecosystems.

Conclusion

As global biodiversity declines at an alarming rate, it is imperative that the CBD extends to the nocturnal environment and adapts to address under recognised threats, including light pollution. By recognising light pollution as a significant driver of ecological change, the CBD can play a pivotal role in fostering international cooperation to restore and protect nocturnal ecosystems. COP17, taking place in Armenia in 2026, presents an opportunity to embed light pollution mitigation within global biodiversity policy, ensuring that future generations inherit a world where the nocturnal environment is preserved as an essential component of ecological integrity.

Seeking Tranquility: Assessing Ecological Risk from Artificial Light and Noise Pollution

Theme: Biology and Ecology

Tim Smyth,[1,2,*] Benjamin O'Driscoll,[1] and Thomas W. Davies[3]

[1] Plymouth Marine Laboratory, Plymouth, UK
[2] University of Exeter, Penryn, UK
[3] University of Plymouth, Plymouth, UK

tjsm@pml.ac.uk
[*] presenting author

Introduction

Over the past decade there has been an increasing weight of scientific evidence regarding the harmful impact of Artificial Light at Night (ALAN) on marine ecosystems (Marangoni et al., 2022). However, ecosystem stressors rarely act in isolation (O'Hara & Halpern, 2022) and there is a recognition that a framework needs to be constructed which operates in multi-stressor space. The EC AquaPLAN project aims to quantify the combined impacts of Light and Noise Pollution (LNP) on aquatic biodiversity in European waters and facilitate the implementation of empirically sound strategies for managing these pollutants through novel interdisciplinary approaches. To that end interactive global maps have been developed to identify marine "hotspots" where LNP intersect. Using a risk-based approach, each stressor is categorized into four intensity levels (Nil, Low, Medium, High), with their combined impact determined through a multiplicative model.

Key Findings and Methodology

- ***Underwater Noise Assessment:*** Based on shipping noise data from Jalkanen et al. (2022), noise energy (Joules) was converted to sound pressure levels (SPL) (dB), with thresholds defined to align with recommendations from the Technical Group on Underwater Noise, Marine Strategy Framework Directive.
- ***Artificial Light at Night (ALAN) Estimation:*** the global atlas of underwater ALAN (Smyth et al., 2024; Smyth et al., 2021), which gives a measure of light penetration below the water surface (critical depth - Z_c), was used to assess ecological exposure.
- ***Risk Calculation:*** The intersection of ALAN and SPL categories creates a composite risk map, highlighting areas where marine ecosystems face significant dual stressors.

Web Portal and Future Developments

To facilitate decision-making, a web-based portal (https://aquaplan.eofrom.space/) was developed. This portal allows users to easily visualise, analyse and download datasets associated with this work. The addition of habitat distribution overlays provides users with the context they need to translate dual-stressor risk ratings into insightful species-specific decisions. Future enhancements will expand datasets to include freshwater ecosystems, additional noise sources, and new habitat maps.

This study underscores the need for targeted mitigation strategies to protect marine biodiversity from the compounded effects of ALAN and noise pollution.

References

Jalkanen, J. P., Johansson, L., Andersson, M. H., Majamäki, E., & Sigray, P. (2022). Underwater noise emissions from ships during 2014-2020. *Environmental Pollution*, *311*, Article 119766. https://doi.org/10.1016/j.envpol.2022.119766

Marangoni, L. F. B., Davies, T., Smyth, T., Rodriguez, A., Hamann, M., Duarte, C., Pendoley, K., Berge, J., Maggi, E., & Levy, O. (2022). Impacts of artificial light at night in marine ecosystems-A review. *Global Change Biology*, *28*(18), 5346-5367. https://doi.org/10.1111/gcb.16264

O'Hara, C. C., & Halpern, B. S. (2022). Anticipating the Future of the World's Ocean. *Annual Review of Environment and Resources*, *47*, 291-315. https://doi.org/10.1146/annurev-environ-120120-053645

Smyth, T. J., O'Driscoll, B., Martin, N., & Davies, T. W. (2024). *A Global Atlas of Artificial Light At Night Under the Sea V2* PANGAEA. https://doi.org/10.1594/PANGAEA.969081

Smyth, T. J., Wright, A. E., McKee, D., Tidau, S., Tamir, R., Dubinsky, Z., Iluz, D., & Davies, T. W. (2021). A global atlas of artificial light at night under the sea. *Elementa-Science of the Anthropocene*, *9*(1), Article 1. https://doi.org/10.1525/elementa.2021.00049

Female moths call in vain: Streetlights diminish the promise of mating

Theme: Biology & Biology and Ecology

Mona Storms[1,*], Tobias Degen[1], Jacqueline Degen[1]

[1] Biocenter of the University of Würzburg, Würzburg, Germany
mona.storms@uni-wuerzburg.de
[*] presenting author

Introduction

Artificial light at night has increased significantly in recent decades [1], profoundly impacting moths, which are key contributors to pollination networks [2,3]. The global shift to light-emitting diode (LED) streetlights has further transformed the nocturnal light environment, especially because of their high variability in spectrum and intensity [4-7]. However, the impact on moths' mating success remains poorly understood, highlighting the urgent need to investigate their behavioural responses.

Methods

We recorded the flight behaviour of male moths (*Sphinx ligustri* L.) using a symmetrical flight tunnel (*Figure 1a*). Two different light environments, homogeneous and heterogeneous, with a female positioned on one side of the tunnel were used to test in different combinations the effect of LEDs (Amber, Warm white, Neutral white, *Figure 1b*) and intensities (0.05, 150, 370 and 590 lux) on arrival location, flight duration, and direction changes of males.

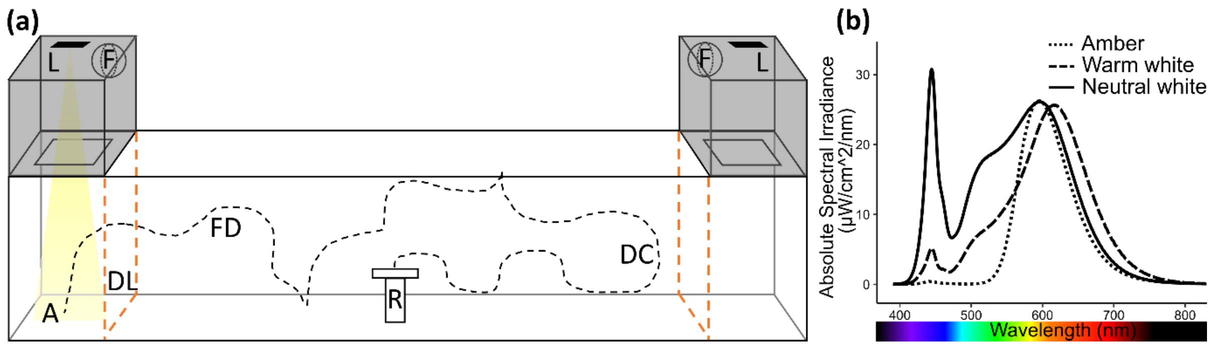


***Figure 1:** (a) Flight tunnel used to observe the flight behaviour of male moths. (b) Spectral properties of the tested streetlights (LEDs) with 370 lux: Amber 1800 K, Warm white 2200 K and Neutral white 3900 K. Image credit: the Authors.*

Results

In a homogeneous light environment, all tested LEDs significantly reduced arrival frequency of males at the females compared to a dim light condition (*Figure 2a*), demonstrating that streetlight negatively affects encounter rates. However, neither flight duration nor direction changes were significantly affected.

In a heterogeneous light environment, the highest proportion of males was able to reach the females in the presence of Warm white (*Figure 2b*), indicating that Amber may not be a universal solution for mitigating the negative effects of artificial light. Both flight duration and direction changes were significantly reduced for Neutral white compared to Warm white, concluding that this LED type induced fast and directed flights towards the light source. Interestingly, light intensity did not significantly affect any of the analysed parameters.

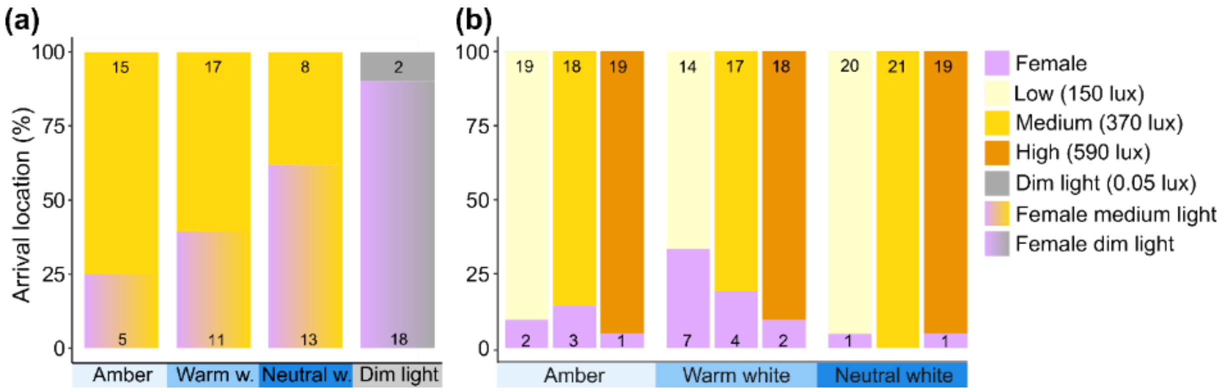


Figure 2: *Flight behaviour of male moths (a) Fraction of arrival location within the homogeneous light environment. (b) Fraction of arrival location within the heterogeneous light environment. Image credit: the Authors.*

Conclusions

The presence of light drastically reduced the probability of males reaching the females. Furthermore, LEDs with the lowest correlated colour temperature (CCT) were not the ones leading to the highest promise of mating success, indicating that the spectrum of an LED might have an optimum. As LED efficiency decreases with lower CCT values in addition, this finding is of crucial importance when considering the indirect effects of light pollution, such as the CO_2 footprint, when developing lighting strategies as minimally disruptive as possible.

References

[1] Kyba, C. C. M., Altıntaş, Y. Ö., Walker, C. E. & Newhouse, M. (2023) Citizen scientists report global rapid reductions in the visibility of stars from 2011 to 2022. *Science (New York)*, 379(**6629**), 265–268.

[2] Knop, E., Zoller, L., Ryser, R., Gerpe, C., Hörler, M. & Fontaine, C. (2017) Artificial light at night as a new threat to pollination. *Nature*, 548, 206–209.

[3] Potts, S. G., Imperatriz-Fonseca, V., Ngo, H. T., Aizen, M. A., Biesmeijer, J. C., Breeze, T. D., Dicks, L. V., Garibaldi, L. A., Hill, R., Settele, J. & Vanbergen, A. J. (2016) Safeguarding pollinators and their values to human well-being. *Nature*, 540(**7632**), 220–229.

[4] Almeida, A. de, Santos, B., Paolo, B. & Quicheron, M. (2014) Solid state lighting review – Potential and challenges in Europe. *Renewable and Sustainable Energy Reviews*, 34, 30–48.

[5] Boyes, D. H., Evans, D. M., Fox, R., Parsons, M. S. & Pocock, M. J. O. (2021) Is light pollution driving moth population declines? A review of causal mechanisms across the life cycle. *Insect Conservation and Diversity*, 14(**2**), 167–187.

[6] Morgan Pattison, P., Hansen, M. & Tsao, J. Y. (2018) LED lighting efficacy: Status and directions. *Comptes Rendus Physique*, 19(**3**), 134–145 [Online].

[7] Taguchi, T. (2008) Present Status of Energy Saving Technologies and Future Prospect in White LED Lighting. *IEEJ Transactions on Electrical and Electronic Engineering*, 3(**1**), 21–26.

Investigating the Effects of Angular Position of Light on Flight Behaviour of Moths

Theme: Biology & Biology and Ecology

Mona Storms[1,*], Tobias Degen[1], Jerome Beetz[1], Keram Pfeiffer[1], Jacqueline Degen[1]

[1] Biocenter of the University of Würzburg, Würzburg, Germany
mona.storms@uni-wuerzburg.de
** presenting author*

Introduction

Insects represent a key component of the world's biodiversity and are vital to ecosystem functioning [1]. Light pollution has been identified as a driver in the dramatic insect decline of the past years [2,3], yet little is known about its impact on natural insect orientation behaviour. Insects attracted to light become vulnerable to predation and exhaustion, with some studies estimating that a third dies before the end of the night [2]. In addition, light pollution affects movement patterns of moths beyond the previously assumed extent, namely flight-to-light behaviour [4]. In their experiment, only 4% of the male moths ended their flight at a streetlight, raising the question of how behavioural responses to light are dependent on flight altitude in relation to the light source. To tackle this question, we performed experiments within a flight simulator that allowed us to test the effect of various positions of an LED light (as a substitute for streetlights) on the flight behaviour of a tethered moth.

Experiment

For the experiment, we used males of a species from the Sphingidae family, which is primarily nocturnal or crepuscular and is among the most important pollinators within moths [5]. *Sphinx ligustri* are robust, good fliers and have already been studied in laboratory experiments [6]. To record their fictive flight trajectories in a flight simulator, a piece of tungsten wire (stalk) was glued to the dorsal side of the thorax (*Figure 1*). Connecting this stalk to a specialized encoder enabled the recording of heading direction and turning velocity of the tethered moth. The light stimulus was provided via horizontal LED strips. The colour and intensity of each LED could be controlled individually. In addition, a diffuse background illumination (0.05 lux) was switched on during each flight.

Figure 1: Experimental animal (*Sphinx ligustri*) with a tethered stalk. Image credit: the

Every tested sequence of light stimuli started with one illuminated LED in front of the tethered moth. Afterward, the light stimulus moved in different ways: (1) upward, back to the middle and upward again for two minutes each (middle-top-middle-top, *Figure 2a*), (2) downward, back to the middle and downward again for two minutes each (middle-bottom-middle-bottom, *Figure 2b*), and (3) sideward in 45-degree steps for one minute each (0° - 45° - 0° - 90° - 0° - 135° - 0° - 180°, *Figure 2c*). After 8 minutes, the light stimulus was turned off, and the recording was concluded. For the control with background illumination, no additional light stimuli were provided, and moth flight behaviour was recorded for 8 minutes starting from the moment of flight initiation. In the dark control, moths were introduced into the arena without any light stimulus as all lights were switched off. Flight behaviour was recorded for 8 minutes, if possible. A total of 22 male moths were used for all experimental conditions (Upward, downward, sideward, background control and dark control). Each moth has been tested in as many experimental conditions as possible but had only one flight attempt per day.

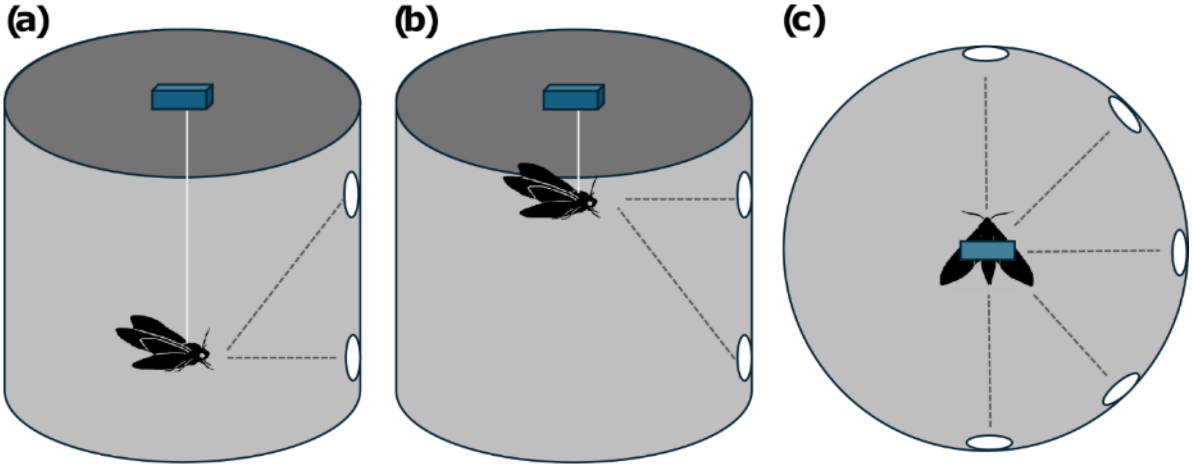


Figure 2: Flight simulator scheme. Side view of (a) upward angle and (b) downward angle. (c) Top view of sideward angles. Image credit: the Authors.

Research objective

The overall aim of this study is to gain a better understanding of the effect of flight altitude in relation to the light source on the flight behaviour of male moths. We hypothesize that a light source from above (upward) is used as natural directional information (like the moon, see [7]) and leads to a more directed flight compared to the test situation when the light source is below. This finding would support the assumption that "unnatural" directional information from below (downward) receives less attention and thus leads to reduced flight-to-light behaviour [4]. Furthermore, the heading direction relative to the light source will provide information about the phototactic responses. The results could lead to new insights into how these animals navigate their environments, with broader implications for conservation efforts. With our results, we hope to provide more understanding why streetlights affect flight behaviour of moth and help counteract the dramatic insect decline of the past years.

References

[1] Knop, E., Zoller, L., Ryser, R., Gerpe, C., Hörler, M. & Fontaine, C. (2017) Artificial light at night as a new threat to pollination. *Nature*, 548, 206–209.

[2] Owens, A. C., Cochard, P., Durrant, J., Farnworth, B., Perkin, E. K. & Seymoure, B. (2020) Light pollution is a driver of insect declines. *Biological Conservation*, 241, p. 108259.

[3] van Grunsven, R. H. A., van Deijk, J. R., Donners, M., Berendse, F., Visser, M. E., Veenendaal, E. & Spoelstra, K. (2020) Experimental light at night has a negative long-term impact on macro-moth populations. *Current Biology*, 30(12), R694-R695.

[4] Degen, J., Storms, M., Lee, C. B., Jechow, A., Stöckl, A. L., Hölker, F., Jakhar, A., Walter, T., Walter, S., Mitesser, O., Hovestadt, T. & Degen, T. (2024) Shedding light with harmonic radar: Unveiling the hidden impacts of streetlights on moth flight behavior. *PNAS*, 121(42).

[5] Winfree, R., Bartomeus, I. & Cariveau, D. P. (2011) Native Pollinators in Anthropogenic Habitats. *Annual Review of Ecology, Evolution and Systematics*, 42(1), 1–22.

[6] Storms, M., Degen, T. & Degen, J. (2025) Female moths call in vain: Streetlights diminish the promise of mating. *Ecological Entomology* [Online].

[7] Storms, M., Jakhar, A., Mitesser, O., Jechow, A., Hölker, F., Degen, T., Hovestadt, T. & Degen, J. (2022) The rising moon promotes mate finding in moths. Communications biology, 5(1), p. 393.

Spectral attenuation of artificial light sources under water

Theme: Measurement and Modelling

Konrad Sucher,[1,*] Franz Hölker, [2] and Andreas Jechow[1]

[1] Brandenburg University of Applied Sciences, Brandenburg an der Havel, Germany
[2] Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
konrad.sucher@th-brandenburg.de
[*] presenting author

Light pollution is a growing environmental concern of global extent and its impact on ecology has come into focus during the last decades (Longcore & Rich 2004). Due to the vicinity of humans to water bodies (Kummu et al. 2011), light pollution affects aquatic systems overproportionally (Hölker et al. 2023). However, while terrestrial ecosystems have been thoroughly studied, aquatic ecosystems have gained much less attention by research (Jechow & Hölker 2019). Nevertheless, several studies have shown the diverse impacts of light pollution on aquatic ecosystems including microbial communities (Hölker et al. 2015), phytoplankton (Poulin et al. 2014), zooplankton (Moore et al. 2000) as well as fish (Riley et al. 2012). Recently, it was even shown that skyglow, a dim form of light pollution caused by artificial light scattered in the atmosphere can create biologically significant irradiances at the sea-floor in some areas (Davies et al. 2020).

A peculiarity of aquatic ecosystems is the spectral attenuation of light by different water bodies. While clear ocean water is more transparent for short wavelength visible (blue) light, inland waters or coastal waters can be more transparent for longer wavelength (orange) light. This can have implications on conservation efforts regarding spectral tuning, which for terrestrial systems often favor long wavelength over short wavelength emissions.

In this work, we will show results of spectral irradiance at specific depths caused by different light sources propagating through different, so-called Jerlov, optical water types (Jerlov 1968). We find that light emitting diodes (LEDs) with high correlated color temperature (CCT) of 5000K have higher irradiance than high pressure sodium (HPS) at 50m depth of clear ocean water (Jerlov type I). This actually shifts to the opposite for coastal waters (Jerlov type 7C) after only 5m of propagation, where HPS has a higher irradiance than the high CCT LED. More light sources and water types will be presented.

References

Davies, T. W., McKee, D., Fishwick, J., Tidau, S., & Smyth, T. (2020). Biologically important artificial light at night on the seafloor. Scientific Reports, 10(1), 12545.

Hölker, F., Wurzbacher, C., Weißenborn, C., Monaghan, M. T., Holzhauer, S. I., & Premke, K. (2015). Microbial diversity and community respiration in freshwater sediments influenced by artificial light at night. Philosophical Transactions of the Royal Society B: Biological Sciences, 370(1667), 20140130.

Hölker, F., Jechow, A., Schroer, S., Tockner, K., & Gessner, M. O. (2023). Light pollution of freshwater ecosystems: principles, ecological impacts and remedies. Philosophical Transactions of the Royal Society B, 378(1892), 20220360.

Jechow, A., & Hölker, F. (2019). How dark is a river? Artificial light at night in aquatic systems and the need for comprehensive night-time light measurements. Wiley Interdisciplinary Reviews: Water, 6(6), e1388.

Jerlov, N. G. (1968). Optical oceanography. Elsevier. Amsterdam

Longcore, T., & Rich, C. (2004). Ecological light pollution. Frontiers in Ecology and the Environment, 2(4), 191-198.

Kummu, M., De Moel, H., Ward, P. J., & Varis, O. (2011). How close do we live to water? A global analysis of population distance to freshwater bodies. PloS one, 6(6), e20578.

Moore, M. V., Pierce, S. M., Walsh, H. M., Kvalvik, S. K., & Lim, J. D. (2000). Urban light pollution alters the diel vertical migration of Daphnia. Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen, 27(2), 779-782.

Poulin, C., Bruyant, F., Laprise, M. H., Cockshutt, A. M., Marie-Rose Vandenhecke, J., & Huot, Y. (2014). The impact of light pollution on diel changes in the photophysiology of Microcystis aeruginosa. Journal of plankton research, 36(1), 286-291.

Estimating mesospheric structures from all-sky images

Theme: Measurement and Modeling

János Sztakovics,[1,*] András Rázsi,[1] Tamás Hajdu,[1] and Zoltán Kolláth[1]

[1]*Eszterházy Károly Catholic University, Department of Physics, Eger, Hungary*
sztakovics.jan@uni-eszterhazy.hu
[*] *presenting author*

Changes in the structure of the mesosphere play an essential role in the formation of airglow. Climate change may also be related to the atmospheric structure in the upper atmosphere. Changes in airglow strength also affect long-term sky quality monitoring. Therefore, it is essential to collect data from the mesosphere.

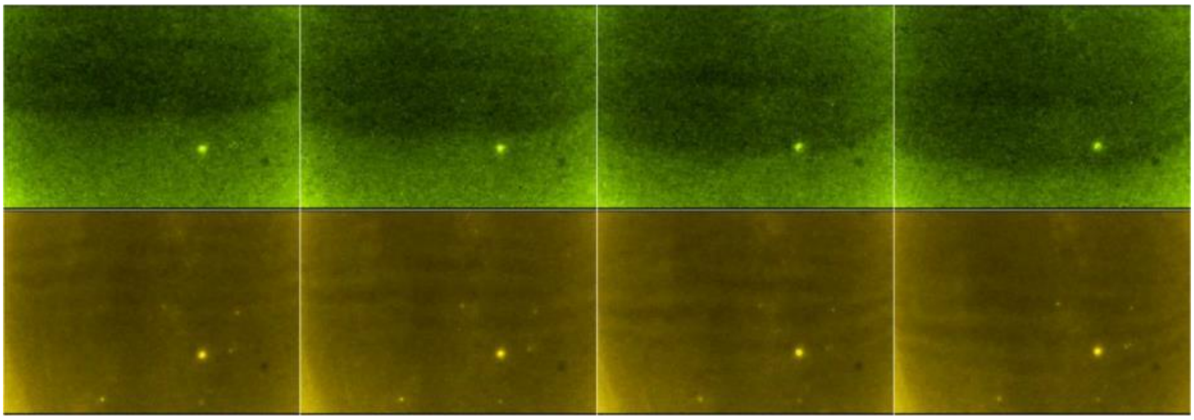


Fig. 1: Estimeted 558 nm green airglow (top) add 589 nm orange airglow (bottom) structures. The photos were taken at 3 minutes interwals.

In a recent study (submitted to JQSRT), we demonstrated that it is possible to estimate the 558 nm green oxygen and 589 nm orange sodium airglow from RGB data (see also Kollath et .al 2020). Thus, separate images of the most probable airglow structures can be obtained. We detected an interesting structure during an intense airglow event observed on 7 November 2024 in Bükk International Dark Sky Park, Hungary. Figure 1 demonstrates that the green and the orange airglow structures were different. Waves appeared mainly in sodium radiation. The green oxygen sky brightness shows some traces of the waves, but it is dominated by a structure resembling a shock wave. Remarkably, oxygen and sodium follow a different structure, indicating that the dynamics of the atmosphere are changing even on a short-distance scale. Airglow waves originate from gravity waves triggered by transient atmospheric events. Parallel observations of the oscillations and the shock help us better understand these events. Future parallel (stereoscopic) imaging observations of such events can be used to derive vertical profiles of the airglow waves.

Acknowledgments

This research was supported by the Hungarian Scientific Research Fund (OTKA K143376)

References

Kolláth, Z., Cool, A., Jechow, A., Kolláth, K., Száz, D., & Tong, K. P. (2020). Introducing the dark sky unit for multi-spectral measurement of the night sky quality with commercial digital cameras. Journal of Quantitative Spectroscopy and Radiative Transfer, 253, 107162

Best view in the city: Exploration of an all-sky imaging dataset of the Chicago night sky

Theme: Measurement and Modeling

Giacomo Terreran[1]*, Lauren Wisbrock[1], Cynthia Tarr[1], Ken Walczak[1], and Geza Gyuk[1]

[1] *Adler Planetarium, Chicago, United States*
lwisbrock@adlerplanetarium.org

Situated directly between the dense downtown core of Chicago and the 50+ km wide expanse of Lake Michigan, the Adler provides a unique opportunity to measure the night sky above Chicago and its variability. In this analysis, we explore the impact of environmental variables and changes in urban emission on sky brightness.

We have deployed a Ground Observation Network (GONet) camera on Adler's roof top for over 75 nights. GONets are compact, automated, all-sky nighttime imaging systems that produce a set of 5 2π images with RGB data every five minutes. Deployments began sporadically in 2022 and became regular in Fall 2024. Imaging occurred in a range of lunar phases and weather conditions, including clear, cloudy, and hazy nights, but excluded nights that risked precipitation (Figure 1).

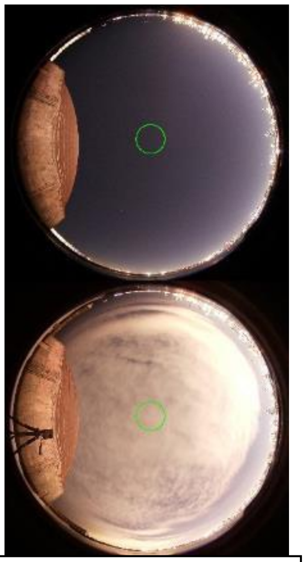


Fig. 1 *Two images taken by the GONet during a clear night (top) and a cloudy night (bottom). The area where zenith brightness was sampled is shown in green.*

For each image, we extracted pixel brightness of the RGB channels from a 10-degree radius around zenith. Using available databases we then tagged each image with environmental variables including cloud cover, humidity, moon altitude and snow cover. Across these variables, we compare the average zenith brightness, quantifying their differences and variability. We also track temporal changes, both over the course of a single night and across multiple nights.

Figures 2 and 3 present some of our preliminary findings. Figure 2 shows some of the more interesting patterns we explore: an unexplained decrease in brightness between the hours of 22:00 and 2:00 local time, and an increase in brightness both when the moon is present in the sky, and with

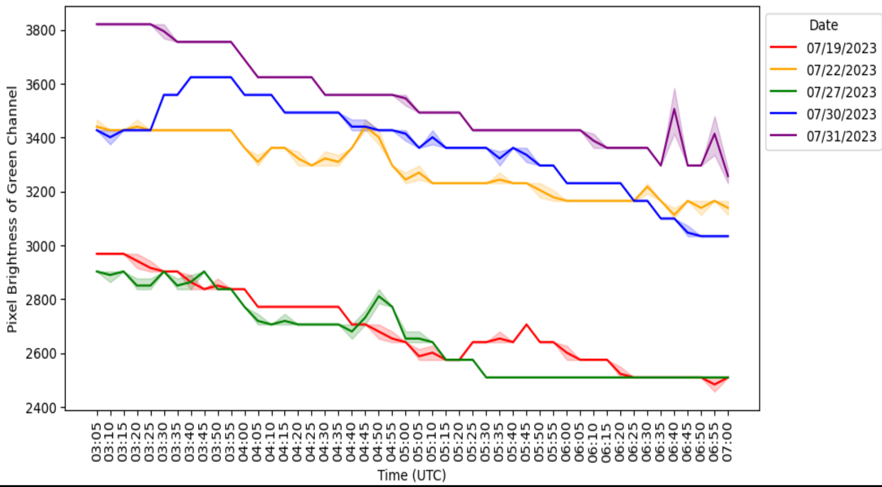


Fig. 2 *Green zenith brightness of images from 5 nights that were clear of clouds. 7/22 there was haze present from wildfire smoke. 7/30 and 7/31 the 3rd quarter moon was present outside of the zenith sample area.*

particulates in the high atmosphere. We are continuing to explore the data to more precisely quantify and understand our initial observations.

In addition we considered the ratio R/B, a proxy for the color of the sky. Redder skies will have a higher R/B, or color index. We have found an extremely strong non-linear correlation between the brightness of the sky and its color index, as shown in Figure 3. The color of the points shows a likely explanation for this correlation: cloud cover. The color of each point (image) is based on a rough measure of the cloudiness of the sky at that time. A simple model of the effect of clouds is given by the dashed lines. The model assumes that light from the clear sky background and from the cloud- reflected city have distinct colors and brightnesses. Cloud fraction interpolates between the two, generating a non-linear correlation matching the observed data reasonably closely. Each line corresponds to a different color ratio for cloud-reflected city light.

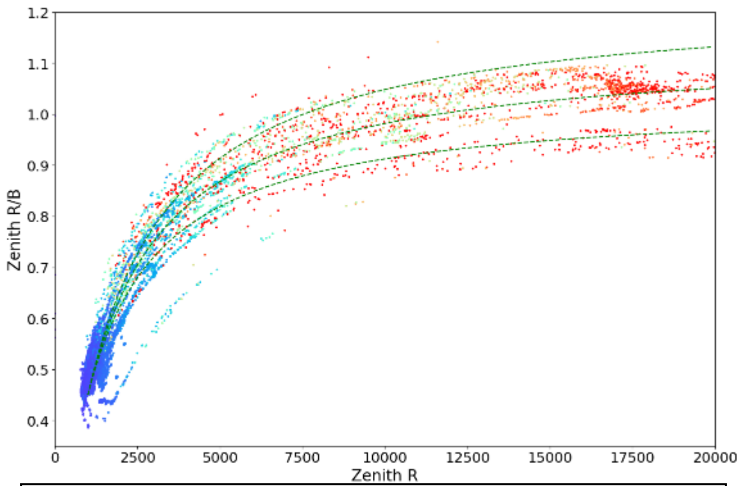


Fig. 3 Zenith R/B channel color index versus R channel counts for images with no moon. The color of each point is based on a rough measure of cloudiness where blue is clear and red is cloudy.

Utilizing the full-sky nature of our images, we extracted and modeled the skyline by sampling radial brightness profiles at regular angular intervals around the circular field of view. For each angle, the algorithm searched inward along the radius to detect a significant increase in brightness, which marks the transition from sky to skyline. The corresponding (x, y) coordinates were recorded as candidate skyline points, converted to polar coordinates (θ, r) and sorted to form a continuous polar skyline curve. Over 3000 such skyline extractions were processed, stretched and aligned to construct a stable median model, shown in Figure 4. This model will be used for an upcoming study of the contributions of specific sources to the sky brightness.

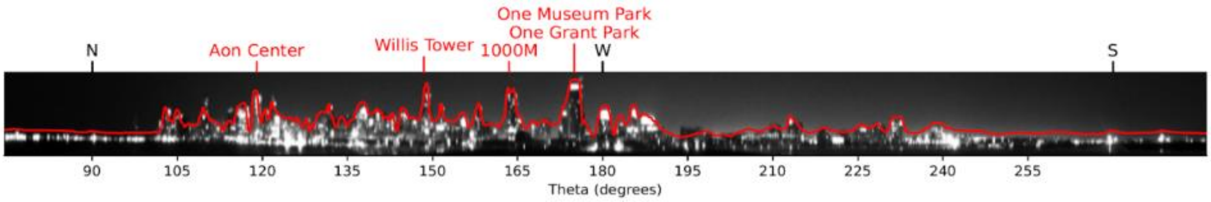


Fig. 4 *The detected skyline "unwrapped" and linearized into a flat view.*

As we add more nights of data, our analysis will establish baseline conditions of the complex, urban lighting environment of Chicago. It will also support attributing specific sources of urban emission to changes in zenith brightness and the impact of light pollution reduction campaigns, such as the Lights Out bird migration program. With the low cost and the ease of deployment of the GONet, we also hope to collect similar datasets from other locations. This exploration can be a starting point for spatial comparisons of GONet data.

Urban streetlights impair mating success by disrupting moths 'orientation

Theme: Biology & Ecology

Makrina Tsinoglou*, Nina Dauer, Ronja Sinzinger, Jacqueline Degen

Biocenter of the University of Würzburg, Würzburg, Germany
makrina.tsinoglou@uni-wuerzburg.de
* presenting author

Introduction

Recent global insect declines are an urgent issue caused by different factors and their synergy (Seibold et al, 2019; Wanger et al.,2021). Nocturnal insects are facing an additional threat, artificial lights at night (Owens et al., 2020). Especially streetlights are widespread across urban and rural areas, making the investigation of their impact crucial for conservation strategies (Gaston et al., 2012). Moths, a group that has recorded declines and plays a key role in ecosystems as important pollinators and food source, are the ideal study organism for monitoring behavioural responses to light pollution that impact their populations (Potts et al., 2016; van Langevelde et al., 2017; Boyes et al.,2021). Although famously attracted to light sources, moths are affected by streetlights beyond simple positive phototaxis as their flight behaviour changes even if they do not fly towards the light (Degen et al.,2024).

Methods

To address the question if the height of a streetlight is crucial for eliciting a positive phototactic response, we released and monitored male and female hawk moths (*Sphinx ligustri* & *Deilephila elpenor*) at a special site in the centre of Berlin (Germany). This location allowed us to investigate the impact of different streetlight heights and distances to the light source on free-flying individuals in a highly light polluted area (Fig. 1). Full-sphere images retrieved with an all-sky camera mounted on a programmable camera mount (Fig. 1) allowed a detailed quantification of the light environment.

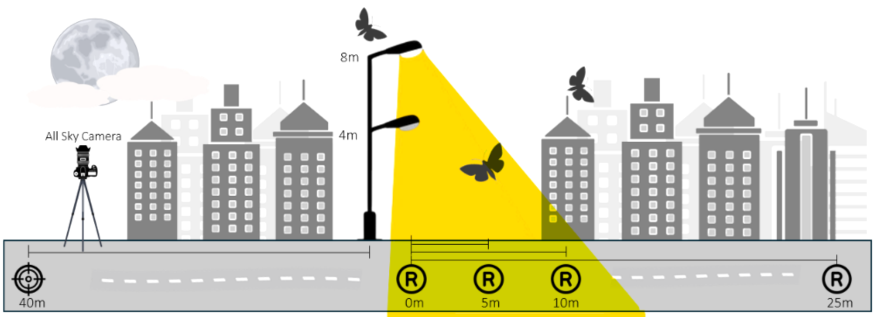


Figure 1. Infographic of the experimental set up. R indicates the positions of the release sites and the goal (female, plant) is marked by a crosshair.

Results

Within this environment (Fig. 1), the tested hawk moths exhibited a variety of behaviours never observed before, characterised by movements on the ground rather than flying (Fig. 2). This way, their ability to reach a goal (female or forage plant) was greatly disrupted. Only three male *S.ligustri* (4%) reached the goal (females) during the whole experimental period of 5 weeks under various lunar phases and light conditions. Additionally, the brightness of the night sky varied dramatically under different conditions (clear sky, high cloud cover, full moon). In all cases, light levels were considerably higher than those of natural environments.

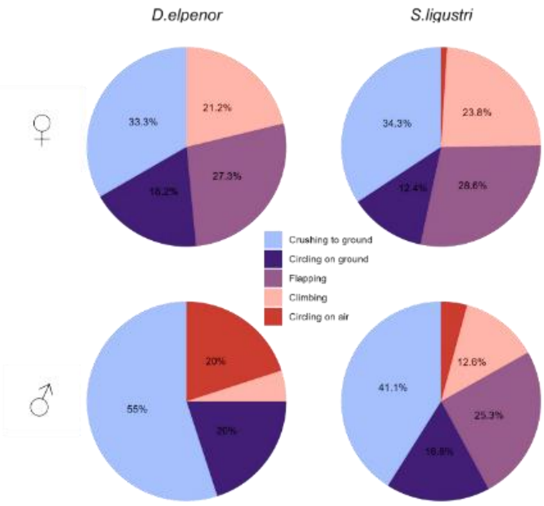


Figure 2. Percentages of disoriented behavior for each species and sex. All trials excluding control. (*S.ligustri*: n_{males}=64, $n_{females}$=51, *D.elpenor*: n_{males} =34, $n_{females}$ =23)

Conclusions

Artificial light triggered a strong disorientated behavior in the highly light polluted environment. In this context, neither the height of the streetlight nor the distance to the light source were decisive, leading to the conclusion that urban light pollution severely interferes with the orientation performance of moths. Moreover, our results indicate a clear difference in behavior of males and females within the same species as males were more likely to fly away and escape the light cone of the streetlight than females.

References

Boyes, D. H., Evans, D. M., Fox, R., Parsons, M. S., & Pocock, M. J. (2021). Is light pollution driving moth population declines? A review of causal mechanisms across the life cycle. Insect Conservation and Diversity, 14(2), 167-187.

Degen, J., Storms, M., Lee, C. B., Jechow, A., Stöckl, A. L., Hölker, F., ... & Degen, T. (2024). Shedding light with harmonic radar: Unveiling the hidden impacts of streetlights on moth flight behavior. Proceedings of the National Academy of Sciences, 121(42), e2401215121.

Gaston, K. J., Davies, T. W., Bennie, J., & Hopkins, J. (2012). Reducing the ecological consequences of night-time light pollution: options and developments. Journal of Applied Ecology, 49(6), 1256-1266.

Owens, A. C., Cochard, P., Durrant, J., Farnworth, B., Perkin, E. K., & Seymoure, B. (2020). Light pollution is a driver of insect declines. Biological Conservation, 241, 108259.

Potts, SG, Imperatriz-Fonseca, V, Ngo, HT & Vanbergen, AJ (2016) Safeguarding pollinators and their values to human well-being. Nature, 540(7632), 220–229

Seibold, S., Gossner, M. M., Simons, N. K., Blüthgen, N., Müller, J., Ambarlı, D., ... & Weisser, W. W. (2019). Arthropod decline in grasslands and forests is associated with landscape-level drivers. Nature, 574(7780), 671-674.

van Langevelde, F., Braamburg-Annegarn, M., Huigens, M. E., Groendijk, R., Poitevin, O., van Deijk, J. R., ... & WallisDeVries, M. F. (2018). Declines in moth populations stress the need for conserving dark nights. Global change biology, 24(3), 925-932.

Wagner, D. L., Grames, E. M., Forister, M. L., Berenbaum, M. R., & Stopak, D. (2021). Insect decline in the Anthropocene: Death by a thousand cuts. Proceedings of the National Academy of Sciences, 118(2), e2023989118.

Assessing Light Pollution in The Republic of Lithuania: Status Quo, Legislation and Challenges

Theme: Governance & Regulation

Tulušienė G.[1,*], prof. dr. Stasiškienė Ž.[1]

[1]Kaunas University of Technology Institute of Environmental Engineering, Kaunas, Lithuania
gaila.tulusiene@ktu.edu
**presenting author*

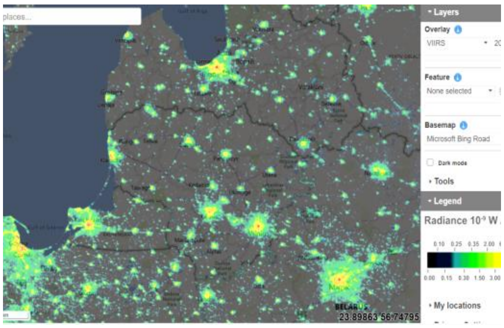


Figure 1. Map of light pollution in the territory of Republic of Lithuania in 2023, https://www.lightpollutionmap.info/

While light pollution and its diverse impact on environment is being addressed and researched in many countries worldwide, Lithuania falls behind not only in addressing light pollution, but even in acknowledging it as a type of pollution. The fundamental environmental legal document of Lithuania – *Environmental Protection Law of Republic of Lithuania* – describes **pollution** as the release (discharge, dispersion) of substances, mixtures, organisms and micro-organisms or compounds thereof into the environment as a result of human activities. In comparison, European Environment Agency gives such a description: “Pollution is the introduction of substances or **energy** into the environment, resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems, and impair or interfere with amenities and other legitimate uses of the environment”. The only document that mentions light pollution is *Guidelines for Sustainable Cities and Recommendations for Their Implementation*: Article 14.5 indicates that one of the principles of the Green City has to be “less pollution created by lighting”.

As the main light pollution sources are street lights, illuminated signs, industrial and commercial infrastructure, residential buildings and landscape lighting, electronic billboards, parking lots, sports infrastructure and greenhouses, documents that can have impact on mitigating light pollution are documents regulating installation of electrical lighting equipment in streets, public places, etc. In Lithuania *Rules for The Installation of Electrical Lighting Installations* (approved by Order No 1-28 of the Minister of Energy of the Republic of Lithuania on 3 February 2011) define the requirements for electrical equipment for interior lighting in residential and non-residential buildings, for outdoor lighting of streets, roads, squares, parks and territories in urban and rural areas, in the territories of enterprises and manufactures, for advertising lighting, for signs and illuminations, and for installations for long wave ultraviolet radiation. However, those regulations are mostly related to safety issues and determine only minimal requirements for luminance. Other relevant documents that could be important for mitigating light pollution are construction technical regulations and hygiene standards.

Modern street lighting has been installed in 20 out of 60 Lithuania's municipalities, and in 2025-2026 more than half of Lithuania's municipalities will have high-quality LED lighting. Municipalities have been completing the renewal not only of old, worn-out luminaires, but also of power lines, poles, control cabinets and other lighting-related infrastructure. To mitigate light pollution at the city-level steps are already being taken by several municipalities of Lithuania. Capital City Vilnius is one of the newest members of the LUCI (Lighting Urban Community International) and in 2023 prepared VILNIUS CITY LIGHTING STANDARD which also addresses dark sky friendly aspects while planning lighting systems in the City of Vilnius. Starting from 2019 existing street light figures were replaced with new LED lamps and remote control and adjustment system was implemented (Light pollution reduction measures in Europe, 2022). Kaunas, the second largest city in Lithuania, has replaced 98 % of old type luminaires in the streets and public spaces with LED luminaires that have integrated dimming scenarios with 4-time intervals during the night. Times of turning on and turning off differ depending on the sunrise and sunset times. When designing lighting in different urban spaces, according to the lighting categories provided by the LST EN 13201 standard, different luminaires (power, distances, height) are selected using software. Correlative temperatures are indicated by the administration of Kaunas city municipality: 4000K lights are usually chosen for streets, and 3000K lights for parks.

Until now there has not been research conducted to assess light pollution in Lithuania. In the *Review and Assessment of Available Information on Light Pollution in Europe* (Widmer et al., 2022), it is indicated that the relative increase in brightness in the territory of Lithuania between the averaging periods of (2020/21) and (2014/15) is from 26 to 100 %, according to monthly average radiance composite images of night-time data from VIIRS. The same report shows that approximately 47 % of the total population of Lithuania is exposed to light emission levels higher than > 2 nW/cm2/sr during the two time periods 2014/15 and 2020/21, implicating that the above-mentioned percentage of population is exposed to at least low negative impact from light pollution (Hale et al., 2018). While analyzing Light pollution map created from VIIRS data, it is obvious that the highest radiance forms above largest cities: Vilnius, Kaunas, Alytus, Marijampolė. Vilnius and Kaunas form cluster of radiance because of the A1 highway connecting two cities, smaller towns and industrial facilities located in between. Cluster of radiance forms along coast of Baltic Sea with port town Klaipėda being the largest contributor. Another tendency is the areal increase of light pollution, especially around cities of Vilnius, Kaunas and Klaipėda. This is related to growth of the population living in the suburbs of these three towns or in the surrounding municipalities. In 2023 19% more people lived in the suburbs of Vilnius than in 2018. In Kaunas district municipality which is “ring” municipality of Kaunas city increase in population was 25 % from year 2015 to 2024.

Conclusions

A thorough examination of the legal documents of Republic of Lithuania is needed to propose sollutions for addressing light pollution. Light pollution has to be assessed in chosen case study city of Lithuania to indicate main sources of the different light pollution types.

References

Light pollution reduction measures in Europe (2022) Working paper for the international workshop Light Pollution 2022, during the Czech Presidency of the Council of the European Union

Widmer, K., Beloconi, A., Marnane, I., Vounatsou, P. (2022) *Review and Assessment of Available Information on Light Pollution in Europe*. Eionet Report – ETC HE 2022/8

Hale, J., Blumenstein, C., Carannante, D., & Arlettaz, R. (2018). *Ecological light pollution in the Naturpark Gantrisch* (Vol. 3). Technical report.

Measurement and Analysis of Night Sky Brightness: A Mathematical Modeling Approach in Ankara

Theme: Measurement and Modeling

Sevcan B. Uğur, [1,*] Erkin Sidiq, [2]

[1] Bilkent University, Ankara, Turkey
[2] Reflect Orbital, California, USA
sevcanbugur@gmail.com
[*] Sevcan B. Uğur

Introduction

The natural brightness of the night sky is primarily contributed by faint stars, airglow, and zodiacal light. The contribution of airglow increases with zenith angle, while zodiacal light peaks near the ecliptic plane. Light pollution, primarily caused by artificial light sources, impacts the quality of the night sky, especially near urban areas. To quantify the brightness of the sky and its variations with zenith angle, we used the Unihedron SQM-L device, a portable and cost-effective tool for measuring sky brightness. The data collected will be compared to Garstang's (1989) model of natural sky brightness, and mathematical modeling will be used to predict sky brightness in different regions of Ankara.

Methods

For this study, the Unihedron SQM-L device was employed to take measurements of night sky brightness at varying zenith angles. The measurements were conducted in multiple locations around Ankara, focusing on both urban and semi-urban areas. The device was set up on a tripod, with a protractor and compass to ensure consistent positioning for each measurement. The sky brightness was measured in magnitudes per square arcsecond (mag/arcsec^2) for each zenith angle. To assess the impact of light pollution, we also measured the brightness in different azimuthal directions, with particular attention to the urbanized areas surrounding Ankara.

Conclusions

The study confirms that night sky brightness in Ankara varies significantly with zenith angle, with airglow being the dominant contributor. The comparison with Garstang’s (1989) model indicates that local light pollution and atmospheric conditions play a crucial role in altering sky brightness, especially in urban regions. The integration of mathematical modeling has proven effective in predicting sky brightness variations and will serve as a valuable tool for future studies. This research highlights the importance of monitoring light pollution and offers a reliable method for assessing sky quality in urban and semi-urban environments.

References

Birriel, J., & Adkins, J. K. (2010). A simple, portable apparatus to measure night sky brightness at various zenith angles. Journal of the American Association of Variable Star Observers, 38, 224-230.

Garstang, R. H. (1989). Predictions of the brightness of the night sky caused by a city. Astronomical Society of the Pacific, 101(625), 368-372.

Leinert, C., et al. (1998). The Nature of the Night Sky: Contributions of Zodiacal Light, Airglow, and Starlight. Astronomy and Astrophysics, 127(2), 437-450.

Pike, C. D. (1976). Photometric Measurements of Night Sky Brightness and Its Variations. Astronomical Journal, 81(5), 890-900.

From Awareness to Action: Empowering Youth for Light Justice through Adler's Youth Organization for Lights Out (YOLO)

Theme: Social Sciences & Humanities

Waleska Valle,[1,*] Kelly Borden[2] and Qian Xiao[3]

[1,2] *Adler Planetarium, Chicago, USA*
[3] *University of Texas Health Science Center (UT Health), Houston, USA*
wsantos@adlerplanetarium.org
[*] *presenting author*

Introduction

For nearly a decade, the Adler Planetarium has spearheaded efforts to combat artificial light at night (ALAN) through its Adler Teens programs, including the Youth Organization for Lights Out (YOLO). What began as a biology project has grown into a dynamic after-school program that focuses on both reducing urban light pollution and advancing environmental justice.

Through hands-on projects like the *Little Village Night Sky Photovoice Exhibit* [1], YOLO empowers high school students to identify and address local light pollution issues, raise awareness, and inspire meaningful change. By amplifying student voices, the program has led to impactful initiatives, such as a lighting inventory at their school. YOLO also supports other Adler Planetarium efforts, like the *Climate Change & Me* activity [2], which uses Photovoice stories from the exhibit to help middle school students explore the connection between light pollution and climate change.

Fig. 1: YOLO participants engage with the community at the Adler Planetarium. Photo by Ken Walczak, in the public domain.

In partnership with the University of Texas Health Science Center at Houston (UT Health) and Enlace Chicago, YOLO launched *CIELO: Chicago's Initiative for Environmental Justice and Light Pollution Outreach*, a NASA-funded project aimed at developing a GIS dashboard that integrates satellite-derived ALAN data with sociodemographic and health information. This tool will support advocacy efforts and expand the YOLO program by creating a light pollution curriculum for high school students. These collaborations blend youth-led activism with cutting-edge research, advancing both environmental justice and the fight against urban light pollution.

Rooted in Paulo Freire's *Pedagogy of the Oppressed* [3], YOLO uses education as a tool for social change. Offering culturally relevant activities and peer mentorship, the program empowers youth to confront light pollution and its disproportionate impact on marginalized communities. By nurturing leadership, critical thinking, and advocacy skills, YOLO equips the next generation with the tools to drive lasting change in their communities and beyond.

Methods

YOLO's collaborative model brings together community organizations, academic institutions, and local stakeholders to tackle light pollution and promote environmental justice. The program prioritizes youth-led initiatives, ensuring activities reflect community values and needs. Key partnerships strengthen this model:

- **Community Engagement**: Collaborations with Enlace Chicago and the Adler Planetarium enhance local outreach and ensure culturally relevant engagement.
- **Institutional Partnerships**: Work with the Chicago Park District and Lincoln Park Zoo raises awareness about light pollution’s effects on wildlife, such as bats.
- **Youth and Parent Involvement**: Peer mentorship and parental involvement in field trips and activities reinforce community support.
- **Academic Collaborations**: Partnerships with institutions like UT Health to build interdisciplinary teams and develop initiatives such as CIELO, which integrate GIS tools for advocacy and enable data-driven decision-making.

Maintaining flexibility across partnerships and activities ensures that YOLO’s approach remains adaptive and effective, enabling the program to respond to the unique and evolving needs of diverse communities. This adaptability amplifies its capacity to address light pollution and advance environmental justice in a meaningful, sustainable way.

Conclusions

YOLO has developed a model for sustainable change through hands-on projects, strategic partnerships, and academic collaborations. This model amplifies youth voices, strengthens community engagement, and advances environmental justice. With support from institutions like UT Health, Enlace Chicago, and NASA, YOLO is well-positioned to expand its impact, creating tools like the GIS dashboard and curriculum that equip future generations with the knowledge and skills to combat urban light pollution. This model benefits youth and communities, while also supporting the broader light pollution community by raising awareness and offering actionable solutions. Grounded in social change and critical education, YOLO’s work shows that when young people are given resources and platforms to lead, they can drive lasting transformations for the environment and their communities.

References

[1] Wang, C., & Burris, M. A. (1997). Photovoice: Concept, methodology, and use for participatory needs assessment. *Health Education & Behavior, 24*(3), 369–387. https://doi.org/10.1177/109019819702400307

[2] *NASA. (2023, June). Climate change and me: Engaging young people with NASA data, missions, and careers through immersive visualizations, planetarium programs, and virtual experiences. https://www.nasa.gov/wp-content/uploads/2023/06/adler-planetarium-508.pdf*

[3] Freire, P. (2000). *Pedagogy of the oppressed* (30th Anniversary ed.). Continuum.

CIELO: Chicago's Initiative for Environmental Justice and Light Pollution Outreach

Theme: Social Sciences & Humanities

Waleska Valle,[1,*] Qian Xiao[2], Kelly Borden[3], Ken Walczak[4]

[1,3,4] *Adler Planetarium, Chicago, USA*
[2] *University of Texas Health Science Center (UT Health), Houston, USA*
wsantos@adlerplanetarium.org
[*] *presenting author*

Introduction

Chicago's Initiative for Environmental Justice and Light Pollution Outreach (CIELO) is a NASA-funded project inspired by Adler Planetarium's presentation, *"Teens Using Photovoice to Promote Light Pollution Awareness,"* at the 2023 Artificial Light at Night (ALAN) Conference. This presentation highlighted the Little Village Night Sky exhibit at the Adler Planetarium, which was created by high school students who participated in Adler's afterschool program Youth Organization for Lights Out (YOLO). Student participants used Photovoice to document light pollution in their neighborhood, engage key stakeholders and raise awareness to develop solutions for light pollution. CIELO, a NASA-funded project, brings together youth, the community, and academics to work collaboratively on this issue, in partnership with Adler Planetarium, UT Health Texas, and Enlace Chicago, a local nonprofit organization.

Over the next three years, CIELO will focus on two primary objectives: (a) developing a GIS-enabled dashboard for the greater Chicago area that integrates multiple data sources with interactive tools for easy visualization and analysis, and (b) expanding Adler's YOLO program by creating a new high school curriculum that enables students to explore the ecological and health-related impacts of ALAN, while developing and investigating original research questions within their own communities.

Fig. 1: Teachers attending the CIELO Overview Meeting. This image, by Waleska Valle, is in the public domain.

Methods

DASHBOARD

CIELO aims to develop an interactive dashboard for the Greater Chicago area that enables the visualization and analysis of neighborhood-level data on ALAN, social indicators, health statistics, and crime data. This dashboard will provide high school students with an opportunity to engage in hands-on science projects focused on ALAN, allowing them to explore light pollution, develop evidence-based solutions, and take data-driven actions in the Little Village community. The dashboard will integrate the following data:

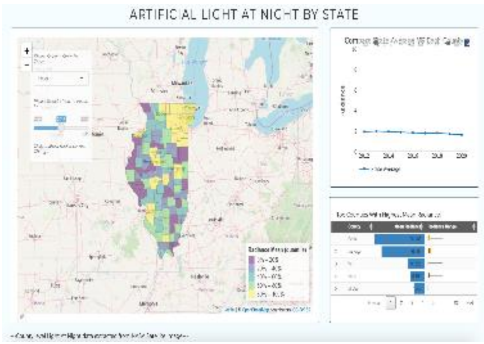


Fig. 2: The prototype dashboard offers analytical capabilities through three key components: interactive mapping, temporal analysis, and a user-friendly interface.

1. **Total ALAN and Blue Light**: ALAN will be measured using NASA's Black Marble data, SDG-SAT satellite blue light data, and ISS images, including annual composites and data for specific days or months. High-resolution RGB data from Adler Planetarium's balloon missions and NITELite maps of Chicago will provide detailed nighttime light information.

2. **Demographic and Socioeconomic Characteristics**: Data from the CDC's Social Vulnerability Index will be used to assess the demographic and socioeconomic characteristics of the neighborhood.

3. **Health Statistics**: Health data will include prevalence rates of sleep deficiency and chronic diseases like diabetes, obesity, cardiovascular disease, and cancer, sourced from the CDC's PLACES dataset.

4. **Crime Data**: Crime statistics from the Chicago Police Department will be added to the dashboard to help users explore the relationship between crime and ALAN. For more detailed insights, street-level or geo-coded crime data will be included to highlight specific crime trends in smaller areas.

CURRICULUM DEVELOPMENT

The dashboard will be used to develop a light pollution curriculum for formal high school education. It will include scientifically accurate content, real-world applications, and hands-on activities. YOLO participants will actively provide feedback to ensure the dashboard is user-friendly for students, while also supporting the expansion of the program across the Chicago's Little Village Lawndale High School campus by hosting events and creating light pollution materials to educate community members. Meanwhile, the CIELO team will work closely with eight high school teachers to ensure the curriculum meets the community needs, offering training and support to help integrate light pollution topics into classrooms effectively and also promote positive solutions.

Conclusions

By combining these datasets, the dashboard will help educate and empower not only YOLO program participants but also countless young people and community members outside the program to take action in reducing the impacts of ALAN.

References

Centers for Disease Control and Prevention. (n.d.). *Social Vulnerability Index (SVI)*. Agency for Toxic Substances and Disease Registry. Retrieved March 16, 2025, from https://www.atsdr.cdc.gov/place-health/php/svi/index.html

Centers for Disease Control and Prevention. (n.d.). *PLACES: Local Data for Better Health*. Retrieved March 16, 2025, from https://www.cdc.gov/places/index.html

Spatiotemporal Data Science. (n.d.). *Artificial Light at Night (ALAN) interactive visualization tool*. Retrieved March 16, 2025, from https://spatiotemporal-data-science.shinyapps.io/ALAN/.

The Astronomical Darkness Necessity Map – a Tool for Lighting Projects

Theme: Governance & Regulation

Stijn Vanderheiden,[1,*] Fleur De Nil, [1] and Friedel Pas[1]

[1] Leve(n)de Nacht vzw / Living Night, Boortmeerbeek, Belgium
stijn.vanderheiden@livingnight.org
[*] presenting author

Introduction

Flanders, the northern part of Belgium, is one of the most light-polluted areas in the world. The sky brightness there is so high that there are hardly any dark environments to enjoy the starry sky. The impact on biodiversity there is also significant.

Flanders has no certified Dark Sky Places and probably only qualifies for Urban Night Sky Places or International Dark Sky Communities, the labels where true darkness is less decisive.

Light pollution in Flanders or Belgium is not a recent problem. Observatories left city centers decades ago to escape the growing (poor) lighting in cities. These moves did not happen in recent years, but the first half or mid-20th century.

However, it was only recently recognized as a problem. And since there has been improvement, not yet in the facts or tangible, but at least in the minds of policy makers, administrations, ... Recently, the provincial authorities commissioned a study on the impact of ALAN on biodiversity and human health.

In 2024, the Agency for Nature and Forests (ANB, an agency of the Flemish Government) published an ecological darkness necessity map. This map, by combining freely consultable GIS layers, shows the locations where at least from an ecological point of view custom lighting should be carefully considered. This map shows nature reserves, European protected areas, valley areas, rivers, creeks, etc. and thus provides an insight into the areas that deserve extra attention to darkness from a biodiversity or environmental point of view. The map works with data for the whole of Flanders and is therefore an approximation. Local knowledge of populations of bats or other animal species that necessity darkness has not yet been added and is a useful addition when considering lighting in the field.

This map is a good first step, but is still too one-sided. It does not yet contain info on other than ecological motives to preserve or bring back darkness.

Concept

In addition to the ‘ecological darkness necessity map’, there could also be an ‘astronomical darkness necessity map’. This map could indicate where, from an astronomical point of view, extra attention should be paid to appropriate lighting to highlight the scientific and recreational value of the night sky.

The ‘astronomical darkness necessity map’ could be a living map that depicts where astronomers need dark skies for scientific, educational or recreational reasons.

Different types of locations can be envisioned on the map:

- observatories and research institutes (private and public) and observing sites in the field: pinpointed with a buffer around it
- private locations (observatories, ...): not marked on the map but with a buffer sufficiently large so that the observatory/observation site cannot be immediately identified (privacy reasons).
- areas where a starry sky/darkness is important for astronomical, scientific or cultural reasons. These could be silence areas, heritage landscapes with views, national or landscape parks with a focus on darkness, ...

The map can grow with input from the public, especially than (amateur) astronomers. The submitted locations will be added to the map after review and approval. In this way, the map becomes a living document that can grow all the time.

Purpose

Like the ecological darkness necessity map, the astronomical version can also be used to advise or substantiate lighting projects. The map can be consulted on the Leve(n)de Nacht vzw website, but the map layer will also be available to interested parties (authorities, etc.).

Leve(n)de Nacht vzw will actively communicate about the existence of this extra darkness necessity map and will set up a communication campaign around it, e.g. at awareness-raising events such as the Night of Darkness.

Like the 'ecological darkness necessity map', the map does not aim to be exhaustive. This should also be communicated as such, because it is not intended to put darkness in a 'reserve' and that darkness can only be enjoyed from reserves. Even places that do not appear on the map can be important for darkness, from an astronomical, ecological or other point of view.

Remarks

The map must take privacy issues into account. For instance, it is not desirable to reveal private observatories when the owner or user does not want it. However, if this map cannot be accurate, it also has less quality and its importance can be less demonstrated.

It is therefore necessary to consider how to combine data protection and locations on the map.

References:

Website ecological darkness necessity map, https://natuurenbos.vlaanderen.be/dieren-en-planten/soortenbescherming/duisternisbehoeftekaart, Agentschap voor Natuur en Bos (ANB), 2024

A De Decker, I Wolters, I Gabaret, L De Prins, E Den Hond (2023). Artificiële nachtelijke buitenverlichting en verbanden met fysieke en mentale gezondheid. Rapport literatuurstudie. Provinciaal Instituut voor Hygiëne (PIH), 2023

D Dekeukeleire, R Gyselings, L De Bruyn (2023). Effecten van nachtelijke verlichting op biodiversiteit. Een literatuurstudie voor beleidsondersteuning. Rapporten van het Instituut voor Natuur- en Bosonderzoek (INBO) 2023 (32). DOI: http://doi.org/10.21436/inbor.96637982

Website leve(n)de nacht vzw, https://eng.levendenacht.be/, leve(n)de nacht vzw, 2025

WE AND THE NIGHT –
AN INTERDISCIPLINARY EUROPEAN OUTREACH & INFOTAINMENT PROJECT

Theme: Society

Caroline Vilbrandt,[1,*]

[1] *Stiftung Planetarium Berlin*
[2] *umWeltgerecht Beleuchten*
cv@vilbrandt-lichtplanung.de
[*] *presenting author*

Introduction

In Focus: Light pollution is increasing worldwide by up to 10% every year, with devastating effects on biodiversity and society, without the quality of light really improving. In the private sector, only 2-5% (luxury segment up to 30%) and in the public/commercial sector 20-50% of building projects are professionally planned. In the general public, lighting is a phenomenon that is rather difficult to assess and has a major impact in public spaces.

It's about time for the professional lighting world to get active and share their knowledge and their awareness of the impact and effects of lighting with the general public. This could take place in the form an interdisciplinary socio-cultural and lighting technology outreach or research project with infotainment character and added cultural value.

Goal: A contribution to more environmentally friendly and sustainable lighting in higher quality and more biodiverse friendly lit environments.

Fig. 1: Overview We & The Night, ©C. Vilbrandt

Status quo report, finding more partners from socio-cultural and lighting research and artistic application for the realization > Team composition > Acquisition of funds > Implementation of general education mission with cultural participation.

Status Quo & Target

The example of two "Symposiums Zukunftsfähig Beleuchten" (Symposia on Sustainable Lighting) financed by the lighting industry has shown that a successful positioning of the topic in society as a whole requires at least the following:

1) A team, 2) Public and non-profit funding 3) A public educational mission 4) Transdisciplinary cooperation of professional associations and research institutions, 5) Local community involvement, 6) Regular and diverse low-threshold activities and offers 7) Another "Symposium Zukunftsfähig Beleuchten" as a milestone of the research project, where all participants are experts.

This could be successfully achieved with the above-mentioned project. We're presenting the status quo of the project concerning partners, content and financial concretion etc.

In a speech I will present: 1) the real framework - a phenomenological research, 2) a summary of the activities so far; 3) the concept - with the motto "if you don't come to us, we will come to you"; 4) the target group: Villages / cities / municipalities / wholesalers / guilds / representatives of the real estate industry; 5) the participation concept of local actors; 6) similar projects in Europe; 7) financial concept and schedule; 8) potential partners already addressed or yet to be addressed from professional associations, social, literary, religious and cultural studies, lighting research, astronomical research, applied and performing arts.

In a RollUP I will present the contept aditionnally

Degree of realization: in planning

References

Concept: Stiftung Planetarium Berlin, UmWeltgerecht Beleuchten (Caroline Vilbrandt)
graphics & images: Caroline Vilbrandt www.umweltgerecht-beleuchten.ded

Assessing and Mitigating Light Pollution in Lauwersoog Harbor: A Transdisciplinary Approach

Theme: Governance and Regulation, Measurement and Modeling

N. Visser[1*], E. Morin[2]

[1] *Kapteyn Astronomical Institute, Groningen, The Netherlands*
[2]*Université de Bretagne Occidentale, Brest, France*

visser@astro.rug.nl
[*] *presenting author*

Lauwersoog Harbor, situated between the UNESCO-designated Wadden Sea and the Dark Sky Park of Lauwersmeer National Park, presents a unique case study in light pollution mitigation. As one of the brightest sources of artificial light in the region, the harbor significantly impacts both the ecological balance and the quality of the night sky. Lighting policies must go beyond energy efficiency to address artificial light's broader effects. This shift requires a transdisciplinary approach that recognizes the importance of darkness and the consequences of its loss, along with behavioral changes to mitigate these effects (Hölker et al., 2010).

DARKER SKY is an Interreg North Sea project whose main objective is to reduce light pollution in order to increase biodiversity and ecological connectivity in the North Sea area (France, Netherlands, Germany, Denmark). It involves 13 partners from four countries and has a budget of €4.2 million, 60% of which is co-funded by the Interreg North Sea programme (ERDF funds). As part of the DARKER SKY project, Lauwersoog Harbor is one of nine pilot locations where innovative strategies are being tested to reduce light pollution. The site provides a rare opportunity to study the interplay between artificial lighting, biodiversity, and astronomical visibility in a highly sensitive environment. Sky brightness measurements, spectral analysis, and ecological monitoring are being conducted to assess the impact of current lighting conditions, while co-design processes involving local authorities, businesses, conservationists, and astronomers ensure that solutions are both scientifically effective and socially viable.

This presentation will showcase preliminary findings from the ongoing monitoring efforts, highlighting the relationship between artificial light and environmental disruption in coastal and protected areas. It will also discuss the effectiveness of bottom-up engagement strategies in implementing sustainable lighting solutions, demonstrating how participatory approaches can bridge the gap between scientific research and policy implementation. By leveraging a site of both ecological and astronomical significance, this study contributes valuable insights into the broader field of light pollution research and mitigation.

In a Personal Light: Investigating the Distribution of Residential Lighting Using Demographic and Environmental Variables

Theme: Measurement and Modelling

Ken Walczak,[1,*] Cynthia Tarr,[1] and Holly Burd,[1,2] Alex Lindsey,[1,3] Jessica Ramirez,[1,4] Dorsa Valipourkarimi[1,5]

[1] Adler Planetarium, Chicago, USA
[2] DePaul University, Chicago, USA
[3] Harold Washington College, Chicago, USA
[4] North Central College, Naperville, USA
[5] Loyola University, Chicago, USA
kwalczak@adlerplanetarium.org
[*] presenting author

Introduction

The use of remote sensing data to quantify the distribution of nighttime light emissions in developed areas can lead to a better understanding of the effects of artificial light at night and help guide policy that may mitigate its growth. Light at night is increasing at a rate of nearly 10% per year (Kyba et al., 2023). The sources contributing to this change in urban areas are not uniform. Our previous research (Walczak et al., 2023) has shown that, due to its disproportionately large area, residential land is the greatest contributor to total light emission in and around Indianapolis, a mid-size US city. For this study, we focused on emissions from nearly 132,000 single-family homes across multiple suburbs around the city of Chicago to better understand the variations in the use of lighting at private homes.

The brightness of residential light across the areas we sampled was found to be rather inhomogeneous (Figure 9). This offered an opportunity to explore what factors may drive or indicate the amount of light being used at night. We considered variables in multiple categories – spatial, environmental, demographic, etc. – to explore possible correlations between the quantity of nighttime residential lighting and numerous factors across these communities.

Figure 9 Mean brightness of 43,443 single family homes in an area west of Chicago on the night of March 19, 2023 showing the variation in parcel brightness.

Methods

We sampled three regions near Chicago for this analysis – areas north, south, and west of the city, which contain 14 towns and 93 distinct census tracts. The areas to the north and south are centered on dark sky communities as designated by DarkSky International. Zoning information at the parcel level was obtained from multiple local government agencies. Other datasets such as tree canopy, land cover, and sky brightness models were also integrated into the analysis. Light emission data at the parcel level was obtained from SDGSAT-1 observations taken at different times of the year in 2023. Demographic data such as income, home value, population age, etc., at the census tract level (600-3000 homes per tract) were obtained from the U.S. Census.

As an example of this analysis, we see a significant correlation between the mean value of the homes in each census tract and the mean brightness of those properties (Figure 10).

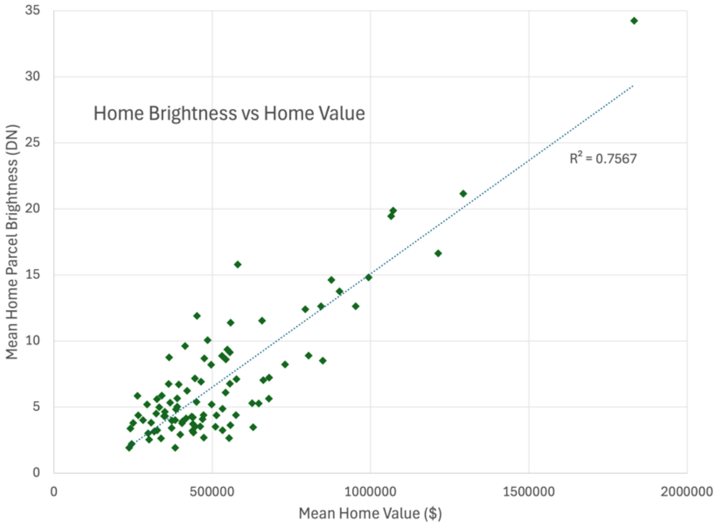


Figure 10 Census tract level correlation between parcel brightness and mean home value.

Conclusions

We believe these methods and subsequent results can help bring to light the factors which most strongly correlate to the use of excessive lighting seen from private homes. This information may also help anticipate future changes in light pollution from residential properties. This analysis can provide actionable information for communities to address the impacts and avert potential growth of light pollution.

References

Kyba, C. C. M., Altıntaş, Y. Ö., Walker, C. E., & Newhouse, M. (2023). Citizen scientists report global rapid reductions in the visibility of stars from 2011 to 2022. *Science*, *379*(6629), 265–268. https://doi.org/10.1126/science.abq7781

Walczak, K., Wisbrock, L., Tarr, C., Gyuk, G., Amezcua, J., Cheng, C., Cris, J., Jimenez, C., Mehta, M., Mujahid, A., Pritchard, L., Suquino, K., & Turkic, L. (2023). Quantifying nighttime light emission by land use from the stratosphere. *Journal of Quantitative Spectroscopy and Radiative Transfer*, *310*, 108739. https://doi.org/10.1016/j.jqsrt.2023.108739

Imaging earth at night from Space using the Unicorn-2 Satellite constellation

Theme: **Technology and Design**

Tom RL. Walkinshaw,[1,*] and Dr Martin Dunn [1]

[1] Alba Orbital 1, Glasgow, Scotland
tom@albaorbital.com
[*] presenting author

Introduction

The Unicorn-2 PocketQube represents a groundbreaking advance in picosatellite technology, showcasing an innovative platform for Earth observation at night. Designed with a compact 5 cm x 5 cm x 19 cm form factor, Unicorn-2 is equipped with a high-sensitivity imaging payload optimized for low-light conditions. This capability enables the satellite to capture detailed imagery of urban lighting, maritime activity, and natural phenomena such as auroras and wildfires during nighttime. The mission aims to provide critical data for urban planning, environmental monitoring, and disaster response, addressing gaps in current Earth observation technologies.

Unicorn-2's mission builds on novel hardware and software advancements, including miniaturized low-light cameras and efficient onboard processing to maximize data yield. Leveraging these innovations, the satellite aims to deliver unprecedented nighttime imaging data at a fraction of the cost of traditional Earth observation missions. This paper will discuss the satellite's design, mission objectives, and its potential contributions to the study of artificial light at night (ALAN) and global light pollution. Unicorn-2 represents a significant step forward in picosatellite capabilities, offering a scalable platform for future low-cost, high-impact missions.

Impact of Day-Night Cycles on Atmospheric Extinction under Cloudless Skies at the Kanzelhöhe Observatory for Solar and Environmental Research

Theme: Measurements & Modeling

Sonja Wenig,[1,2,*]

[1] *Institution of Physics, University of Graz, 8010 Graz, Austria*
[2] *Kuffner Observatory, Vienna, Austria*
sonja.wenig@gmail.com.
[*] *presenting author*

Introduction

A comprehensive understanding of light pollution requires not only the consideration of light sources but also the complex atmospheric influences that significantly impact the propagation of light. Some principles from daylight research can also be applied to nighttime conditions, but the fundamentally different physical conditions of the atmosphere between day and night must be taken into account (Reimann et al., 1992). These differences – such as stable stratification, reduced turbulence, and often higher aerosol concentrations at night – have direct effects on light scattering and absorption and therefore require precise quantification of day-night variability (Barreto et al., 2019).

Methods

Against this background, this study presents a method for systematically and precisely capturing the differences in irradiance between day and night, while keeping all other parameters as constant as possible. The data for this study were collected at the Kanzelhöhe Observatory for Solar and Environmental Research, in Austria (1526 m above sea level) over a seven-year period. These measurements include data from the Lightmeter (Müller et al., 2011), the ARAD station (Olefs et al., 2016), and the TAWES weather station. These long-term measurements provide a unique opportunity to quantify the day-night variability of atmospheric extinction under clear sky conditions. The newly developed global extinction coefficient integrates both solar and lunar light measurements and captures the specific dynamics of the nocturnal atmosphere, including stable stratification and reduced turbulence (Román et al., 2020).

Results and Conclusions

The results show statistically significantly higher extinction values at night compared to the day. This systematic analysis helps to better understand the mechanisms of light propagation and ensures that the specific characteristics of the nocturnal atmosphere – such as stable stratification and inversion layers – are appropriately considered in future models. These findings are essential for more accurate quantification of the impacts of light pollution and for developing more targeted measurement strategies, interpretations, and mitigation strategies. This work thus makes a valuable contribution to reducing light pollution and protecting the natural night sky.

References

Barreto, A., Román, R., Cuevas, E., Pérez-Ramírez, D., Berjón, A. J., Kouremeti, N., Kazadzis, S., Gröbner, J., Mazzola, M., Toledano, C., Benavent-Oltra, J. A., Doppler, L., Juryšek, J., Almansa, A. F., Victori, S., Maupin, F., Guirado-Fuentes, C., González, R., Vitale, V., . . . Yela, M. (2019). Evaluation of night-time aerosols measurements and lunar irradiance models in the frame of the first multi-instrument nocturnal intercomparison campaign. *Atmospheric Environment*, *202*, 190-211. https://doi.org/https://doi.org/10.1016/j.atmosenv.2019.01.006

Müller, A., Wuchterl, G., & Sarazin, M. (2011). Measuring the Night Sky Brightness with the Lightmeter. *Revista Mexicana de Astronoma y Astrofsica*, *41*, 46-49.

Olefs, M., Baumgartner, D., Obleitner, F., Bichler, C., Foelsche, U., Pietsch, H., Rieder, H., Weihs, P., Geyer, F., Haiden, T., & Schöner, W. (2016). The Austrian radiation monitoring network ARAD – best practice and added value. *Atmospheric Measurement Techniques*, *9*, 1513. https://doi.org/10.5194/amt-9-1513-2016

Reimann, H. G., Ossenkopf, V., & Beyersdorfer, S. (1992). Atmospheric extinction and meteorological conditions - A long time photometric study. *Astronomy and Astrophysics*, *265*, 360-369.

Román, R., González, R., Toledano, C., Barreto, Á., Pérez-Ramírez, D., Benavent-Oltra, J. A., Olmo, F. J., Cachorro, V. E., Alados-Arboledas, L., & de Frutos, Á. M. (2020). Correction of a lunar-irradiance model for aerosol optical depth retrieval and comparison with a star photometer. *Atmos. Meas. Tech.*, *13*(11), 6293-6310. https://doi.org/10.5194/amt-13-6293-2020

Implementation of Municipal Measures for Night Sky Protection in the Rhön Dark Sky Reserve

Challenges, Solutions and Opportunities

Theme: Governance & Regulation

Hanne L. Winter[1]

[1] Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany
hanne.winter@student.uni-halle.de

Introduction

Light pollution (LP) is a growing problem (e.g. Cinzano et al., 2001; Falchi et al., 2016; Kyba et al., 2023), that poses a significant threat to biodiversity (e.g. Eisenbein, 2006), human and ecosystem health (e.g. Deshouhant et al., 2019; Kim et al., 2023; Knop et al. 2017; Min & Min, 2018). The impacts caused by LP cannot be reversed immediately – nevertheless, it is possible to reduce a large proportion of light emissions through targeted measures such as retrofitting or switch-offs (e.g. Falchi et al., 2016). However, it is apparent that local authorities and politicians are often hesitant when it comes to regulating light pollution (e.g. Hölker et al., 2010; Krause, 2015). The measures that are implemented face a variety of challenges (e.g. Silver & Hickey 2020).

This presentation explores the difficulties, solutions and opportunities regarding the implementation of measures against light pollution in rural municipalities of the Rhön International Dark Sky Reserve (IDSR) within the Rhön Biosphere Reserve (BR) in Germany and the impact of the Kurzfristenergieversorgungssicherungsmaßnahmenverordnung (EnSikuMaV; Short-Term Energy Supply Security Measures Ordinance) adopted in the wake of Russia’s war of aggression against Ukraine in 2022.

Methods

This presentation is based on 13 qualitative, guideline-based interviews with representatives from six Bavarian, four Hessian and three Thuringian municipalities within the Rhön IDSR conducted by the author. Data were analysed using Kuckartz & Rädikers’ (2024) content-structuring qualitative content analysis.

Conclusions

Results show that municipalities in the Rhön IDSR have implemented different measures against LP including: adjustments of light distribution and light colour, LED-conversions, dimming and switch-offs.

The contexts in which the measures were implemented vary from one municipality to another and are shaped by a combination of ownership structures, motivational factors, stakeholders, financing and available options for selecting measures.

Key challenges include the perceived urgency of the problem, technical challenges, costs and financing, acceptance and local authority staff resources while opportunities lie in strategic anchoring and support by the administrative offices of the Rhön BR.

The EnSikuMaV was unique in that it was limited in time and focused on aesthetic public lighting. This ordinance did create a short-term incentive to change municipal building lighting practices, but the long-term effect of the regulation was heavily dependent on the assessment of the municipal lighting situation and willingness to implement it.

Overall, the findings highlight both the obstacles and the potential of rural municipalities as actors in night-sky protection.

References

Cinzano P, Falchi F, Elvidge CD (2001) The first World Atlas of the artificial night sky brightness. Monthly Notices of the Royal Astronomical Society 328(3): 689–707.

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 Exp Applicata 167(1): 37–58.

Eisenbein G (2006) Artificial Night Lighting and Insects: Attraction of Insects to Streetlamps in a Rural Setting in Germany. In: Rich C & Longcore T, editors: Ecological Consequences of Artificial Night Lighting. Island Press: 281–304.

Falchi F, Cinzano P, Duriscoe D, Kyba CCM, Elvidge CD, Baugh K, Portnov BA, Rybnikova NA, Furgoni R (2016) The new world atlas of artificial night sky brightness. Science advances 2(6): e1600377.

Hölker F, Moss T, Griefahn B, Kloas W, Voigt CC, Henckel D, Hänel A, Kappeler PM, Völker S, Schwope A, Franke S, Uhrlandt D, Fischer J, Klenke R, Wolter C, Tockner K (2010): The Dark Side of Light. A Transdisciplinary Research Agenda for Light Pollution Policy. In: Ecology and Society 15(4).

Kim M, Vu, T-H, Maas MB, Braun RI, Wolf MS, Roenneberg T, Daviglus ML, Reid KJ, Zee PC (2023) Light at night in older age is associated with obesity, diabetes, and hypertension. Sleep 46(3).

Knop E, Zoller L, Ryser R, Gerpe C, Hörler M, Fontaine C (2017) Artificial light at night as a new threat to pollination. Nature 548(7666): 206–209.

Krause K (2015): Regulating Urban Lighting. Prospects for Institutional Change. In: Meier J et al., editors: Urban lighting, light pollution and society. Routledge Taylor and Francis group: 125–140.

Kuckartz U & Rädiker S (2024) Qualitative Inhaltsanalyse. Methoden, Praxis, Umsetzung mit Software und künstlicher Intelligenz. Beltz Juventa.

Kyba CCM, Altıntaş YÖ, Walker CE, Newhouse M (2023): Citizen scientists report global rapid reductions in the visibility of stars from 2011 to 2022. Science (New York, N.Y.) 379(6629): 265–268.

Min J & Min K (2018) Outdoor light at night and the prevalence of depressive symptoms and suicidal behaviors: A cross-sectional study in a nationally representative sample of Korean adults. Journal of Affective Disorders 227: 199–205.

Silver DA & Hickey GM (2020) Managing light pollution through dark sky areas: learning from the world's first dark sky preserve. Journal of Environmental Planning and Management 63(14): 2627–2645.

Following Their Curiosity: Empowering Teens to Lead Light Pollution Research

Theme: Social Sciences & Humanities

Lauren Wisbrock[1,*]

[1] *Adler Planetarium, Chicago, USA*
lwisbrock@adlerplanetarium.org

Over the last decade, the Far Horizons research team has brought together experts, volunteers, undergraduates, and teens to investigate light pollution and its impact in and around Chicago. For Far Horizons Teens, past programming has been shaped by the larger Far Horizons research team, finding places within existing research where teens work would be meaningful and rewarding. For example, in 2021, they collected and presented data used for the designation of the Palos Forest Preserves as an Urban Night Sky Place and in 2024 took part in simultaneous all-sky imaging alongside the National Park Service to characterize the Chicago light dome.

Top: Teens learning how to deploy the Adler's all-sky imaging cameras in preparation for data collection with the National Park Service Bottom: Teens observing the light from Chicago reflected on an overcast sky from the Palos Forest Preserves.

This year, Far Horizons Teens have been laying the foundations for a research project made entirely from young people's questions, ideas, and efforts. In addition to the existing benefits of participating within a larger research group, this allows teens to take place in the practice of crafting a scientific question based on their own observations and curiosity. This allows for more culturally relevant research to take place, as it is the teens themselves choosing the direction of the research.

We will outline the planning, implementation, and reflection of the first year of this teen-led original research project. It will include the journey of three different cohorts of teens during the last year:

- Fall 2024 - working within a leadership team to brainstorm and refine the project idea and find meaningful community and research partners.
- Spring 2025 - refining research questions, drafting experimental design and procedure and collecting preliminary data.
- Summer 2025 - iterating experimental design, collecting further data, and beginning data analysis.

We will also address the challenges associated with the piloting of this structure of programming. This includes navigating the additional time needed to build background knowledge and relevant partnerships as well as building a sense of community and trust within a working cohort.

The integration into the larger research landscape at the Adler is an excellent experience for teens. It exposes them to light pollution sources, impacts, and solutions, demonstrates the collaborative nature of research, allows them to build skills related to instrumentation use, data collection, and analysis, and brings them together in community under the night sky. They gain these skills in a way that usually isn't possible within the more formal and time-restricted structure of the classroom. By empowering young people to lead their own research, it benefits young people through developing critical thinking skills and building familiarity with experimental design. It also benefits the field of light pollution research by raising awareness about career opportunities through direct, hands-on participation and by broadening the perspectives included at the start of the research process.

Integrating ALAN in landscape scale conservation of lesser horseshoe bats in Ireland

Theme: Biology and Ecology

Patrick G. R. Wright[1] and Kate McAney[2,*]

[1] Wright Wildlife, Livarot, France
[2] Vincent Wildlife Trust, Galway, Ireland
patrick@wrightwildlife.com
[*] presenting author

Introduction

Ensuring the ability of light sensitive species to move through a highly anthropomorphic modified landscape is critical for their long-term survival. The lesser horseshoe bat (*Rhinolophus hipposideros*) is restricted to six western counties from Mayo to Cork in the Republic of Ireland and is the only Annex II bat species in the country. The species is extremely photophobic, but has strong positive associations with linear landscape features, broadleaf woodland and riparian vegetation (Bontadina et al. 2002, Boughey et al. 2011). These characteristics make it particularly susceptible to the expansion of urbanisation and changes in agricultural practices. It is thought that Galway city could be acting as a significant barrier to movement for the species due to the extent of artificial illumination. In this study, commissioned by Galway City Council, we performed some high-resolution landscape modelling (15m) to identify the potential pathways and barriers to movement of lesser horseshoe bats throughout the city.

Methods

To identify pathways for the species, we followed the method developed by Finch & McAney (2020) and used five environmental variables (e.g. street light density, land cover) that were assigned a specific slope and maximum resistance value that would correspond to the impact that these have on lesser horseshoe bat movement. These were then combined into a single resistance surface illustrating the species' ability to move through each cell, and we used the software Circuitscape (McRae & Nürnberger, 2006) to examine functional connectivity. We then tested the removal of specific street lights to assess changes in functional connectivity.

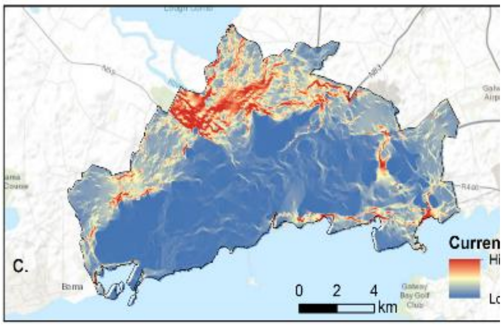


Fig. 1: Map representing functional connectivity for lesser horseshoe bats throughout Galway city.

Conclusions

Lesser horseshoe bat movement is likely to be restricted to a narrow pathway along the northern edge of Galway city. It is therefore critical that this pathway is retained to allow connectivity between populations east and west of Lough Corrib (Figure 1). Street lighting had the strongest impact on the species' ability to move through the landscape, and the removal of targeted lights resulted in an increase in connectivity. The identification of key ecological corridors has now been used by Galway City Council to inform its strategic planning policy via the *Green Network for the Galway City Green Spaces Strategy*, which aims to support the movement of sensitive species, such as the lesser horseshoe bat.

References

Bontadina, F., Schofield, H., & Naef-Daenzer, B. (2002). Radio-tracking reveals that lesser horseshoe bats (*Rhinolophus hipposideros*) forage in woodland. *Journal of Zoology* 258: 281-290.

Boughey, K.L., Lake, I.R., Haysom, K.A., & Dolman, P.M. (2011). Effects of landscape-scale broadleaved woodland configuration and extent on roost location for six bat species across the UK. *Biological Conservation* 144: 2300-2310.

Finch, D., & McAney, K. (2020) Using Circuitscape to identify potential landscape corridors for the lesser horseshoe bat in Ireland. Unpublished report. Vincent Wildlife Trust.

McRae, B. H., & Nürnberger, B. (2006). Isolation by resistance. *Evolution* 60: 1551-1561.

ALAN increases the cardio-metabolic risk in spontaneously hypertensive rats and after high fructose intake

Theme: Health

Michal Zeman[1], Lubos Molcan[1], Hana Mauer Sutovska[1], Valentina Sophia Rumanová[1], Monika Okuliarova[1]

[1]*Department of Animal Physiology and Ethology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovak Republic.*

michal.zeman@uniba.sk
**presenting author*

The global increase in cardiovascular and metabolic diseases is a public health concern (Chew et al., 2023). These diseases are multifactorial in origin, and changes in lifestyle, diet and environmental conditions are generally considered to be the major causes of their growing prevalence. Recent research indicates that increasing levels of artificial light at night (ALAN) can contribute to the burden of cardiometabolic diseases. However, the exact mechanisms are not well understood, and new experimental data are needed. Most hypotheses focus on the disruption of the circadian organization and suppression of melatonin, which is known for its pleiotropic protective effects and represents a direct output of the master circadian clock localized in the suprachiasmatic nuclei (SCN) of the hypothalamus. Almost all animal experiments have been conducted in young, healthy individuals, and there is a general lack of studies in animals with comorbidities. Therefore, in our studies, we have used 1) spontaneously hypertensive rats (SHR), a recognized model of human essential hypertension and insulin resistance, and 2) normotensive Wistar rats exposed to high fructose (10%) in drinking water simulating excessive consumption of sweetened beverages. This experimental approach can address the questions whether hypertension and metabolic load modify the health consequences of ALAN and whether hypertensive and obese patients might be more susceptible to chronodisruption.

In our experiments we investigated the effects of low-intensity ALAN (~2 lux during the night) on the control of the cardiovascular system and the underlying pathophysiological mechanisms. During the light phase, the rats were exposed to broad-spectrum white light of 150–200 lux and a colour temperature of 2900 K (Okuliarova et al., 2020 for more details). We have monitored circadian rhythms in blood pressure (BP), heart rate (HR), locomotor activity and basal temperature and indirectly assessed the sympathovagal balance by telemetry (Data Science, USA). This method allows an undisturbed long-term measurement and offers unique possibilities in circadian studies. To identify underlying mechanisms, we measured the expression of clock- and clock-controlled metabolic genes in the liver and heart, and plasma levels of several hormones. Daily rhythms of the gene expression were assessed by *in situ* hybridization in the brain and by real-time PCR in peripheral organs. Circulating hormones were measured by immunoassays.

Exposure to ALAN attenuates the daily rhythms in cardiovascular parameters in experimental animals (Sutovská et al., 2024) and humans (Obayashi et al., 2014), disrupting the central BP regulation. In SHR, we found that the effects of ALAN were more pronounced than in normotensive rats and resulted in a loss of light–dark variability in BP but not in HR. Moreover, ALAN exposure increased systolic BP and enhanced BP response to norepinephrine administration (Molcan et al., 2019). Thus, ALAN may increase cardiovascular risk in predisposed individuals. Because hypertension is often associated with diabetes and the incidence of both diseases is increasing in developed countries, we explored the metabolic consequences of ALAN in SHR rats. We found that circulating insulin concentrations were increased, and the expression of the insulin dependent *Glut4* in the heart was decreased, indicating that ALAN can worsen insulin resistance (Rumanova et al., 2019). Thus, chronodisruption can be considered as a potential risk factor for cardiometabolic diseases and should be further investigated in human studies.

Combined exposure of rats to ALAN and fructose abolished the day/night difference in *Per1* expression, while in ALAN rats, its daily variability was preserved, but the daytime expression was reduced. The data suggest that at the level of the central oscillator, both environmental factors attenuate the clockwork, generating circadian oscillations. Accordingly, we measured the plasma melatonin concentrations, which are directly controlled by the SCN and inhibited by light. ALAN reduced the high nighttime melatonin levels, in line with our previous studies (Molcan et al., 2019; Okuliarova et al., 2022). Surprisingly, the high fructose intake also suppressed nighttime melatonin concentrations, indicating that both factors can attenuate the central circadian control. Moreover, in addition to the decreased circulating melatonin after high fructose intake during the nighttime, there was the same trend in the daytime, suggesting that the suppressive effects of high fructose and ALAN are additive and mediated by different mechanisms (Zeman et al., 2025).

In conclusion, we have shown that SHR rats are more susceptible to ALAN than normotensive rats. Light at night disrupts the central clock and the hormonal axis controlled by the SCN. Co-exposure to fructose and ALAN abolished day/night differences in the core clock gene *Per1* and additively suppressed plasma melatonin concentrations, revealing the increased fructose intake as a new chronodisruptive factor that can be potentiated by ALAN. Our studies suggest that people with hypertension and diabetes may be more susceptible to light pollution, and new human studies are needed to verify this conclusion from animal studies.
The study was supported by the grants APVV-21-0223 and VEGA 1/0309/23.

References

Chew NWS, Ng CH, Tan DJH, Kong G, Lin C, Chin YH, et al (2023) The global burden of metabolic disease: Data from 2000 to 2019. Cell Metab 35, 414-428.

Molcan L, Sutovska H, Okuliarova M, Senko T, Krskova L, Zeman M (2019) Dim light at night attenuates circadian rhythms in the cardiovascular system and suppresses melatonin in rats. Life Sci 231, 116568.

Obayashi K, Saeki K, Iwamoto J, Ikada Y, Kurumatani N (2014) Association between light exposure at night and nighttime blood pressure in the elderly independent of nocturnal urinary melatonin excretion. Chronobiol Int 2014;31:779–86.

Okuliarova M, Dzirbikova Z, Rumanova VS, Foppen E, Kalsbeek A, Zeman M (2022) Disrupted circadian control of hormonal rhythms and anticipatory thirst by dim light at night. Neuroendocr 112:1116–1128.

Okuliarova M, Rumanova VS, Stebelova K, Zeman M (2020) Dim light at night disturbs molecular pathways of lipid metabolism. Int J Mol Sci, 21(18) 6919.

Rumanova VS, Okuliarova M, Molcan L, Sutovska H, Zeman M (2019) Consequences of low-intensity light at night on cardiovascular and metabolic parameters in spontaneously hypertensive rats.

Can J Physiol Pharm 97, 863-871.

Mauer Sutovska H, Molcan L, Obermajer V, Zeman M. (2024) Artificial light at night affects the daily profile of pulse pressure and protein expression in the thoracic aorta of rats. Hypert Res 47:1897–1907.

Zeman M, Stefanik P, Rumanova VS, Okuliarova M. Interactive effects of light at night and high fructose intake on the central circadian clock and endocrine outputs in rats. Cell Mol Endocr (2025) under review.