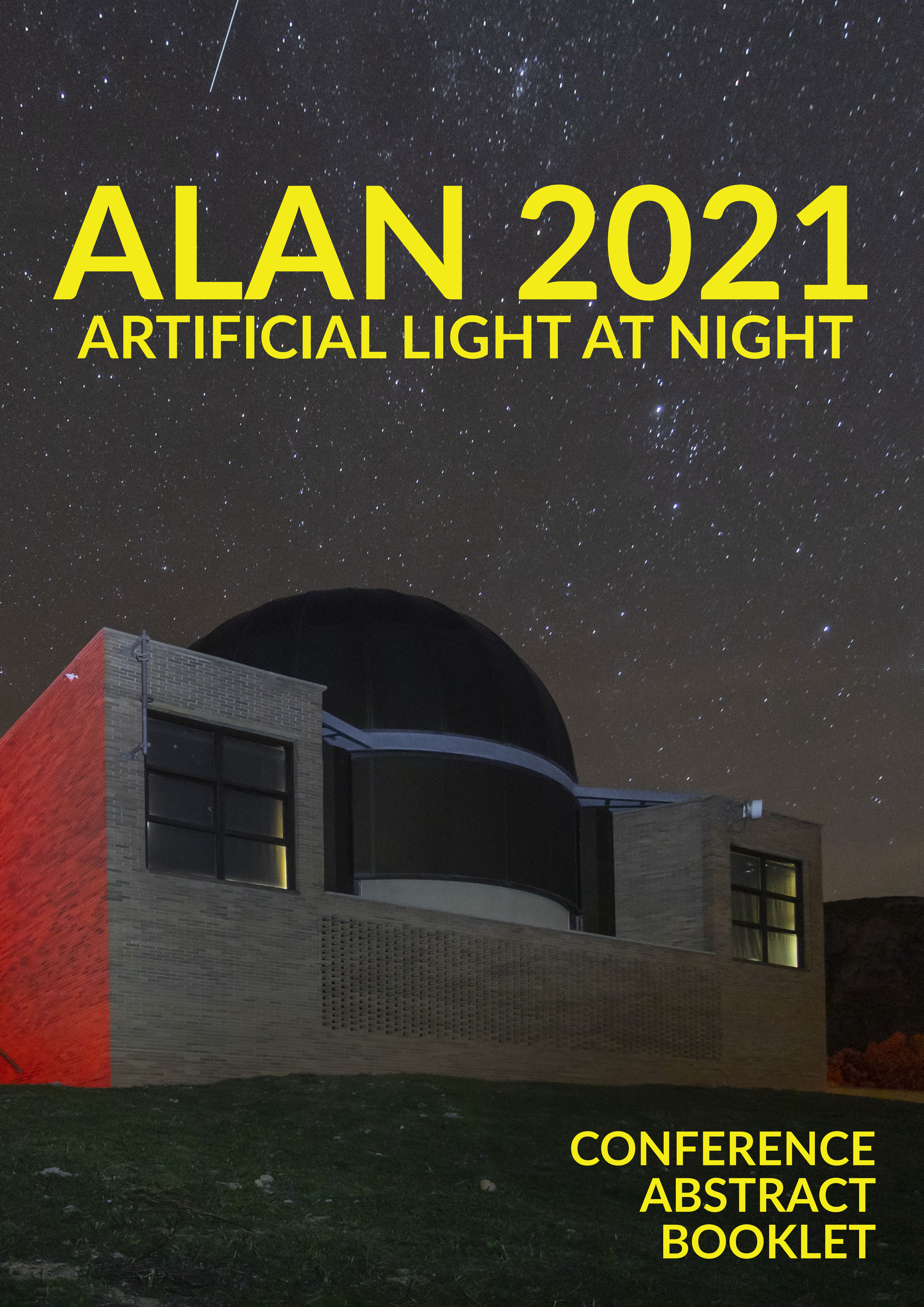
ALAN 2021
ARTIFICIAL LIGHT AT NIGHT



CONFERENCE
ABSTRACT
BOOKLET

Cover image: Eye of Montsec, the planetarium of Parc Astronomic del Montsec
Author: Ramon Vilalta / FGC

Booklet editor: Yiğit Öner Altıntaş, GFZ Potsdam

7th International Conference on Artificial Light At Night

Welcome to ALAN 2021!

#ALAN2021

Dear ALAN participants,

Together with all of you, we've experienced the year since the last ALAN conference as a period of reduced travel, as well as uncertainty as to what will be possible in the future, and when that future might arrive. When we decided to hold a mini e-conference in 2020 and began planning ALAN 2021, we still hoped that by the summer of 2021 it would again be possible to meet in person. This unfortunately turned out not the case.

We hope that the virtual environment that we have prepared will make it possible for everyone to participate in ALAN 2021, regardless of the time zone you live in. We do not expect anyone to be able to connect to the entire live program; please join in at a time that is convenient to you, and watch the recorded videos at your own pace or as part of a watch party.

As this is our first experience hosting a conference in such an environment, there are sure to be some issues. Please do not hesitate to contact the VirtualMeet representative at the helpdesk for issues related to your own connection. Additionally, while we will do our best to prepare the session chairs and speakers, please bear with us if we experience any difficulties during the live sessions.

The hashtag for this year's conference is **#ALAN2021**. For posters, please do not share screenshots without the express permission of the poster presenter. Oral presenters should clearly state at the start of their talk if they do not wish for slides to be shared.

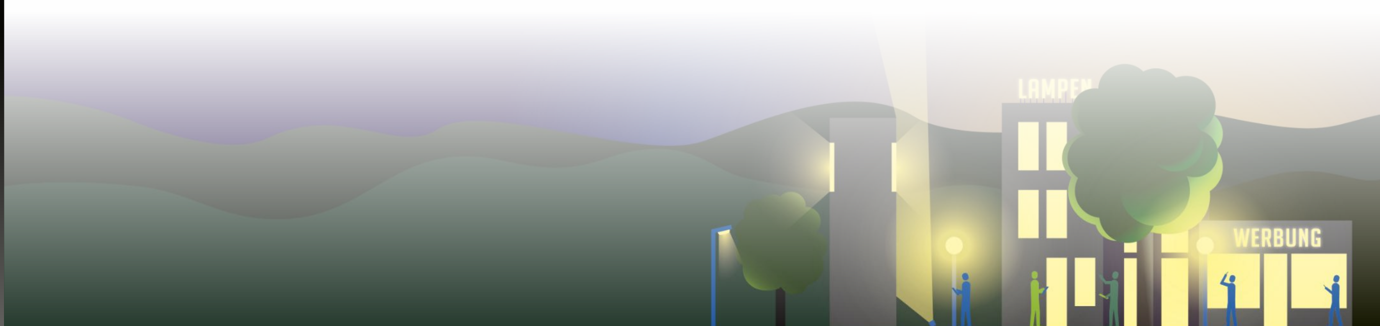
The future of ALAN depends on the continued participation of speakers and audience members. In case you are not already signed up for the conference mailing list, please therefore take a moment to sign up now, so that you will receive our call for papers for ALAN 2023: **http://tinyurl.com/alan-signup**.

The international steering committee is once again very thankful to Salvador Ribas, Fernando Jáuregui, and the rest of the organizational team from Lleida for their doubled work – both the initial planning of a live event in Lleida, and their contribution to this electronic conference. Hopefully, it will be possible to hold a live ALAN in Lleida sometime in the future.

Finally, thank you for deciding to attend this year's virtual ALAN conference!

Sincerely,

Christopher Kyba
Chair of ALAN steering committee



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Online ALAN Sources

Community

ALAN Conference	http://artificiallightatnight.org/
LPTMM Conference	http://lptmm.org/
Consortium for Dark Sky Studies	http://darkskystudies.org/
International Dark Sky Association	http://darksky.org/
LPResearch mailing list	https://groups.io/g/LPResearch
ALAN Research database	https://www.zotero.org/groups/alan_db

Data

VIIRS DNB data online visualization	https://lighttrends.lightpollutionmap.info/
VIIRS DNB data download	https://eogdata.mines.edu/products/vnl/
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World Atlas of sky brightness floating point data	http://doi.org/10.5880/GFZ.1.4.2016.001
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Reasons for the failure of light pollution prevention legislation in Slovenia

Theme: Technology & Design

Aleš Šubic

Initiative for Regulation of Outdoor Lighting, Poljane/Škofja Loka, Slovenia
ales.subic@gmail.com

Introduction

Based on extensive knowledge of light pollution, gathered over past decades, an increasing number of countries are adopting light pollution prevention legislations. In 2007, Slovenia was one of the first countries to adopt such legislation with the *Regulation on limit values of light pollution*. As such, Slovenian experience is ideal for studying the effectiveness of the taken measures and of remaining factors, preventing fully resolving the problem.

Fig. 1: Illumination of a regional road exit and a school turnaround in Slovenian countryside (photo: A. Šubic)

Undisputed progress has been made with the Regulation in many respects. Different sources of light pollution are covered and the country is largely respecting the Regulation requirements. Following the requirement to harmonize the lighting with the Regulation by 2017, today more or less all street lighting meets the ULOR = 0 condition and some other most problematic issues have been mostly resolved. Following the technology advances, LED lighting is largely introduced, thus making it easier to meet the Regulation limitation of power consumption.

Despite all the progress, the country is facing an unprecedented spread of light pollution, as the road and street lighting are intensively spreading to new locations. The Regulation sought to limit the total amount of public lighting with a limit of power consumption of 44,5 kWh/capita/year, but with technology shift to LED the effect of this limit has completely failed. Furthermore, the analysis of cases over the country shows that technical measures and quantitative limits are not sufficient to provide ecologically and spatially appropriate lighting. In the lack of comprehensive eco-spatial policies, the lighting is almost completely subject to the technical decisions of the state road authorities, reckless civilizational pressure on the municipality level and international lighting standards, strongly influencing both previously listed factors.

Challenges of light pollution prevention in Slovenia

The Regulation, which was adopted in Slovenia in 2007, is mainly respected, with only minor deviations in particular cases. The recommendations of the lighting profession are followed as well, especially strictly in lighting state roads. While most other major sources of light pollution are well managed, road lighting is a serious problem. It is expanding intensively to new locations, both on state roads and in settlements of all types, with European infrastructure funds playing a significant role in its pace. As far as road lighting is concerned, the only limits are ULOR = 0 and the limit of annual consumption per capita. It is obvious that additional measures need to be taken to manage the problem.

The necessary additional measures can be roughly divided into the following main sections:

- Limiting locations and amount of lighting
- Limiting the lighting intensity
- Switching off or dimming after curfew
- Environmentally friendly color temperature, reduction of intrusive light on windows
- Ensuring aesthetical acceptability (landscape, urban appearance)

While it will be relatively easy to achieve more appropriate CCT and turning off or dimming after curfew is also in the interest of lighting providers (this indirectly allows them to install more lighting), all other measures pose very difficult challenges:

- Extremely difficult-to-move approaches of state traffic infrastructure authorities, lighting standards and recommendations
- Civilizational expectations regardless of actual needs and cumulative effects
- Inability of state structures and urban planning expert circles to introduce comprehensive spatial planning policies

A further detailed review of individual factors shows that above all the aspect of comprehensive spatial planning is critically absent in the whole issue, both at the macro level of anticipation and limitation of cumulative effects, as well as at the micro level of ecologically, aesthetically and ethically acceptable placement of individual lighting projects. In these conditions, the technical lighting parameters and the unrestrained and reckless civilizational pressure to illuminate (at least) all populated areas, prevail almost entirely. It seems that it would be necessary to limit lighting locations much more decisively, not only by restricting lighting outside settlements, but also by theoretically justified avoidance of lighting particular types of settlements or their parts when the needs do not reach a certain threshold.

The influence of international standards (e.g. EN 13201) and, in the event of their inadequacy, their potentially extremely problematic and extensive negative effects should be emphasized. As these are expert recommendations, they are very difficult to challenge, therefore both residents and local authorities are usually practically completely powerless even in cases where it is obvious that unacceptable environmental and spatial effects are caused.

Conclusions

The Slovenian example shows that significant progress can be made with measures to limit light pollution. However, the achievements can quickly be nullified, if the spread of lighting to new locations is not effectively limited. This can partly be done by setting appropriate quantitative cumulative limits, but it's evident that for a complete solution to the problem also qualitative spatial planning approaches are needed. In addition, an ethical shift needs to be made in attitude to the lighting. It should be seen as a pollutant that should only be used in case of undisputed needs.

The corresponding measures have to be defined in both the environmental and the spatial planning legislation. In addition, the very concrete technical starting points need to be revised. The later mainly derive from internationally agreed standards, therefore it's very important that these standards are made unquestionably environmentally and spatially acceptable.

Local mapping of sky quality in existing and potential dark sky places

Theme: Measurement & Modelling

Alexandra Pusztai-Eredics,[1,*] Andrea Pozsgai,[1] Flóra Siska,[1] Dénes Száz,[1] Kornél Kolláth,[1,2] József Vanyó[3] and Zoltán Kolláth[3]

[1] *Eötvös Loránd University, BDPK, Department of Physics, Szombathely, Hungary*
[2] *Hungarian Meteorological Service, Budapest, Hungary*
[3] Eszterházy Károly University, Department of Physics, Eger, Hungary

zkollath@gmail.com
[*] *presenting author*

A major criterium for establishing an international dark sky place is the objective determination of night sky quality. Since multiple measurements are necessary to establish a firm foundation of the qualification, massive observational datasets exist at each location. However, the measurements are heterogeneous due to the varying atmospheric conditions. We developed a mapping technique based on ground-based and satellite observations and radiation transfer modelling to minimize sky quality determination uncertainties.

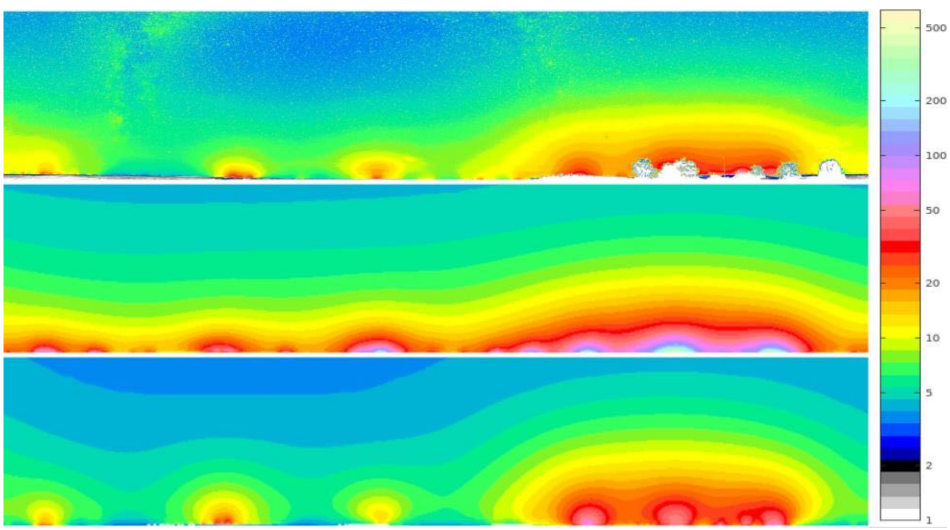

Fig. 1: False-colour sky brightness map taken in the Hortobágy Starry Sky Park (top) and a two models of the sky radiance with AOD=0.05 (center) and AOD=0.3 (bottom). The radiance is given in nW/m2/sr/nm (dsu).

Our method includes the following steps:

- Monte Carlo radiation transfer method is used to estimate artificial sky radiance based on satellite data.
- The light output of the cities is corrected by the actual spectra of the light domes to eliminate the mismatch due to the spectral response of satellite measurements.
- An additional correction is made for the light output by fitting the observations. It also provides the possibility to estimate the aerosol optical depth at the time of measurements.

The models fitted to the observations taken at different times and locations makes it possible to provide a high-quality light pollution map of a given protected area or other territories.

Simple methods to calibrate a digital camera

Theme: Measurement & Modeling

Alexandre Simoneau[1*], and Martin Aubé[1,2]

[1] *Université de Sherbrooke, Sherbrooke, Canada*
[2] *Cégep de Sherbrooke, Sherbrooke, Canada*
alexandre.simoneau@usherbrooke.ca
[*] *presenting author*

The use of digital cameras for scientific purposes has been widespread in astronomy since its introduction. However, in order to obtain useful data from these sensors, they must be thoroughly calibrated. In more recent years, digital cameras have become omnipresent with digital single-lens reflex (DSLR) and smartphone cameras, but the calibration methods remain out of reach for most users, particularly for those that are not initiated to the calibration of imaging sensors. Moreover, the usual methods tend to be harder to implement for multispectral or large field of view (FOV) systems such as fisheye lens.

In the present work, we propose a set of calibration procedures that are simple to use with the intent to allow an easier access to scientific image analysis. The proposed methods include a calibration of the angular deformation of images using a picture of a star field and the evaluation of the non-linear radiometric response and the absolute calibration of the spectral bands sensitivities using photography of a star of known out of atmosphere absolute spectral emission combined with an atmospheric extinction model. Moreover, we propose a way to produce a flat field for large FOV systems using a photography shooting tent with a robotized mount. The lit surface of the tent is photographed from multiple camera orientation and the obtained photographs are selectively averaged to only keep the part that images the surface, effectively looking at the same surface for the whole sensor. Moreover, the averaging of images taken from multiple orientations statistically reduces the variance of the observed luminance of the surface. This method, although more complex than the use of an integrated sphere, is at a much lower barrier to entry considering the fact that professional integrating spheres typically cost thousands of dollars while shooting tents can be found for roughly a hundred dollars.

Figure 1. DSLR camera used to test the calibrating method. Sony a7s equipped with a Samyang T1.5 50mm lens. Photo credit: Alexandre Simoneau

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Point Spread Functions for mapping artificial night sky luminance over large territories

Theme: Measurement & Modeling

A. Simoneau[2], M. Aubé[1,2,3], J. Leblanc[1*], R. Boucher[4], J. Roby[1] and F. Lacharité[1]

[1] *Cégep de Sherbrooke, 475 rue du Cégep, Sherbrooke, Québec, Canada, J1E 4K1*
[2] *Université de Sherbrooke, 2500 boulevard de l'Université, Sherbrooke, Québec, Canada, J1K 2R1*
[3] *Bishop's University, 2600 College St., Sherbrooke, Québec, Canada, J1M 1Z7*
[4] *Parc national du Mont-Mégantic, 189 route du parc, Notre-Dame-des-Bois, Québec, Canada, J0B 2E0*
alsimoneau@gmail.com
* *presenting author*

Both astronomical observations and the study of nocturnal ecosystems require knowledge and understanding of night sky radiance. Measuring this radiance can prove to be a complex endeavor depending on the desired spectral, spatial and temporal resolutions. One solution to this problem is to model the night sky radiance computationally. However, the modeling of artificial night sky radiance for a large array of points over any given territory can represent a significant amount of computing time depending on the complexity of the model used. It has been suggested that such computations be performed using the convolution of a point spread function with a map of the light sources present on the studied territory. The main focus of our work is to determine how the Point Spread Function is sensitive to variations of the main parameters of artificial night sky radiance using the light pollution model Illumina v2. Studied parameters are the light source's wavelength, the ground reflectance, the Upward Light Output Ratio, the Aerosol Optical Depth and the obstacles properties. We then used the obtained functions to model the artificial night sky radiance over the territory of the Mont-Mégantic International Dark Sky Reserve, which was then compared to in-situ measurements as well as to the New world atlas of artificial night sky brightness and to the Illumina model in order to evaluate the effectiveness of the convolution method. We found that, compared to those in-situ measurements, the atlas overestimates the artificial sky brightness by 55% whereas the model underestimates it by 48%. This may be explained by the presence of snow for some of the atlas monthly data and the fact that the Illumina model only accounts for public light sources. Differences in atmospheric conditions and the spectral and ULOR properties of lights sources in the Dark Sky Reserve also probably play a role in these discrepancies.

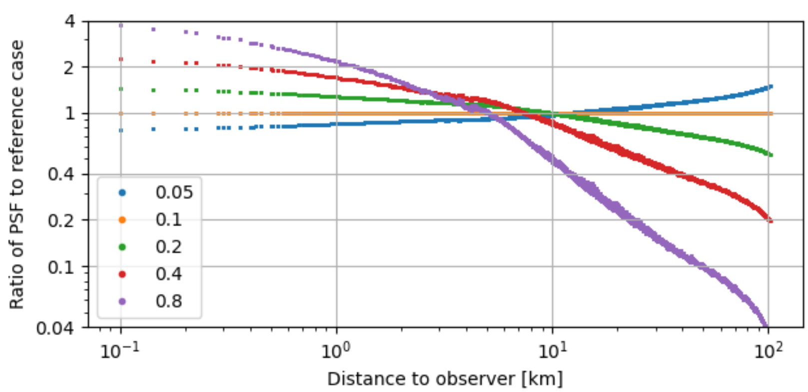

Fig. 1: Simulated point spread functions relative to a reference case for varying optical depths in summer conditions

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Procedure to estimate lighting at mesopic/scopic levels in epidemiological studies

Theme: Measurement & Modeling

A. Pereira,[1] J. Escofet,[2,*] and M. Tàpias[2]

[1] *Facultat d'Òptica i Optometria (Universitat Politècnica de Catalunya), Terrassa, Spain*
[2] *Departament d'Òptica i Optometria (Universitat Politècnica de Catalunya), Terrassa, Spain*
jaume.escofet@upc.edu
[*] *presenting author*

Introduction

It is well known that exposure to artificial light at night (ALAN) may cause negative health effects, such as breast cancer, circadian phase disruption and sleep disorders. It is a topic of interest in epidemiological studies to investigate the health effects of the low residual light that remains in a bedroom when it is dark and can interact with people suffering from lagophthalmia and even can overstep the eyelids. This residual light can be due to exterior light that seeps through windows and doors, small clock screens, indicator lights, etc ...

In more epidemiological studies[1], multi-channel wristband devices attached to patients allow continuously record, among other measures, the rhythms of body temperature, activity, body position and exposure to light. This light sensors have an absolute threshold at 0.01 lux so that, they are unable to measure the lower levels in a dark bedroom at night. While it is true that there are devices in the market that measure low light levels with a resolution of μlux they are excessively expensive. Nowadays this low light level is qualitatively estimated through questions as "How many fingers do you see?" or "Can you detect the hand movement?" being the uncertainty of the estimation very high.

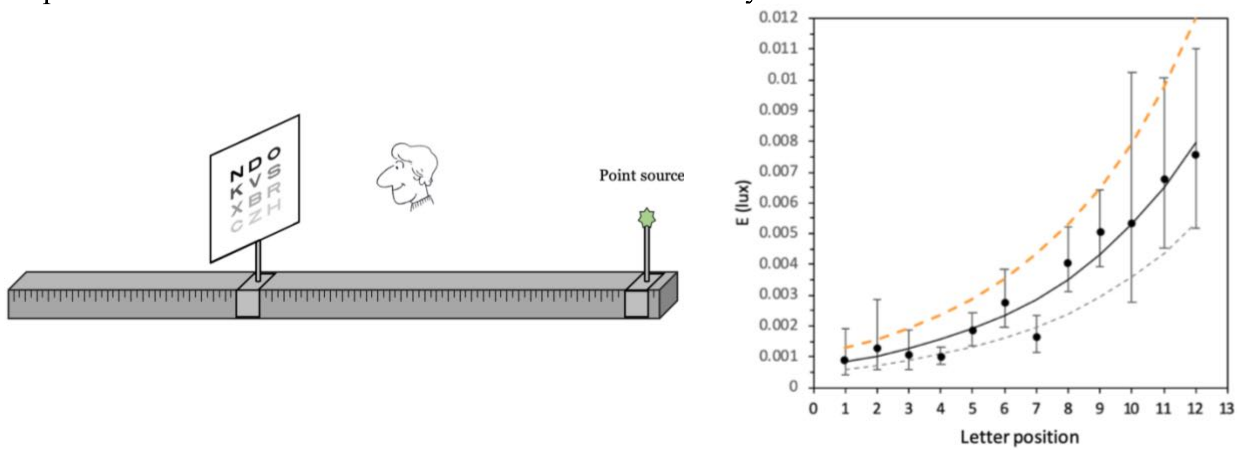
In this work we present a subjective procedure for estimating low level light values comprised between 10^{-2} lx and 10^{-3} lx. The method is based on visual detection of the minimum contrast letter, in a letter contrast sensitivity chart, for different levels of light.

Methods

A green LED point source with a very faint light emission has been placed at the extreme of an optical bench and a GOSSEN MAVOLUX 5032C USB lucimeter has measured the illumination at seven different distances from the source. A linear fitted expression, based on inverse square law, has been obtained from the logarithmically transformed variables. This expression allows us to derive, by extrapolation, the illumination level at further distances, where the light levels are below of the lucimeter absolute threshold of 0.01 lux.

A letter contrast sensitivity chart, with twelve Sloan letters of 42 mm size in decreasing values of modulation, displayed in 4 rows and 3 columns, has been printed in a DIN A-4 white card stock sheet. The contrast of the letters decreased in a geometrical progression with common ratio √2 from the maximum contrast (0,913) in the letter 1 to the minimum (0,020) in the letter 12.

Figure 1(a) shows the experimental setting. The green LED point source has been placed at the right end of an optical bench. The first distance from the source to be tested was the one in which the illumination level was barely 0.01 lux. The four following distances were chosen to have half of illumination level than the previous one. The distance between the chart and the observer was about 40 cm. The light levels analyzed varies from low mesopic to high scotopic and range measurement is from 0,01 lx to 0,001 lx. Therefore, eccentric fixation was needed to guess the letters as the distance increased, due to so dimming light. To avoid letter memorization, seven different copies of the chart were printed so as for the observers have a new chart at every tested distance.



(a) (b)

Figure 1. (a) Experimental setting, (b) Results obtained.

A group of thirty visually healthy people (9 men and 21 women) aged between 18 and 50 has been recruited in order to relate the position of the letter with minimum contrast discerned and the light level (lx) in the place.

Results

Figure 1(b) displays results obtained with its corresponding uncertainty ranges. The letter with highest contrast (letter 1) may be discerned at approximately 0,001 lx while observers needs a mean illumination of 0,007 to discern the letter with lowest contrast (letter 12). As expected, the uncertainty increases as the position of the letters increases, that is, as the contrast of the letters decreases.

The high variability in the results obtained recommends to assign a range of illumination to each value instead of a single value.

Results obtained are redundant because uncertainty ranges overlap between them but overlapping aids to obtain more precision in this type of measurements.

Conclusions

A subjective method to measure low light levels has been presented. It allows estimating light measurements that ranges between 10^{-2} lx and 10^{-3} lx.

This method is not expensive and with a little training it can be applied to estimate low light levels in dark rooms.

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Cosmic Connections: An Intuitive Inquiry into the Sociocultural Experiences of Engaging with Outer Space in Scotland

Theme: Society

Allison R. Wilkerson,[1]

[1] *University of Edinburgh, Edinburgh, United Kingdom*
allison.r.wilkerson@gmail.com

At the international level, efforts to address the long-term sustainability of outer space activities (LTSOSA) are scientific and technical in nature (Martinez, 2018). These efforts centre the perspectives of space-faring entities, often failing to incorporate perspectives of relevant ground-based actors (Martinez, 2018; UN, 2018), such as concerns of space-based light pollution from satellite mega-constellations (McDowell, 2020). This study sought to counter the technical literature through exploring sociocultural perspectives on dark skies and outer space sustainability in the Scottish context. At a national level, Scotland is a unique and advantageous place to engage with dark-sky studies, home to some of the most expansive dark sky stretches in Europe (Dark Sky Parks, 2020). Additionally, Scotland's space industry is rapidly growing (Scotland's Space Sector, 2020), which offers unique opportunities to build sustainability into the heart of Scottish space culture.

Utilizing the intuitive inquiry research method (Anderson, 2019), I interviewed 12 individuals across four interest groups in Scotland – art, astronomy, environment, and space – regarding their individual experiences of engagement with outer space and the night sky and the factors that shape those engagements. This research method facilitated the integration of experiences across a diverse range of fields and allowed me to incorporate significant personal experiences and perspectives. Each participant completed a pre-interview creative exercise, and the semi-structured interviews included discussions on the submitted creative expressions, outer space sustainability, experiences of outer space and the night sky, light pollution, and potential loss of free and unimpeded access to space from Earth's surface.

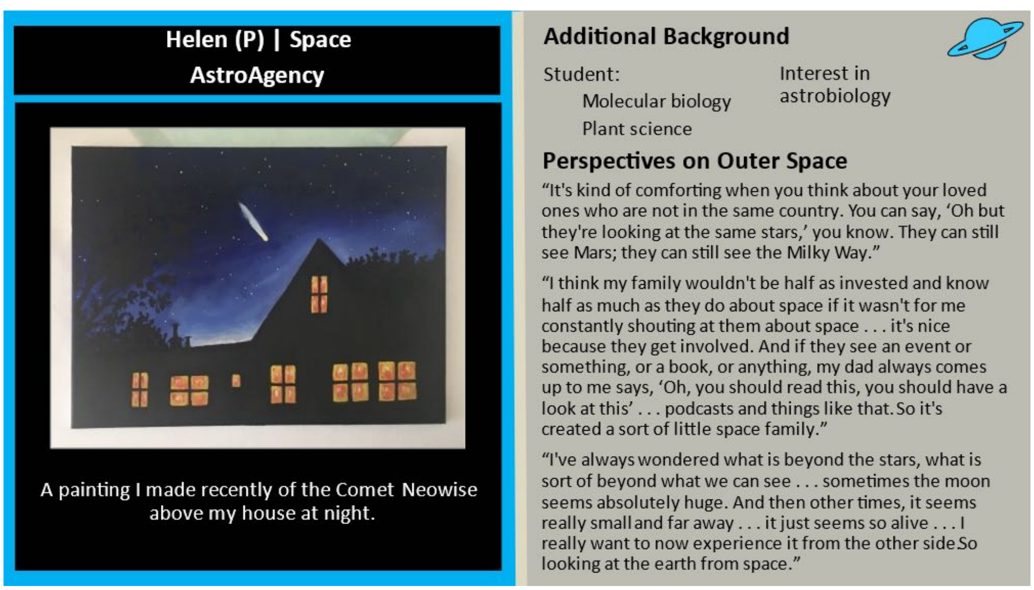

Figure 1: Inspired by one of the intuitive inquiry meditative cycles (Anderson, 2019), I presented participant information in the form of trading cards, similar to baseball cards in United States popular culture. (P) indicates the use of a pseudonym.

The results (Figure 1) reveal that within Scotland, engagement with outer space can be conceptualized as a complex, cyclical process comprised of three phases: perception, access, and benefit (Figure 2). Perception and access are primarily influenced by seven categories: physical geography, culture, social determinants, interpersonal relationships, health and wellbeing, ethics, and time. The specified benefits spanned all three pillars of sustainability: environmental, economic, and social.

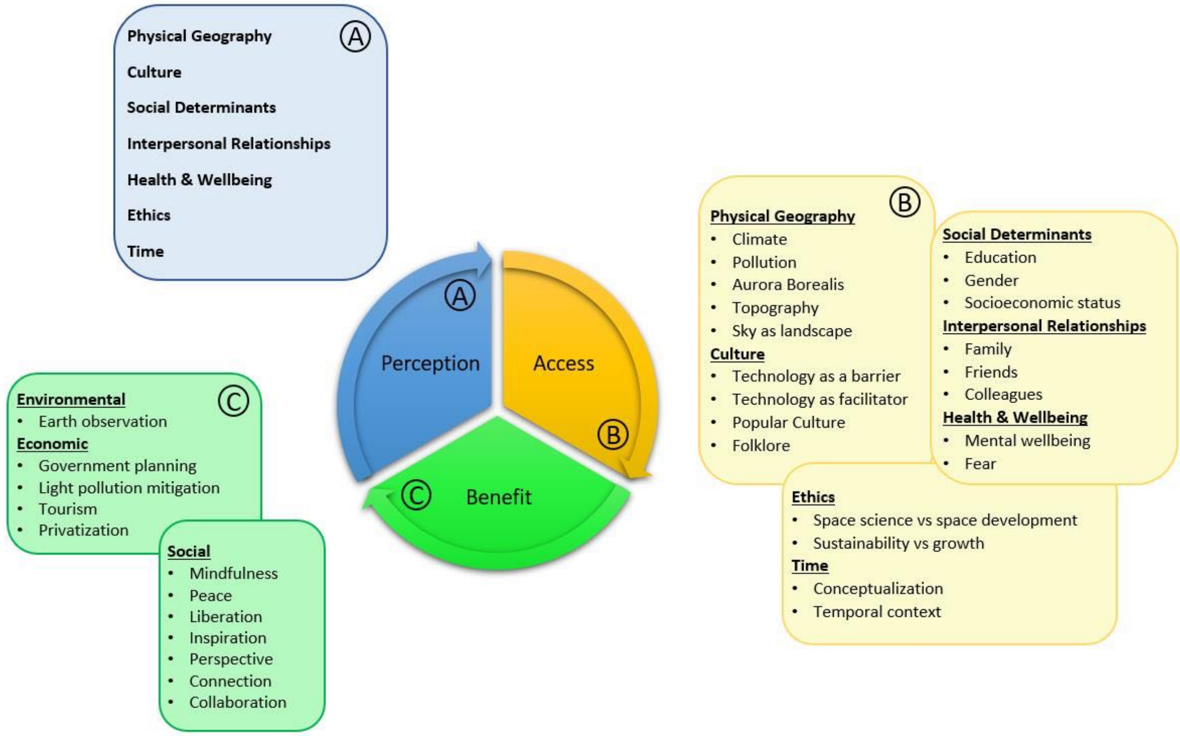

Figure 2: Process of Engagement with Outer Space in Scotland

This study identified entry points for a more comprehensive analysis of access to outer space as a natural resource in the Scottish context. It also revealed areas to consider when addressing diverse audiences regarding space exploration, development, and exploitation. With additional bodies of evidence, these perspectives could be refined and potentially utilized to support strategic interdisciplinary collaboration within the space industry in support of a non-imperialistic approach to the long-term sustainability of outer space activities.

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Mapping the Melatonin Suppression Index in Sherbrooke (Canada) with the LANcube

Theme: Measurement & Modeling

A. Farkouh,[1,*] A. Dufour,[1] M. Aubé,[1,2] C. Marseille,[2] A. Simoneau,[2] and J. Roby[1]

[1] Cégep de Sherbrooke, Sherbrooke, Canada
[2] Université de Sherbrooke, Sherbrooke, Canada
martin.aube@cegepsherbrooke.qc.ca
[*] presenting author

Increased exposure to artificial light at night (ALAN) causes circadian disturbances among living organisms. This disruption increases the risk of hormone-dependent cancers in addition to multiple other negative impacts on flora and fauna. These impacts are frequently linked to the colour of light or more precisely to its spectral content. Most current ways to map light pollution are based on spaceborne images, which are often panchromatic and therefore insensitive to colour. We have developed a method that allows the creation of light pollution maps of a city.

Fig. 1: A LAN3, a multispectral and multiangular nightlight sensor

The maps are created using multispectral irradiance data captured by the LANcube (LAN3), a new device intended to sample the multispectral and multidirectional properties of the direct artificial light at night into the urban or natural environment (indoor or outdoor), shown in Figure 1. The device separates the light detected to its three principal colour components: red, green, and blue (R,G,B) and provides this information for six faces of a cube. The LANcube can be installed on top of a vehicle to measure artificial light while moving through a city.

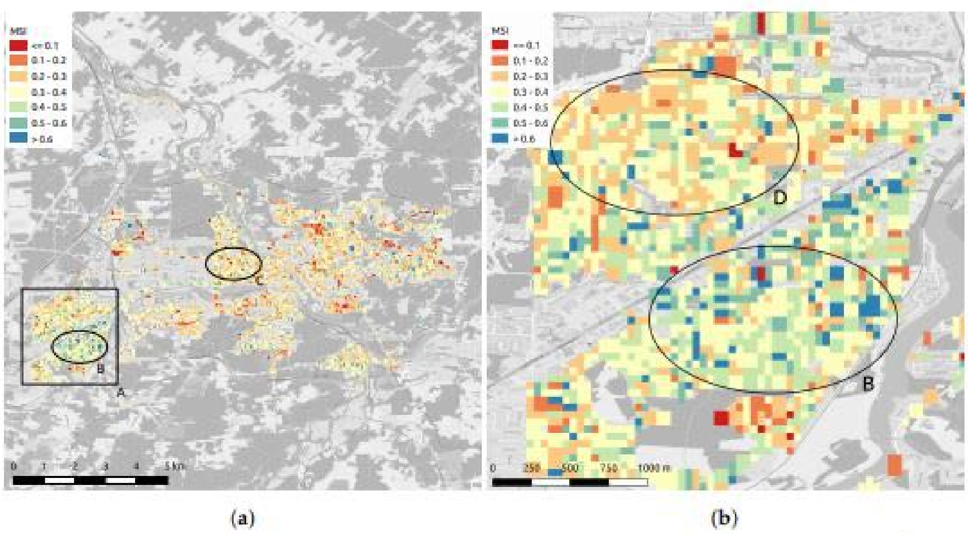

Fig. 2: Map of the MSI for Sherbrooke, Canada. The panel (b) shows a zoomed view of MSI for the Mi-Vallon sector of Sherbrooke, Canada (zone A in panel (a)). Zones B–D are outlining three residential zones of Sherbrooke. In the maps, blue colour is associated with the higher MSI values.

It is possible to calculate the Melatonin Suppression Index (MSI) using the multispectral information obtained with the device. In this presentation, we show how we can map this index for a whole city in a few hours using the data recorded by a LANcube installed on a vehicle. We present such a map for the city of Sherbrooke (Canada) in Figure 2.

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Effect of Artificial light at night (ALAN) on brain plasticity, melatonin, and behavior in birds: An interim summary

Theme: Biology & Ecology

Anat Barnea[1,*]

[1] The Open University of Israel, Raanana, Israel
anatba@openu.ac.il
[*] presenting author

Artificial light at night (ALAN), which disrupts the daily cycle of light/dark, has vast biological impacts on all organisms, and is also associated with several health problems. The few existing studies on neuronal plasticity and cognitive functions in mammals indicate that disruption of the circadian cycle suppresses neurogenesis and impairs learning and memory. However, relatively little is known regarding the effects of ALAN on brain plasticity in birds. In the last few years our lab has studied this question, by using zebra finches (*Taeniopygia guttata*) as a model (Fig. 1). In this talk I present the data we obtained so far, and describe in a broader view the effect of ALAN on brain plasticity, melatonin, and behavior.

Fig. 1: zebra finches (*Taeniopygia guttata*); a female on the left, a male on the right. (Photo: Keren Levy).

We first exposed our birds to ecologically relevant ALAN intensities (0.5, 1.5 and 5 lx) for 3 weeks to quantify cell proliferation in their brains, compared to controls that were kept under dark nights. We found that ALAN significantly increased cell proliferation in the ventricular zone (VZ) in a dose-dependent manner. After their birth in the VZ, these cells migrate to various brain regions, differentiate into neurons, and are being recruited into neuronal circuits in their target destinations. However, we found that despite the increase in cell proliferation that we observed in the VZ, there was a decrease in total neuronal densities at the target brain regions. We suggested two alternative explanations for these observations: 1) The decrease in neuronal densities in the target regions might indicate that many of the new neurons that were born in the VZ did not survive the migration to these regions under ALAN conditions. 2) ALAN causes a significant reduction in existing neurons, so that even the increased proliferation and probable consequent increased influx of new neurons do not compensate for the loss due to neuronal death. However, it could also be that our 3-week manipulation was too short to permit such compensation.

Although that study was the first to report that ALAN affects neuronal plasticity in birds, and added to the growing body of compelling evidence that ALAN alters basic biological processes, it could not distinguish between the above possibilities. Therefore, in a recent experiment we exposed birds to a longer exposure to ALAN (6 weeks), and recorded the recruitment of new neurons into their target regions in the brain. We found that ALAN increased neuronal recruitment in three brain regions that differ in their function: the medial striatum (MSt; part of the avian somatomotor basal ganglia and linked to visual perception and associative learning), the nidopallium caudale (NC; involved in vocal communication and in the integration of auditory information), and the hippocampus (HC; involved in the processing of spatial information and stress response). In addition, in the MSt, the increase under ALAN relative to control was higher compared with the other two regions, indicating a possible differential effect of ALAN on neuronal recruitment in different brain regions.

Analysis of medial and lateral sub-regions of the MSt separately revealed that ALAN increased neuronal recruitment in both, but it was more evident in lMSt than in mMSt. This differential increase suggests that mMSt is more resilient to ALAN than lMSt, which might be related to the functions of these sub-regions: The mMSt receives dopaminergic inputs from the ventral tegmental region that is responsible for homeostatic and reflexive pathways, whereas the lMSt receives dopaminergic inputs from the substantia nigra pars compacta and pallial input from regions involved in somatosensory, visual, auditory, and motor function. Therefore, we suggested that the modifications in the lMSt are induced by changes in the birds' sleeping behavior, assuming that ALAN causes the birds to be more awake and active during the nights. And indeed, in a current behavioral study, we found that the birds increased their nocturnal locomotor activity under ALAN, compared to control birds that were kept in dark nights. In addition, birds under ALAN were observed to feed several times during the night. Moreover, nocturnal locomotion intensified with the duration of ALAN exposure (3 vs. 6 weeks), indicating a chronic effect.

ALAN also affected nocturnal melatonin levels, which were significantly lower compared to controls, indicating that very low ALAN intensities suppress melatonin not only in nocturnal, but also in diurnal species. Taken together, our findings add to the growing body of evidence that ALAN has deleterious effects of on the behavior and physiology of birds. We believe that our studies lay the ground for further investigation of possible effects of ALAN on brain plasticity, behavior, and melatonin.

Multispectral sky quality survey in the Hungarian national parks

Theme: Measurement & Modelling

Andrea Pozsgai,[1,*] Alexandra Pusztai-Eredics,[1] Flóra Siska,[1] Dénes Száz,[1] Kornél Kolláth[1,2] and Zoltán Kolláth[3]

[1] *Eötvös Loránd University, BDPK, Department of Physics, Szombathely, Hungary*
[2] *Hungarian Meteorological Service, Budapest, Hungary*
[3] *Eszterházy Károly University, Department of Physics, Eger, Hungary*

zkollath@gmail.com
[*] *presenting author*

We have started a night sky quality survey in the Hungarian national parks and at other locations planned for international dark sky park designation. We developed a spherical high-resolution and high-dynamic-range night sky radiance mapping method using a robotic panorama head and a calibrated digital camera. This method gives the complete information of the local light field, which can be used to estimate the impact on a possible observer or specific living creature. At some locations, we collect spectral data by a dedicated spectroradiometer, to perform a continuous calibration check of the cameras.

Our project's final goal is to develop a map that can be used to estimate the full multicolour "light-scape" at any location in the protected areas. In order to provide such an interactive map, the real measurements should be interpolated for any geographic coordinate inside dedicated ranges. The grid of measurements sufficient for such purpose depends on the topography and geomorphology. For our first demonstration, we selected national parks from the flat parts of Hungary.

The spatial interpolation of the data can be performed at different complexity models. In the simplest case, a functional fit to the observations and the geometrical distribution of the main sources provide enough information to obtain sufficient performance and precision. We also present tests, how radiative transfer modelling helps in interpolation.

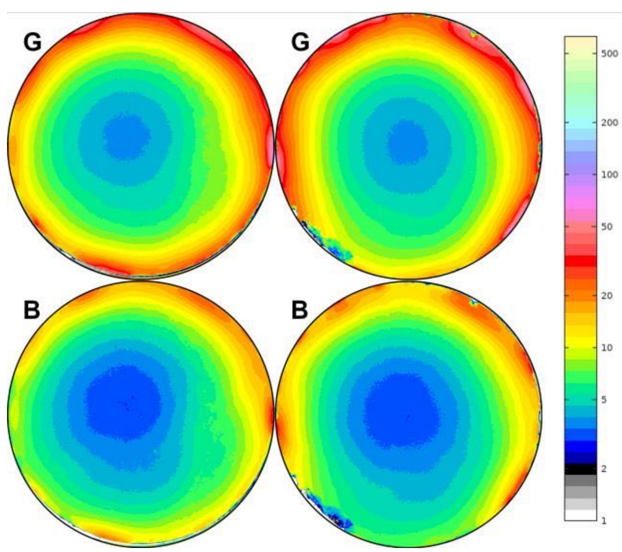

Fig. 1: Green (G) and blue (B) band-averaged radiance measurements in the Fertő-Hanság National Park, Hungary at two locations. The colour scale is given in nW/m2/sr/nm (dsu) units.

At some locations, we also measure the spectral distribution of the light domes. This additional database helps in the geometrical mapping of the multispectral data. During 2020, we also install permanent whole sky cameras in most of the national parks. They contain the same digital camera, so the uniformity of spectral sensitivity is guaranteed. It adds the possibility to correct the map for temporal changes.

Acknowledgements: The project is supported by the European Union and co-financed by the European Social Fund (Grant no. EFOP-3.6.2-16-2017-00014; Development of international research environment for light pollution studies).

The fraction and change of public lighting in Preussisch-Oldendorf, Germany

Theme: Society

Andreas Hänel[1,*] and Thomas Kunzemann[2]

[1] *Dark Sky Germany, Georgsmarienhütte, Germany*
[2] *Preussisch-Oldendorf, Germany*
Corresponding: ahaenel@uos.de
[*] *presenting author*

Introduction

The relation of public and non-public lighting in cities is not well known. By changing the known flux of public lighting in Tucson and measuring the change of VIIRS radiances Kyba et al, (2020) and the change on sky brightness Barentine et al. (2020) derived a percentage of public lighting of about 14%. Kuechly et al. (2012) derived from camera data taken during flights for Berlin a value of 33% and Hänel (2020) derived about 50 % for Fulda using sky brightness measurements when the flux of public lighting was reduced by a known amount.

Planned observations like in the desert climate of Southern Arizona are not possible under Central European weather conditions. Therefore data have to be taken as they are available or if there is good weather. We have taken sky brightness measurements in 2010 and 2020 in the central part of Preussisch-Oldendorf, where most of the public lighting is switched off during the late night.

Sky brightness measurements in Preussisch-Oldendorf in 2010

In 2010 1390 of 1622 lighting points were switched off from midnight 0:00 till 5:00. Most lighting was fluorescent and some sodium high pressure lamps. Measurements were taken with a handheld SQM-L and a DSLR with fisheye (Canon 1000 D + Sigma 4.5 mm/3.5) during the clear night April 17/18. The SQM-L measurements showed a decrease by 0.35 mag/arcsec². The DSLR measurements were evaluated only in 2020 as in 2010 we had not yet the software Sky Quality Camera (A. Mohar, Euromix). From the photos the zenith sky brightness was derived and a decrease by 0.46 mag/arcsec² was derived. Main structures are beams from ground recessed luminaires on the market.

Sky brightness measurements in 2020

In 2020 public lighting was switched off already at 23:00 to reduce power consumption although part of the lighting was changed to cut-off LED lighting with a cct of 4000 K. 10 years after the first, new measurements were taken in the night of April 22/23. The same instruments as in 2010 were used to exclude instrumental influences. In addition continuous measurements with a SQM-LU were taken at 10 second intervals. Sky brightness before switch-off was about the same as in 2010, but it decreased by only 0.25 mag/arcsec². This was due to the installation of a badly oriented ground recessed flood light of a nearby private house which shines into the sky. This light is switched off at midnight. As our measurements stopped before, further continuous measurements with a SQM-LU were taken during a period of clear skies in September. The switch-off of this flood light decreased the sky brightness by further 0.08 mag/arcsec². But after midnight the sky was typically about 0.1 mag/arcsec² brighter than 10 years before.

The fraction of public lighting and change during 10 years

Assuming that in 2010 and 2020 the same amount of light flux was reduced, for 2010 a fraction of 60 % and for 2020 of 40% can be attributed to public lighting. This means that non public lighting has increased by 50% during the 10 years. A small fraction of the public lighting is reduced due to the fact that part of the luminaires have been changed from typically 3% upward light ratio to 0%. Using the VIIRS radiance data from lighttrends.lightpollutionmap.info an increase of upward lighting from Preussisch-Oldendorf during the late night hours, when the satellite flies over Europe, by more of 50% is observed.

The fraction of public lighting in German cities is higher than in US American cities like Tucson, perhaps due to different definition and use of public light and to less advertising etc. But the example of Preussisch-Oldendorf shows that the amount of non-public lighting is increasing. This is due to the fact that municipalities can control public (especially street) lighting better than non-public lighting. Therefore it is important that effective regulations limiting the use of non-public lighting like façade illumination, advertising etc. will be implemented.

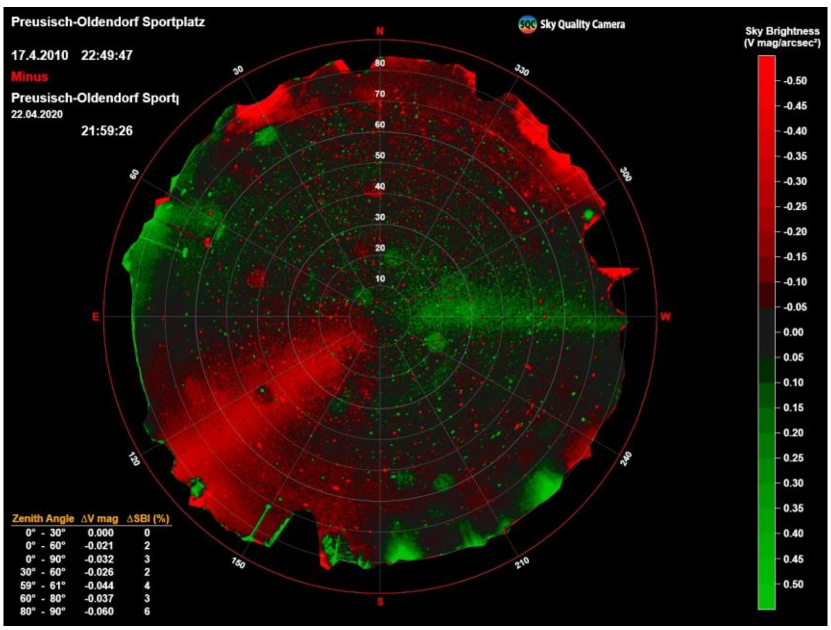

Fig.1: Difference allsky picture from Preussisch-Oldendorf between 2010 and 2020. Visible is the light beam from the market in red, that is switched off with the public lighting and the green beam from façade illumination of a private house which was visibkle only in 2020. (photo: A. Hänel)

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Artificial light at night disturbs zooplankton under lake ice, a case study at Lake Baikal, Russia

Theme: Biology & Ecology

Andreas Jechow,[1,*] Ilya A. Aslamov,[2] Konstantin M. Kucher,[2] Mikhail M. Makarov,[2] Joonatan Ala-Könni,[3] Georgiy Kirillin,[1] and Franz Hölker[1]

[1] Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
[2] Russian Academy of Sciences, Limnological Institute SB, Irkutsk, Russia
[3] University of Helsinki, Helsinki, Finland
andreas.jechow@gmx.de
** presenting author*

Artificial light at night (ALAN) can have diverse effects on the environment (Rich & Longcore 2006) with recent work including studies of night-time pollinators and ecosystem services (Knop et al. 2017) or melatonin suppression in vertebrates at low light levels (Grubisic et al. 2019). However, both freshwater ecosystems (Jechow & Hölker 2019a) as well as cold regions, such as the Arctics (Jechow & Hölker 2018, 2019b), have been notoriously understudied compared to terrestrial ecosystems and temperate regions. Furthermore, hardly any study on ecological effects of ALAN during winter exists (Jechow & Hölker 2018, 2019b).

Zooplankton is a key species in the aquatic food web, and it is well known, that it performs diel vertical migration (DVM) moving vertically depending on the light level. Typically, zooplankton will go to lower depths during the day and rise to shallower depths during night. Marine Arctic zooplankton performs this DVM even under the ice (Bové et al. 2002) and follows the lunar cycle during polar night (Last et al. 2016). ALAN can have an impact on zooplankton as shown by seminal work on the impact of skyglow on DVM in an urban lake at mid latitudes (Moore et al. 2000) or by ALAN of ships during polar night (Ludvigsen et al. 2018). Here we present the first investigation of the influence of ALAN on freshwater zooplankton under lake ice.

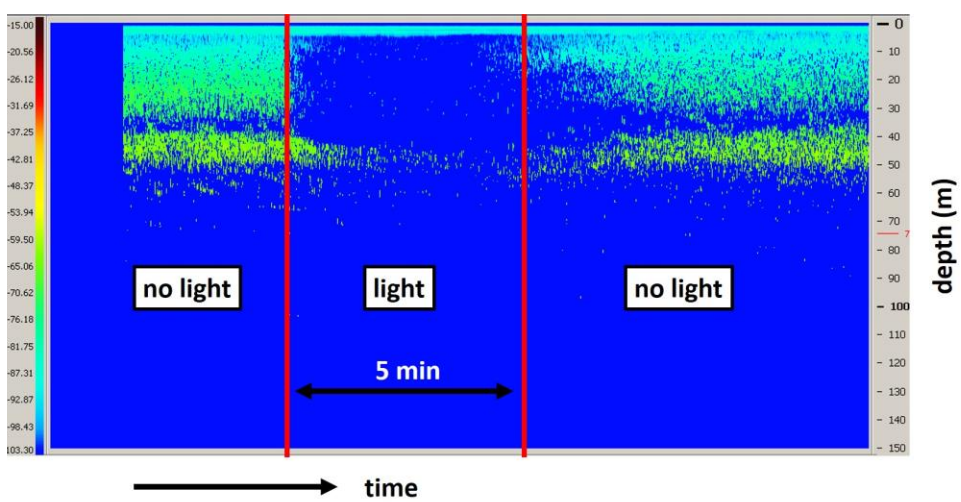

Fig. 1: Echogram obtained 4 km offshore with an FCV-1100 hydroacoustic system. The response of zooplankton under the ice is clearly visible.

The experiment was performed at night on frozen Lake Baikal at position 51.787026°N; 104.94284°E, about 4 km offshore on 29.03.2018 02:30 (local time). The lake ice was determined to be 84 cm thick. An LED floodlight (30W, CCT 4000 K, 2400 lm) was positioned above the ice facing downwards at Nadir and light was switched on for 5 minutes. Zooplankton activity was monitored before, during and after the illumination with ALAN with an upgraded FCV-1100 sonar (Furuno, Japan). The hydroacoustic system was set to 200 kHz, with a pulse repetition rate of 5 Hz, and pulse duration of 0.3 ms. The 3 dB beam width of the hydroacoustic transducer was 6°. More information on the method can be found in (Makarov et al. 2019).

The echogram (Fig. 1) shows zooplankton abundance before the light was switched on at depths between 0 and 50 m depth. Directly after the light was switched on, the zooplankton signal disappeared from the hydroacoustic beam for all depths with a slightly slower response at greater depth. After the light was switched off, the zooplankton returns to the hydroacoustic beam. Again, the response is faster at shallower depth and delayed at greater depths. We assume, that the zooplankton moves horizontally and not vertically, as observed with ship lights in ice-free marine systems during polar night (Ludvigsen et al. 2018).

In conclusion, we have shown that freshwater zooplankton in Lake Baikal shows an immediate response to ALAN even under the ice. A clear avoidance of ALAN was observed, suggesting a negative photo-taxis. Similar experiments were conducted at two lakes in Finland: Lake Kilpisjärvi (Arctic lake) and Lake Kuivajärvi, Hyytiäla, using the same ALAN setup, but acoustic doppler current profilers to track the zooplankton. To our knowledge this is the first demonstration that ALAN has an effect under lake ice.

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Recognition of light pollution problems, search for solutions in human ecological approach

Theme: Society

Anna Apró[1,*]

[1]Eszterhazy Karoly University, Institute of Geography and Environment, Leányka Street 6. Eger 3300, Hungary

apro.anna@uni-eszterhazy.hu

Introduction

For billions of years, life on Earth has existed in a rhythm of light and darkness, illuminated exclusively by the Sun, Moon, and stars. Now, with excessive use of artificial lights, cities also shine at night, disturbing the delicate balance of our natural day and night environment. Excessive use of artificial lights in the evening not only degrades the view of the starry sky, but also adversely affects our environment, safety, energy consumption and health. Less than 100 years ago, everyone could look up and see the spectacular night sky.

Urbanization processes have also greatly influenced the use of light sources. Skyscrapers, tall towers and office buildings have emerged thanks to the fast-growing economies of the developed countries. People, companies should use artificial light more consciously (Georges, 2020). Using fewer lamps reduces costs, consumes less electricity and reduces emissions. However, this requires a change in the mindset in which education can play a prominent role.

Methods

Adverse effects of light pollution include the upset of the balance between daylight and night light alternations over millions of years, the negative effects of which include:

1) disturbance of the ecosystem and wildlife,
2) damage to human health,
3) increasing energy consumption, and
4) disappearance of the starry sky (Kolláth, 2009).

Satellite images of the Earth at night also indicate the extent of the problem geographically, but it can also be seen that the lights are getting more intense as yellow, expensive bulbs are replaced by a larger number of cheap, bright white LEDs. For this reason, physics, geography and biology should be singled out among the science subjects in education, which have an important attitude-forming power in connection with the topic.

In physics, students already encounter elemental light pollution in our Environment and Physics unit. Here, students explore energy-saving opportunities in their households, schools, and places of residence. In the Optics and Astronomy chapter, the relationship between man and light comes to the front . Special emphasis is placed on the experiences of light that we use to protect our environment. Last but not least, they can get an answer to the question of what we call light pollution and what light pollution is like in our country.

In geography, in the name of cultural heritage, light pollution can be mentioned in connection with the systematization of cultural values, national parks and world heritage sites and values. In the case of global challenges, the topic may also appear in the exploration of the territorial characteristics of the urbanization process and the essence of energy management.

In biology, the negative effects of light pollution on disturbing night rest can be directly mentioned in the reading of the effect of pollution on the hormonal system. In the analysis of animal communication, they answer the question of the effect of light and pheromone traps on insects. The Hortobágy National Park plays a role in the discussion of national parks in the discussion of national parks, and as is well known, the star shop park present there reveals a part of our cultural heritage, the less disturbed view of the Milky Way from light pollution.

Conclusions

The ecological consequences of light pollution are documented in a wide range of case studies (Kevin et al 2013). The indirect way of the negative effects of light pollution affects virtually the entire ecosystem. Here, plants can be mentioned primarily as examples of non-pollination. Their direct effect on light is seen in populations of insects, bats, sea turtles and birds, flying to the light (Csörgits & Gyarmathy, 2006). The phenomenon of light pollution is one of the most perceptible, rather complex environmental problems of modern consumer society.

Therefore, this subject related to natural, economic and social sciences is an excellent example very complex problems. The aim of teaching global problems is to emphasize both the socio-economic effects, and the scientific aspects, related to their harmful effects on the living world. The teaching of regional knowledge is suitable for learning about the connections between the development of countries and the light pollution, including future solutions.

Acknowledgments

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The light pollution and the UN Sustainable Development Goals (2016-2030)

Theme: Society

Anna Apró[1,*], János Mika[1]

[1]*Eszterhazy Karoly University, Institute of Geography and Environment, Leányka Street 6. Eger 3300, Hungary*

apro.anna@uni-eszterhazy.hu, *mika.janos@uni-eszterhazy.hu*

Introduction

The term Sustainable Development was effectively distributed by the Bruntland Commission Report (1987) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Nowadays, the scope of the Sustainable Development is much wider than the initial concept of environmental sustainability. Society and economy are not only preconditions of ensuring environmental sustainability, but both economy and society add to the problems to solve. The General Assembly of the United Nations (UN) accepted the 2030 Agenda for Sustainable Development containing 17 Sustainable Development Goals (SDG, 2015) including 169 more detailed Targets. Among the 169 targets, 126 targets have measurable, numeric indicators to be reached by a specific year (mostly 2030). These targets are set into sequence as number.number. The remaining 43 Targets, denoted as number.letter, represent pre-conditions to improve the issue. These Goals spread over all natural, human and economic aspects of sustainability, but they are not ordered into any logical structure. The lack of structure makes the 17 Goals more difficult to colligate and to memorize.

Mika and Tóth (2017) have suggested a classification of the 17 Goals, as follows:

- Primary needs of humans (2. Food, 3. Health, 6. Water and 7. Energy)
- Equality between humans (1. No poverty, 4 Education, 5. Gender equality and 10. Reduced inequalities)
- Efficient, sustainable economy (8. Economic growth, 9. Innovative industry, 12. Responsible consumption and production, 13. Climate action)
- Landscapes in danger (11. Cities, 14. Life in water and 15. Life on land)
- Worldwide cooperation (16. Peace and justice and 17. Partnerships)

Methods

In the first step of our analysis we established that neither the expression *light pollution* (in any spelling) nor the *light* was contained by the text of the 169 Targets, whereas *pollution* was always related to chemical contaminants. In the next step 12 Targets were found to be related to light pollution, all represent the number.number type measurable requests. In the followings, these targets will be introduced according to the above classification of the Goals. The following Tables display the 6-6 original compilations with accentuations added by the authors.

In the first column of Table 1 relevant Targets belonging to the above specified classes of primary human needs, landscapes in danger and worldwide cooperation are listed. These three classes unify 9 Goals, but only 6 Targets from six Goals are found to be related. The second column indicates how the given Target is related to the light pollution or sometimes to the lack of that. In the first column of Table 2 six relevant Targets are listed that belong to 5 different Goals from the altogether 8 possible Goals in the classes of equality between humans and efficient, sustainable economy. The second column indicates relatedness of the given Target to light pollution.

Table 1. Targets related to light pollution that belong to the classes of primary human needs, landscapes in danger and worldwide cooperation.

Target	Relatedness
2.4. By 2030, ensure sustainable food production systems and implement resilient agricultural practices that **increase productivity and production**, …	Light pollution may hinder realization of this target.
3.9. By 2030, substantially **reduce the number of deaths and illnesses** from hazardous chemicals and air, water and soil pollution and contamination.	Light pollution may also cause illnesses.
7.1 By 2030, ensure universal **access to affordable, reliable and modern energy services.**	Consider physiologically advantageous light sources.
11.6 By 2030, **reduce the adverse per capita environmental impact of cities**, including by paying special attention to air quality and … other waste management	Light pollution is an adverse environmental impact, as well.
15.5 Take urgent and significant **action to reduce the degradation of natural habitats**, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.	Help to reduce degradation by physiologically advantageous light sources.
17.7 Promote the **development, transfer, dissemination and diffusion of environmentally sound technologies** to developing countries ….	Consider physiologically advantageous light sources, only.

Table 2. Targets related to light pollution that belong to the classes of equality between humans and efficient, sustainable economy.

Target	Relatedness
1.4. By 2030, ensure that all men and women, in particular the poor and the vulnerable, have **equal rights to economic resources**, …	Consider physiologically advantageous light sources.
4.7. By 2030, ensure that all learners **acquire the knowledge and skills needed to promote sustainable development**, …	Education of the light pollution issue belongs to here
9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and **environmentally sound technologies** and industrial processes...	Consider physiologically advantageous light sources, here
12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to **minimize their adverse impacts on human health and the environment..**	Light pollution also has adverse impact on human health and environment.
12.8 By 2030, ensure that people everywhere have the **relevant information and awareness for sustainable development** and lifestyles in harmony with nature.	Education of the light pollution issue belongs to here.
13.3 Improve **education**, awareness-raising and human and institutional capacity **on climate change mitigation**, adaptation, impact reduction and early warning.	Teach that energy efficiency must consider the physiological aspects

Conclusion

Although, the light pollution is not mentioned by any of the 169 Targets contained by 17 Goals, we found 12 Targets to be related to the light pollution. Nine Targets operate with terms in which light pollution should also be considered. In case of two further targets only the other environmental loads are mentioned, erroneously without the light pollution. One further target is connected through the fact that light pollution may hinder the foreseen positive processes of the target. The presented connections of light pollution to the SDG can be utilised in education of the issue.

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A comparative account of acute versus chronic exposure of LAN on behavior and physiology of resident Indian Weaver bird

Theme: Biology & Ecology

Anupama Yadav[1]*, Jyoti Tiwari[1], Raj Kumar[1], Vaibhav Vaish[1], Shalie Malik[1] and Sangeeta Rani[1]

[1] *University of Lucknow 1, Lucknow, India*
Corresponding:anupamayadav737@gmail.com
[*] *presenting author*

Life on earth is entrained according to the cyclic presence and absence of light. Evolution of life forms and their endogenous biological rhythms are closely coupled with this natural light-dark cycle. However at present, this close coupling of endogenous rhythms to natural *zeitgebers* (zt) is seemingly interfered by increasing urbanization resulting in lighting up the dark nights i.e. Light at Night (LAN). Most of the studies on LAN report the harmful impact of this pollutant on an organism's daily and seasonal responses, but comparative account of acute and chronic effect is scarce. Thus, the present study was designed to assess the acute and chronic effect of light at night on behavior and underlying physiology of an Indian resident bird: Baya weaver (*Ploceous philippinus*). The experiment was performed on adult male baya weaver birds under 12L:12D photoperiodic condition. A longitudinal study was performed on 10 individuals of *Ploceous philippinus*. After acclimation in experimental facility for about 3 to 4 days, birds were kept for 7 days without any nighttime illumination and this phase served as control. Thereafter, birds were exposed to 5 lux night light treatment. One week of LAN exposure was considered as acute whereas four weeks of LAN exposure was considered as chronic. Different behavioral and physiological parameters such as activity-rest pattern, sleep behavior, food intake, body mass, blood glucose and body temperature were monitored weekly during the experiment. The results indicate that light at night altered the normal behavior and physiology of the birds. Activity-rest pattern and sleep behavior analysis reveals that acute exposure of LAN resulted in increased nighttime activity and decreased rest and sleep when compared with control phase and chronic exposure of LAN. Food intake increased during acute exposure whereas body mass decreased but chronic exposure of LAN resulted in gain of body mass in birds under study. Blood glucose is known to show circadian variation. During control phase, pre-prandial (zt 22) and post-prandial (zt 2) blood glucose showed presence of gradient which was subsequently lost after LAN exposure. Chronic exposure resulted in significant variation of body temperature rhythm also when compared with no LAN exposure. Thus, light at night was seen posing significant impact on behavior and physiology of bird under study.

Keywords: Biological rhythm, endogenous, acute, chronic, *zeitgebers* (zt), LAN

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Ground-level nighttime illuminance influences distribution of species on sandy beaches

Theme: Biology & Ecology

Ariel L. Simons,[1,*] Karen L. M. Martin,[2] and Travis Longcore[1]

[1] UCLA Institute of the Environment and Sustainability, Los Angeles, California USA
[2] Pepperdine University, Malibu, California, USA
levisimons@gmail.com
[*] presenting author

Introduction

Artificial light at night (ALAN) is a novel environmental perturbation in coastal ecosystems. It changes the spatial distributions of a variety of species resulting from alterations to their behaviors, ranging from the timing of breeding cycles to predator avoidance. As a result, the widespread presence of ALAN has led to changes in the spatial distributions of a number of species. However, such species distribution models are based on laboratory measures of behavioral responses to levels of ALAN generally far in excess to levels of exposure in the field. Furthermore, earlier models of exposure to ALAN in the field have typically focused on remotely sensed upwards radiance that is not related to light as measured on the ground. To address these limitations in quantifying the role of ALAN in landscape ecology we constructed and evaluated species distribution models (SDMs) for two species, California grunion and Western Snowy Plover, found along the highly developed coast of southern California.

California grunion (*Leuresthes tenuis*) is small (<20 cm) fish that ventures up on to the upper limits of the wash zone on sandy beaches to spawn. Spawning events occur a few days after the new moon or full moon, but strength of runs is appears to be stronger after new moons and grunion may favor the darker parts of the beaches on which they spawn (K. Martin in Nightingale, Longcore, & Simenstad, 2006). We hypothesized that the fish would be sensitive to high lighting levels.

Western Snowy Plover (*Charadrius nivosus nivosus*) is a small shorebird that is listed as an endangered species under the U.S. Endangered Species Act. The beaches of southern California are habitat both for year-round residents that breed and for wintering flocks supplemented by birds from further north on the Pacific coast. The species roosts in flocks on the beach given its small size and susceptibility to predation, we hypothesized that it would roost at darker sites that provide cover from predators.

Methods

The geographic scope of our study area consisted of a 1.5 km wide coastal strip, whose outer boundary is defined by the mean low-tide line, running from 10 km north of Ventura county through 10 km south of Orange county in California.

We (KLMM) organized and aggregated community-based volunteer surveys of grunion runs through the group Grunion Greeters (see Martin, Pierce, Quach, & Studer, 2020). Plover roost areas were obtained from surveys organized by Los Angeles Audubon Society (Ryan, Vigallon, Griswold, & Gummerman, 2014; Ryan et al., 2017), Francesca Ferrara of the Point Mugu NAS, and Alexis Frangis of the California State Parks. Both sets of species observations span the period 2013–2016.

Ground-based estimates of illumination were developed from a sample of 515 samples within the study area where hemispherically integrated scalar illuminance was measured using a Sky Quality Camera (Euromix Ltd., Ljubljana, Slovenia). Values were extrapolated to the entire study area using their relationship with the World Atlas of Artificial Night Sky Brightness (Falchi et al., 2016), which correlated better with ground-level exposure compared with upward radiance measured with VIIRS DNB (Simons, Yin, & Longcore, 2020). In addition to this measure of ALAN, at a horizontal resolution of 10 m, we also obtained measures of: elevation, slope, distance to freshwater, distance to saltwater, beach type (describing conditions behind the beach), and a measure of the fraction of sky obscured by structures along the horizon known as the Sky View Factor (SVF) (Kidd & Chapman, 2012).

Using the environmental data and the two species distributions, we then ran and evaluated three different species distribution models (SDMs): a generalized linear model, MaxEnt, and random forest. Each subset of species observations consisted of 100 presence and 1000 pseudo-absence points randomly generated within either roosting areas (plovers) or run areas (grunions).

Results

Of the SDMs we evaluated, we found those using random forest performed best, explaining 55% of the observed variation in the spatial distributions of plover roosts and 73% of the variation in grunion runs. We also observed exposure to ALAN to be the environmental variable greatest importance for grunion distribution and second greatest importance for plover roosts. The likelihood of plover roosts decreased significantly above scalar illuminance of 50 mlx. Probability of occurrence of plover roosts was reduced by half on average at sites with 100 mlx or greater light pollution. Grunion runs presence increased significantly from 70 mlx to 100 mlx, but declined as illuminance increased beyond 100 mlx. We therefore recommend reductions in nighttime illumination to reduce disturbances to coastal environments given specific nighttime illumination thresholds associated with significant changes in behavior of coastal species.

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The effect of artificial light at night on nocturnal song behaviour in a diurnal bird species

Theme: Biology & Ecology

Ashton L. Dickerson,[1,*] Michelle L. Hall,[1, 2, 3] and Therésa M. Jones[1]

[1] *The University of Melbourne, Parkville, Australia*
[2] *Bush Heritage Australia, Melbourne, Australia*
[3]*University of Western Australia, Crawley, Australia*
ashtond@student.unimelb.edu.au
[*] *presenting author*

Introduction

Diurnal and annual light cycles are key, taxa-wide drivers of behavioural patterns (Gaston, Visser, & Hölker, 2015). However, the development of electric lights has led to a drastic and relatively rapid change to the nocturnal light environment. Artificial light at night (ALAN) has been shown to affect wildlife behaviour (Gaston et al., 2015). While evidence for this has been accumulating over the last two decades, many researchers have taken a simplistic approach to measuring light at night. Research has often been conducted in a lab using light levels that are not ecologically relevant and without considering the potential for differing effects on behaviour dependant on the type of light at night (sky glow versus localized light sources). Further, few field studies have controlled for natural light at night (moonlight). As ALAN continues to spread by more than 2% each year (Kyba et al., 2017), it is imperative that we begin to think about light at night as the multifaceted entity it is.

Fig. 1: Willie wagtail, *Rhipidura leucophrys.*
Image by Ryan Potter used with written permission.

In this study we use both large- and small-scale measurements of light at night to test for effects on behaviour, utilizing both observational and experimental methods. We focus on bird song, due to the substantial evidence that bird song responses to light, whether natural (Dickerson, Hall, & Jones, 2020) or artificial (Da Silva, Valcu, & Kempenaers, 2015).

Methods

Study species – The willie wagtail (*Rhipidura leucophrys,* Fig 1.) is a small, diurnal songbird native to Australia, Papua New Guinea, the Solomon Islands and eastern Indonesia. In Australia, they live in rural and suburban habitats. During daylight hours both male and female willie wagtails sing but during their breeding season males also sing prolifically during the night (Dickerson et al., 2020).

Observational methods – Between 2016 and 2018, we conducted a landscape-scale observational study of the effect of artificial light on nocturnal song. We recorded 1,447 hours of nocturnal song from 25 individual willie wagtails across 16 sites varying in intensity of ALAN. We used sky brightness values at zenith (µcd) obtained from https://www.lightpollutionmap.info to represent sky glow (Falchi et al., 2016). To examine the effects of localized light sources, we measured light at night in lux at each site using a SKL300 light meter, Skye Instruments Ltd, Wells, U.K.

Experimental methods – To create temporary artificially lit sites, we used six LED streetlights mounted on steel poles (Fig. 2). Lights were placed on six willie wagtail territories for two days prior to lighting for a habituation period and then were turned on for four nights. We continued to record data for the next two nights after the lights were turned off to test for any recovery effects. We recorded a total of 461 hours.


Fig. 2: Light set up used for experimental approach. Image by Ashton L. Dickerson.

Statistical analysis – We used generalized linear mixed-models to test for effects of small- and large-scale effects of ALAN, while being able to control for environmental variables known to effect bird song.

Conclusions

Our results show that nocturnal song is less likely with increasing intensity of localized light sources. In contrast, the effect of sky glow on likelihood to sing depended on an interaction with lunar illumination. In areas with low sky glow, the likelihood of song increased with lunar illumination; in areas with high sky glow, increasing lunar illumination reduced the likelihood of song.

Our research revealed a complex relationship between nighttime bird song behaviour and ALAN suggesting that animals may be able to adjust their behaviour to utilize dark refuges within bright city areas. Similar behavioural adjustments have been suggested in other species including birds and bats, but the heterogeneity of light within city areas from the perspective of individual species has rarely been examined and therefore should be the focus of future research.

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Moth survival increases under high pressure sodium lights

Theme: Biology and Ecology

Brett M. Seymoure,[1-3,*] Tessa Parrish,[2] Kaley Egan,[3] Danny Irwin,[3] Cassandra Brown,[3] Jeremy M. White,[2] Kevin Crooks,[3] and Lisa Angeloni[2]

[1] Living Earth Collaborative, Washington University, St. Louis, MO, USA
[2] Department of Biology, Colorado State University, Fort Collins, CO, USA
[3] Department of Fish, Wildlife and Conservation Biology, Colorado State University, Fort Collins, CO, USA

Brett.seymoure@wustl.edu
[*] presenting author

Anthropogenic light at night is growing spatially and in intensity globally while insects are on a global decline(Kyba et al., 2017; Owens et al., 2020). Many nocturnal insects provide numerous ecosystem services and are attracted to anthropogenic lights at night resulting in decreased fitness, greater mortality and population declines(Owens & Lewis, 2018). During crepuscular and night hours, moths are depredated by bats and birds, both of which are using vision to detect and prey upon moths(Macgregor et al., 2015). The visual detection of moths by predators is dependent upon the light environment illuminating the moth's body, and anthropogenic light at night can differ drastically in the color (spectral composition) and intensity of light (Seymoure et al., 2019). Currently, High Pressure Sodium Lamps (HPS) and Light Emitting Diodes (LEDs) are the main light sources used by municipalities and these lights differ in spectral composition with LEDs being broad band and HPS being dominant in longer wavelengths of light (red-shifted). Using plasticine clay models of moths, we tested the survival of moths under different light sources (HPS and LED) as well as under no direct lighting in an urban setting to show that moths are more likely to survive under HPS lighting than LEDs and non-lit poles. Visual model analyses reveal that HPS lamps render moths more cryptic against their background than LEDs or ambient urban lighting, figure 1. Although these results indicate that HPS lighting is the most insect friendly lighting, we further show that the artificial visual environment created by HPS is more likely to make prey detection by birds difficult and could perhaps shift an evolved visual predatory-prey dynamic in urban settings.

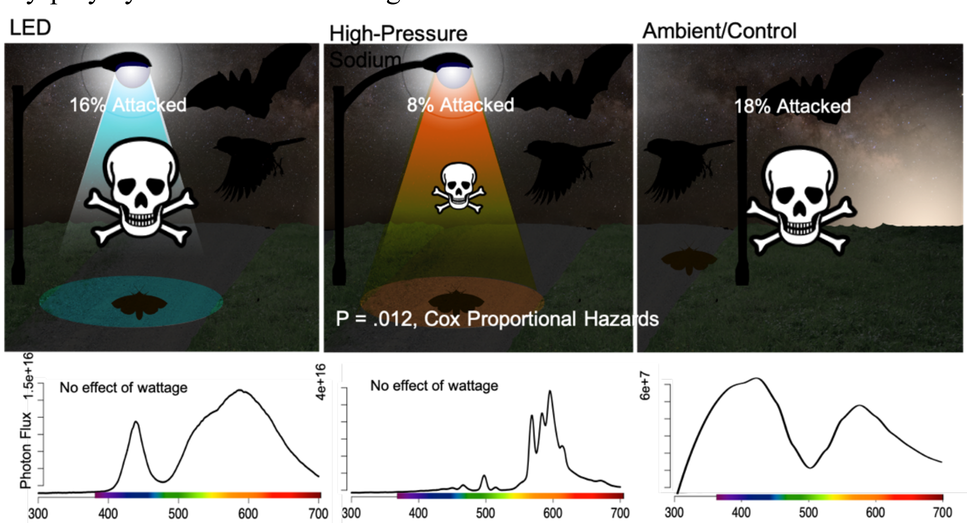

Figure 1. Statistical abstract of the study revealing that moths under HPS lamps had the lowest mortality, whereas moths under LEDs and non-illuminated control moths had higher predation rates.

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Modelling Light Emission Using Real-world Lighting and Obstruction Information

Theme: Measurement & Modeling

Brian Espey[1,*]

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

Introduction

Study of light at night has increased in the last decade due to the recognition of its impact on the environment, potential health concerns, and also for the financial and carbon cost of energy loss. The advent of more extensive and improved ground-based measurements together with quantifiable satellite data has revolutionized the field, though "closing the loop" and finding a detailed connection between these measurements has been more elusive due to atmospheric effects as well as non-uniform emission in both angular and spatial extent from the ground. Although a number of codes now exist which incorporate improved theoretical models of atmospheric effects, the emission from the ground involving in situ effects of real-world lighting and obstructions has not been completed until now. We will present preliminary results and implications from such a study.

Methods

We took as a starting point data of the location and height of structures obtained from publicly available Light Detection and Ranging (LiDAR) data with 1m ground resolution and sub-metre vertical accuracy. These datasets were combined with public lighting data consisting of information on location, pole height, lamp type and wattage. We chose eight rural locations of differing sizes for which International Space Station data indicated that the lighting was almost completely due to public lighting. Additionally, we chose a 1.5km x 0.9km sample area of Dublin which covers a region of mixed size streets and major squares and contains some busy shopping and government areas. In all locations, as elsewhere in Ireland, the lighting stock is dominated by low and high pressure sodium lighting and is of a few major types. From the manufacturer's photometry for the luminaires the azimuthally-averaged emission to the sky for different elevations was obtained and the light falling on surfaces below a typical streetlight height of 6m was calculated. No allowance was made for aging of the lamps and/or degradation of the optics (i.e., a maintenance factor of 1.0 was adopted). For simplicity, we assumed a reflectivity of 10% for all surfaces. Assuming that the diffuse light is dominated by Lambertian reflection, the emission from this component towards any given altitude can be calculated and compared with the direct emission from the luminaires themselves. Account was taken of obstructions such as trees and buildings which block both the direct and/or a portion of the reflected light. Finally, the emission for a given view direction was then summed to provide an estimate of what would be seen from orbit, taking into account the shadowing effects of obstructions from each viewpoint. To sample a representative range of angles we generated a set of data for each location for every 45° of azimuth and for elevation angles of 10°, 30°, 60°, and 90°. The total number of lights in each area ranged from nine to over one thousand in the case of the Dublin model.

Some Results

<u>Altitude dependence of light emission</u> – To provide a point of reference we took the unobscured total emission emitted straight up and scaled it to lower angles under the assumption that *all* such emission was Lambertian. In all locations we found that, due to obstructions, the total light

observed for both 30° and 60° angles fell *below* that expected based on the assumption of Lambertian emission, as might be expected. On the other hand, at the 10° elevation the emission lies *above* that expected from the Lambertian scaling due to a combination of increasing direct emission as well as an increased reflected component from illuminated structures as the angle-of-view lies closer to the emission maximum for these features. The total emission towards 10° altitude ranges from a factor of two or so above the Lambertian emission for the Dublin case to a factor of five in the case of one of the smaller towns. A point to note is that large boulevards and junctions suffer less from shading by surrounding buildings, with roughly 80% of the upward hemisphere visible, which is roughly a factor of five higher than some of the narrower streets = such locations exist not only in Dublin, but also occur in larger market towns. Since intersections and major thoroughfares also contain brighter public as well as commercial lighting the overall effect is to make them more noticeable even at relatively lower altitudes, accentuated by the favourable angle for direct emission from shop windows and/or reflected architectural lighting in such areas. The contribution of the direct component increases towards the near-horizontal, accounting for typically one half of the total emission in this direction and supporting theoretical evidence of the importance of this light source for light pollution.

Azimuthal dependence of light emission – The emission in the azimuthal direction is smoothed depending on the number of features and lights present and is relatively smooth for the case of the city location, whereas variations are more striking for the small rural locations.

Further work

Further improvements are planned including quantified comparison with VIIRS/DNB data and additional test locations incorporating different structural and lighting patterns are available for such studies. It will be instructive to compare the results from this work with the fits to angular variation of radiance with zenith distance for the same towns as calculated by Tong et al. (2020). As there is a known correlation between the azimuth and zenith distance of observations the relationship account needs to be taken of the geometry and emission peculiar to each site when comparing against the night-to-night results. Another goal of this work is to model the underlying public light component from extended built-up areas, such as city centres, and so enable an estimate of the contribution of other light sources to be made. Finally, it would be instructive to use such models as input areas to radiative transfer codes: this would serve two purposes, one being to develop a more realistic input dataset for comparing different codes between themselves, the other being direct comparison of these codes to quantifiable observations.

Acknowledgements

We acknowledge the original owners of the datasets on which this work is based. For Dublin the LiDAR dataset was collected with funding from European Research Council Consolidator project RETURN [ERC-2012-StG-307836] and Science Foundation Ireland [12/ERC/I2534]. For the smaller towns, LiDAR data were provided by the Geological Survey of Ireland. Both datasets were released with an Attribution 4.0 International (CC BY 4.0) license. We also acknowledge the provision of public lighting information by the Executive Engineer of Dublin City Council, and the national Road Management Office.

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The First 365 Nights: Australia's National Light Pollution Guidelines for Wildlife

Theme: Society

Cesar San Miguel,[1,*] Kellie Pendoley,[2] Karen Arthur[1]

[1] *Australian Department of Agriculture, Water and the Environment, Canberra, Australia*
[2] *Pendoley Environmental Pty Ltd, Booragoon, Australia*
cesar.sanmiguel@environment.gov.au
* *Cesar San Miguel*

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 a population. 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 if their nesting habitat never becomes dark. Wallabies exposed to artificial light have been shown to delay reproduction and clownfish eggs incubated under constant light do not hatch.

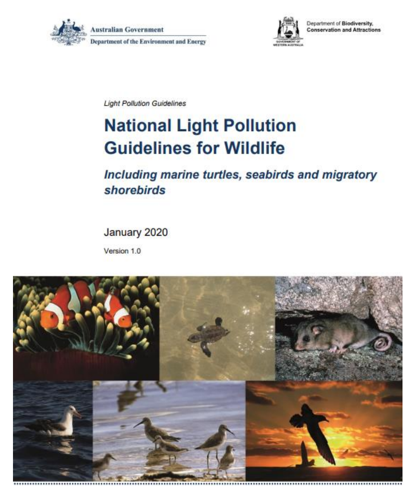

Figure 1 The Australian National Light Pollution Guidelines for Wildlife

To address this conservation challenge, the Australian Government developed the *National Light Pollution Guidelines for Wildlife: including Marine Turtles, Seabirds and Migratory Shorebirds* (Light Pollution Guidelines). Finalised in January 2020, the Light Pollution Guidelines raise awareness about the impacts of artificial light on wildlife and provide a framework for assessing and adaptively managing these impacts. The Light Pollution Guidelines also provide six best practice principles for reducing and managing light pollution (Figure 2).

Since finalising the Light Pollution Guidelines, the Australian Government has received wide support from members of the public, councils, and environmental organisations. The Light Pollution Guidelines were endorsed in February 2020 at the Convention on the Conservation of Migratory Species of Wild Animals (CMS) at its 13th Conference of Parties (COP13). CMS is an International agreement consisting of 132 international Parties aimed at conserving migratory species throughout their range. In its endorsing resolution, CMS recognised light pollution as an emerging conservation issue for wildlife, astronomy and human health and called attention to its the many negative effects on migratory species. CMS Parties also acknowledged the need for appropriate artificial lighting, advocated promotion of the Australian Light Pollution Guidelines to facilitate impact mitigation on migratory species and recommended further scientific research into the impacts of artificial light on wildlife.

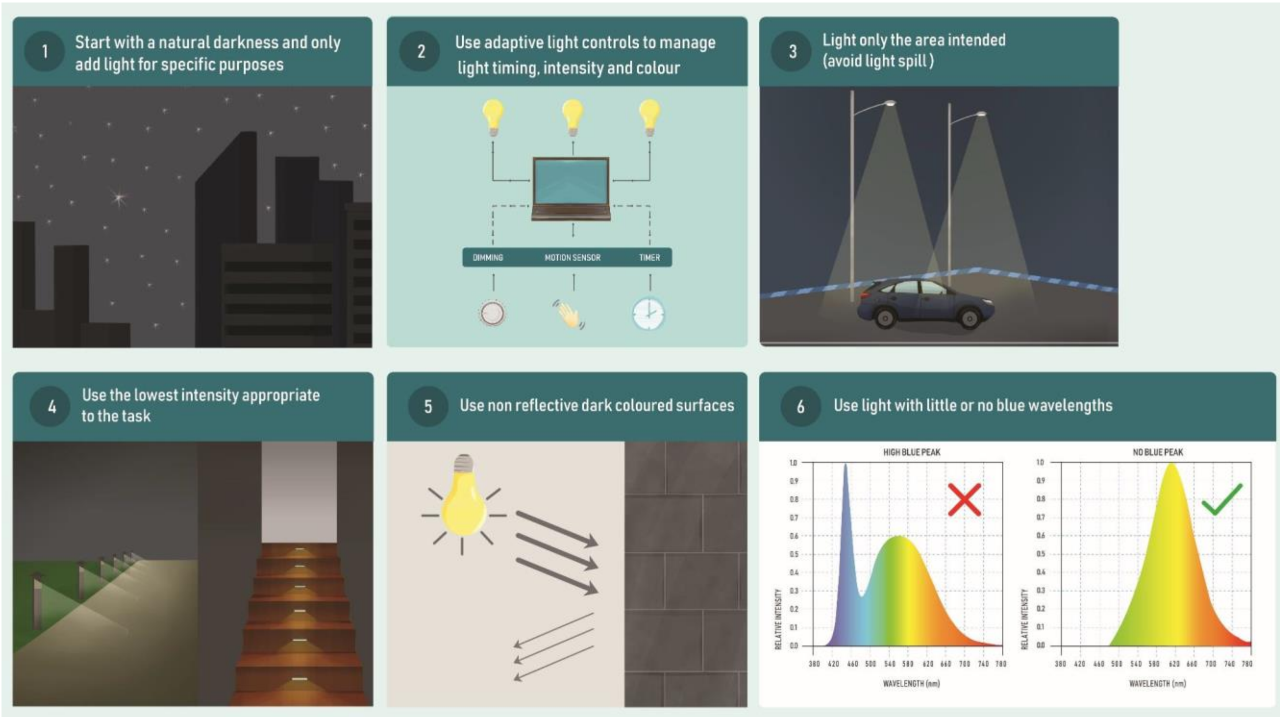

Figure 2 Principles for best practice lighting design.

One year after the finalisation of the Light Pollution Guidelines, it is clear there is still a need to continue to raise awareness about the impacts of light pollution on wildlife among the public, researchers and lighting practitioners. There is also a need for more collaboration and consultation with lighting designers, engineers, manufacturers, industry bodies and governance institutions to encourage new innovative solutions this highly complex environmental challenge.

Temporal variations of the multispectral night sky brightness on Tenerife Island

Theme: Measurement and Modelling

C. Marseille,[1*] M. Aubé,[1,2,3] , [4] Emilio Cuevas, [1] Norman T. O'Neill

[1] *Université de Sherbrooke, Sherbrooke, Canada*

[2] *Cégep de Sherbrooke, Sherbrooke, Canada*
[3] *Bishops University, Sherbrooke, Canada*
[4] *Agencia Estatal de Meteorología, Santa Cruz de Tenerife, Spain*
charles.marseille@usherbrooke.ca
* *presenting author*

Light pollution on Tenerife Island is a concern for astronomers as it gives rise to the artificial sky brightness which impairs astronomical observations. It is known that the short term temporal variation of the sky brightness can depend on the variation of the lighting levels at night but also on the local aerosol content of the atmosphere. Variation of the lighting levels is directly correlated to human activity, implying that it is in most cases similar from one night to another. But it is clearly not the case for the variation of aerosol content through the night. In this work we present the nightly evolution of the sky brightness over an annual period at three different sites on Tenerife Island: Santa Cruz de Tenerife (Urban site at 0m elevation), Teide Observatory (2390m elevation) and Teleferico del Teide (3520m elevation) near the highest peak on the island. At each location was installed a CoSQM radiometer: a Sky Quality Meter (SQM) equipped with 5 visible band filters. Multispectral measurements of the sky brightness are related to the spectral properties of the aerosol optical depth that are highly correlated with the size distribution of the aerosol population. But we must first distinguish the effect of possible color change trends of the lighting used at night. The 3 sites being quite close (less than 40 km apart), we observed similarities in the relative aerosol optical depth variability on each site. With the help of night time and day time measurements of the aerosol optical depth from each sites sun and moon photometers, we compare the aerosol optical depth and the sky brightness in typical atmospheric conditions and we also observe the effect of the calima, an abnormal high aerosol loading episode caused by Saharan dust storms, known to be linked to high aerosol optical depth short term variations.

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Impact of light pollution on freshwater zooplankton distribution along an urban river and at illuminated bridges

Theme: Biology & Ecology

Christina Luchs,[1,*] Tim Walles,[1] Catherine Pérez Vega,[1] Bronwyn L. Dyson,[1] Jens C. Nejstgaard,[1] Franz Hölker[1] and Andreas Jechow[1]

[1] Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
andreas.jechow@gmx.de
** presenting author*

A majority of humans live near freshwater bodies and as a result, artificial light at night (ALAN) over-proportionally affects freshwater ecosystems (Jechow et al. 2019, Hölker et al 2018). Nevertheless, not many measurements of light pollution or studies on impacts of ALAN on freshwater ecosystems exist. Recent studies showed melatonin suppression in fish at skyglow light levels (Kupprat et al. 2020) and that ALAN can have an impact on the diel vertical migration (DVM) of zooplankton in mesocosms deployed in an urban lake (Moore et al. 2000).

Here we show the first non-invasive in-situ measurements of the impact of light pollution on the DVM of zooplankton in an urban freshwater lake-river system. We determined the vertical distribution of zooplankton in the River Spree and Lake Müggelsee in Berlin at different locations and for different ALAN and natural light conditions (bright ALAN, low ALAN, different moon-phase, clouds, fog). We used an infrared illuminated under-water mini deep-focus plankton imaging system that obtains an uninterrupted image allowing to determine zooplankton vertical distribution at cm-resolution. A deep learning automated image recognition tool was used for taxonomic classification, providing unprecedented spatial and species resolution for freshwater zooplankton (Bochinski et al. 2018, Walles et al. in submission). Measurement locations included an illuminated bridge (Oberbaumbrücke) that was part of a light festival the "Berlin Festival of Lights 2020" (Fig. 1) but also bright and dark parts of the river and the lake. At each location, a measurement was performed during the day and during night.

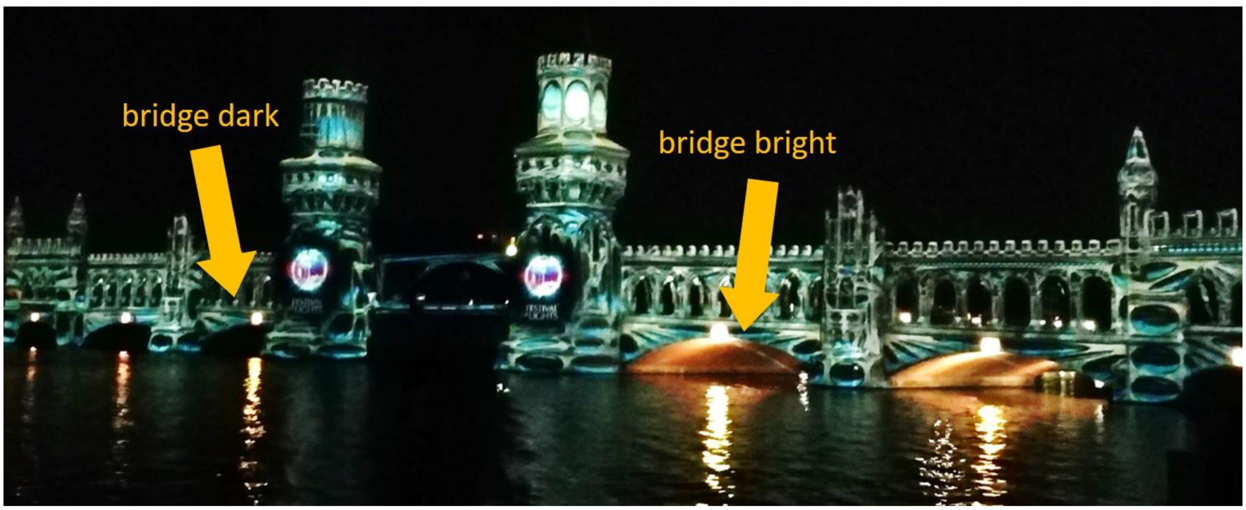

Fig. 1: Oberbaumbrücke in Berlin during Festival of Lights indicating two measurement locations.

Measurements of cladocera at four locations are shown in Fig. 2 with each plot showing two profiles, one for the night (left-hand side in each plot) and one for the day (right-hand side in each plot). At night, the bridge had two illuminated and two un-illuminated arches (arrows in Fig. 1) which are indicated as “bridge bright” and “bridge dark” in Fig. 2. Furthermore, measurements at an urban site (“river bright”) and at a rural site (“river dark”) of the river are shown. As expected for natural zooplankton behavior in more natural darker night locations, the zooplankton tended to stay near the water surface during the night, while it stayed deeper during the day. This natural DVM conducted by many zooplankton is known to have significant impacts on the plankton ecosystem, as it influences what organisms are consumed by the zooplankton throughout the natural day and night cycles. However, at more light polluted locations, the zooplankton remained deeper in the water column both during day and night. Thus, light pollution resulted in loss of strong DVM. In the presentation these results will be compared to further data presently being analyzed. To our knowledge, this is the first comprehensive quantitative study of effects of light pollution in a river-system, spanning from the city center to the sub-urban region.

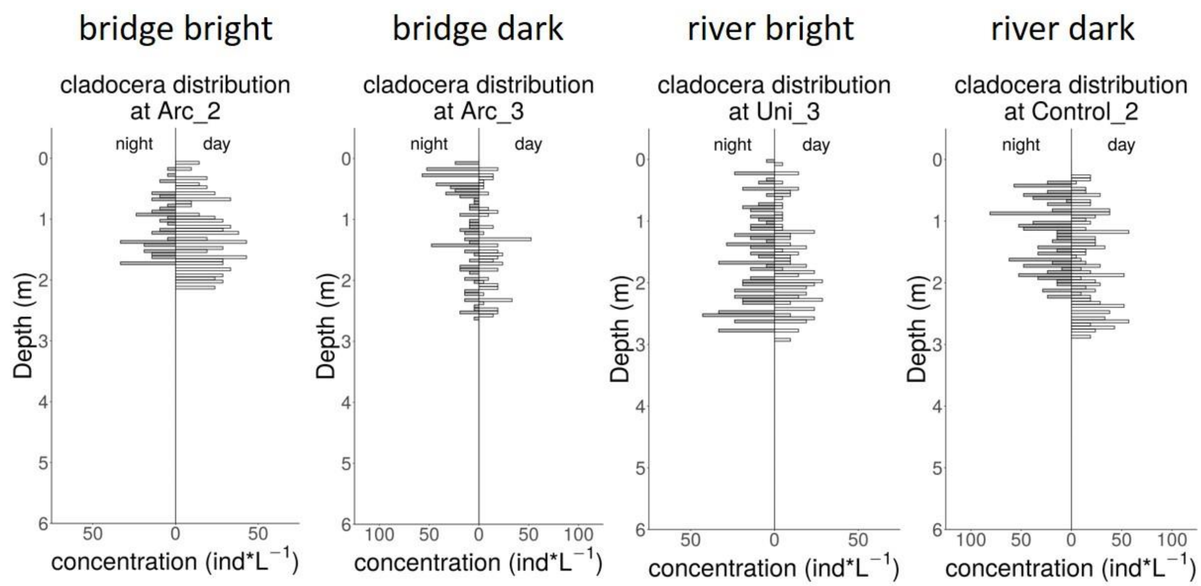

Fig. 2: Vertical zooplankton (cladocera) distribution for night (each left panle) and day (each right panel) at four sites with different levels of light pollution.

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Dark sky measurement data, profile fitting at MHAONB and backscatter ratio.
Theme: Modellling and Measurements

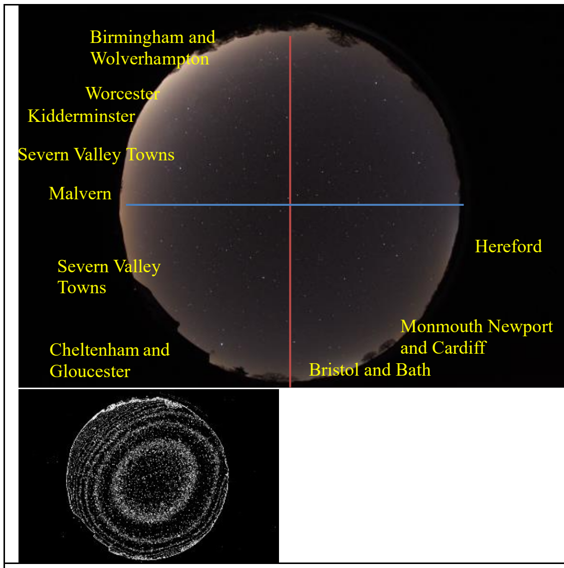
[1]C.J.Baddiley [1] Mathon, UK cj.baddiley@physics.org * presenting author

The sky in the Malvern Hills Area of Outstanding Natural Beauty (MHAONB) has been monitored continually since 2012, when a dark sky survey of the area was carried out commissioned by Malvern Hills Conservators. Ever since then at Mathon observatory, the sky brightness has been measured continually, in the last few years at minute intervals in all weathers. On the darkest of nights, a fisheye lensed camera was used at the same intervals. There is a trend in brightness distribution and colour changes on the sky towards the horizon, with well separated bright sky domes. The sky quality meter (SQM) photometry data near zenith does not show any great change. In 2015, Malvern Hills Conservators commissioned the author for modelling of the effect on the MHAONB sky, of the ongoing blue rich LED re-lighting throughout Herefordshire.

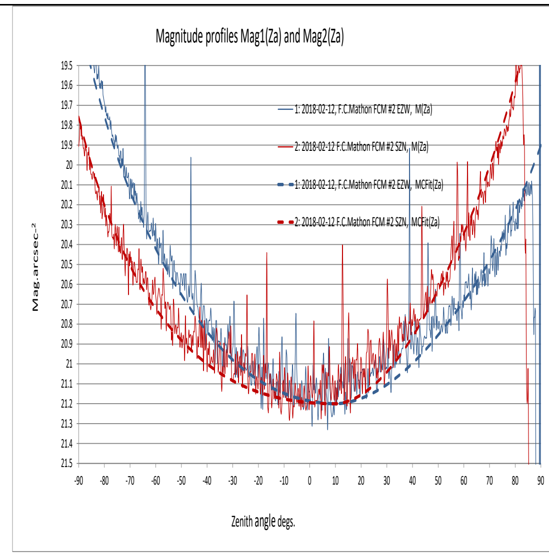
The camera shows the near horizon colour trend from orange-pink to blue-rich LEDs over the years. The SQM photometry shows the sky brightness distribution is very weather dependent. Colour and brightness changes can also occur over hours or even minutes, depending on cloud cover over individual towns on or beyond the horizon. In poor visibility the sky is darker and more dominated by local sources, while over horizon one attenuated. Clear sky brightness always falls overnight, most likely the fall in temperature resulting in humidity reaching dew point. The major advances since previous papers are the following:

- The database now includes 2020 with a study of light pollution changes during Covid-19 complete lockdown. In this rural area, only the normal weather variation was found.
- From samples of the all sky images, isophotes were plotted with identifiable city sky domes up to 120 km away. Images show significant differences of sky dome distributions from satellite data base simulations for the same location.
- An algorithm has been developed to fit parametric curves across from horizon through zenith to opposite horizon with minimal number of parameters for clear skies which has proved to be accurate and consitent. It enabled determination of the Milky Way contribution when present. The yearly archive sampled data was re-analysed using this curve fitting, including the 2012 data for the geographic survey locations, so the weather dependent relative contributions of local to sky dome beyond the horizon sources could be evaluated.
- A study was made of the colour variation trend and also that over very short periods of time.
- Measurements were made of the local clear air back scatter ratio in good visibility, by taking SQM readings of the local overhead sky while repeatedly turning on and off a flat panel luminaire, horizontally mounted. This was found to be consistent, at near 10^-8 /sr/m^2 with a standard deviation 8%. This was applied to lighting planner's total illumination data for an intended lighting scheme to be built adjacent to a school observatory in Norfolk where lighting engineers had avoided any direct lighting, but typically, had not accounted for significant atmospheric scatter degradation.

The Milky Way is only 20% contrast to background at zenith on the darkest nights, (MHAONB typically 21.10 mag.arcsec-2); doubling the road light level across Europe would make it invisible. The new All Party Parliamentary Group for protecting the night sky has recommended to the UK government changes to acts of parliament to make them more effective, and to set up independent assessment and advisory organisation. The government and lighting industry is taking this seriously.



Above: Example 2018-02-12 F.C.Mathon. Image and isophote map. Good visibility.
Sky glow domes from many towns and cities over the horizon, the brightest are Birmingham NE. at 67km, Worcester NE. at 18km, Malvern E. at 5km, Cheltenham & Gloucester SE.. at 55km, Hereford at 27km, Monmouth SW at 45km & Cardiff 105km. The Milky Way is on the horizon.The departure from circular symmetry of the near-zenith isophotes indicates the directional contribution of local to over-horizon sources, also shown in the profiles. In poor visibity, local sources are enhaced and distant ones suppressed; the sky can be darker, changing colour.



Above: Example 2018-02-12 F.C.Mathon, photometry profile, Blue E. to W. via zenith; Red S. to N., spikes are mostly from stars and drops are fixed pattern noise. It shows the pararmetric curve fits (dottted lines). Parameter sets: zenith value, values at specified Zenith angles 60..dgrees or more either side, and fitted power law gradient at those points. Here averaged tilt corrected Zenith value 21.25 mag.arcsec^-2 (0.32 mCdm^-2). The fitting is good to 0.05, mag.arcsec^-2, the meter accuracy, and found to be consistent on the best of nights

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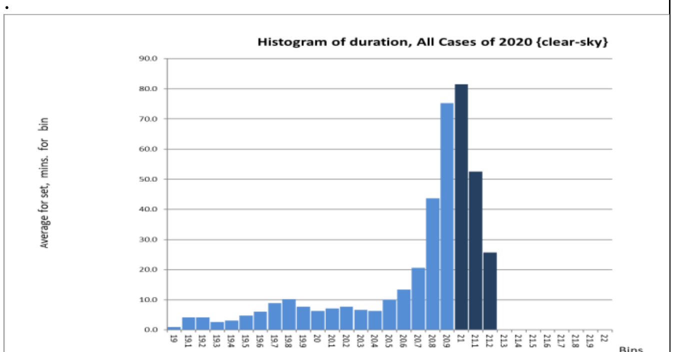
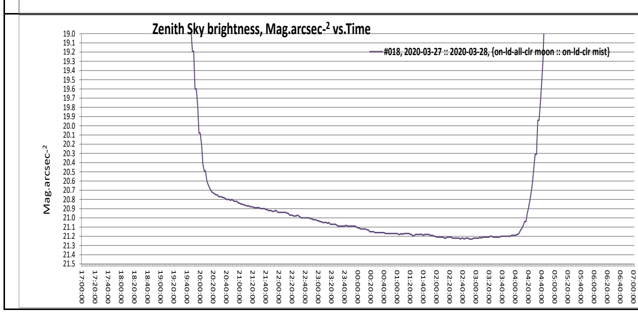
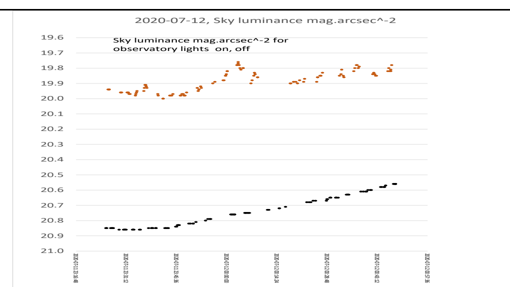


Left: Example 2020 Histogram of photometry for darkest nights. Lower left: Example 2020-03-28 Time plot dusk to dawn of clear night. Sky brightness decreases with time, to before dawn. Lower right: Example Backscatter determination from repeatedly turning an upward facing luminous panel on (orange) and off (black), up to 200 times, out of view of the SQM. This was repeated on a number of nights.





A Multinational Study of Night Sky Brightness patterns: preliminary results from the Globe at Night – Sky Brightness Monitoring Network (GaN-MN)

Theme: Measurement & Modeling

Chu Wing SO,[1,*] Nok Yan Janet CHANG,[1] Shengjie LIU,[1] Lina CANAS,[2] Constance E. WALKER,[3] Sze Leung CHEUNG,[4] and Chun Shing Jason PUN[1]

[1] Department of Physics, The University of Hong Kong, Pokfulam, Hong Kong, China
[2] IAU Office for Astronomy Outreach (OAO), IAU/NAOJ, Tokyo, Japan
[3] NSF's National Optical-Infrared Astronomy Research Laboratory (NOIRLab), Tucson, AZ, United States
[4] National Astronomical Research Institute of Thailand, Chiangmai, Thailand
socw@connect.hku.hk
[*] presenting author

The Global at Night - Sky Brightness Monitoring Network (GaN-MN) is a multinational project for long-term monitoring of night sky conditions around the world. Established in January 2015, the GaN-MN consists of fixed monitoring stations each equipped with a Sky Quality Meter - Lensed Ethernet (SQM-LE), a specialized light sensor for night sky brightness (NSB) measurements. NSB data are continuously collected at high sampling frequency throughout the night, and are instantly disseminated publicly to provide a real-time snapshot of the global light pollution conditions. A unified data collection methodology, including data sampling frequency, data selection criteria, device design and calibration, and schemes for data quality control, was adopted to ensure uniformity in the data collected. The network has currently 57 stations operating in 15 countries/regions in Asia, Europe, Africa, and South America. Around 100 million individual NSB data entries had been collected up to January 2021. This huge NSB database allows for studies of temporal and geographical variations of light pollution and their correlations with various natural and artificial factors.

Preliminary analysis of this multinational data set reveals the huge variation in the night sky worldwide: urban night skies are significantly brighter than night skies in pristine national parks. In general, urban night skies get progressively darker with time over the night due to reduction in light usage. Distinct patterns of temperal variations of the NSB observed in different locations reflect the diverse policy and habit of lighting usage in the locations sampled. By studying the density distribution of data, we confirmed that the cloud amplification factor is highly correlated with the NSB of the location, more specifically, the brighter the night sky of the location is, the more the clouds impact the NSB. The correlation is generally valid over a wide range (over 400× in radiance difference) of light pollution levels. This data collected is intended to provide the scientific backbone in our efforts to contribute to dark sky conservation through education to the general public and policy makers.

Project website: http://globeatnight-network.org/. Archived data from the project also available at the Globe at Night website: https://www.globeatnight.org/gan-mn.php

This project is supported by the University of Hong Kong Knowledge Exchange Fund granted by the University Grants Committee, the Environment and Conservation Fund of The Government of the Hong Kong Special Administrative Region, and the IAU Office for Astronomy Outreach (OAO), IAU/NAOJ, Tokyo, Japan.

Outcomes from the Dark & Quiet Skies Workshop Reports

Theme: Technology & Design

Constance E. Walker[1,*] and the Members of the Dark & Quiet Skies Working Groups[2]

[1] NSF's NOIRLab, Tucson, AZ, USA
[2] Dark & Quiet Skies for Science & Society Report, pp. 7-11
connie.walker@noirlab.edu
[*] presenting author

Introduction

As request by the UN Committee on the Peaceful Use of Outer Space (COPUOS), the UN Office of Outer Space Affairs, the IAU and Spain organized a workshop on "Dark and Quiet Skies for Science and Society" (D&QS). The workshop was held in October 2020. The presentations were the outcome of research done by nearly 80 scientists, illumination engineers, space lawyers and satellite operators from around the world. The Dark & Quiet Skies Workshop report addresses all types of artificial interference that may have a negative impact on the visibility of the night sky and astronomical science. The results from four of the five working groups is summarized here. The first working group investigated the impact of satellite constellations on the field of astronomy. The second through fourth working groups investigated the effects of the artificial emission of light during the night, also known as artificial light at night (ALAN). The ability to provide illumination is essential to modern society. However, excessive, ubiquitous and improperly directed illumination has significant negative impacts on dark skies oases, optical astronomy and the bio-environment.

The Impact of Satellite Constellations on the Science of Astronomy

The pending deployment of tens of thousands of communication satellites in LEO is a very recent technological capability. The main purpose of these satellite constellations is to provide low-latency communication networking to any inhabited region of the globe. While this endeavor may represent a huge advantage to communications within society, the effect of fully deployed constellations on the visibility of the night sky and on professional astronomical observations has not been adequately considered. Owing to their low orbits, a considerable number of satellites may be visible to the unaided eye, especially at low elevations above the horizon near twilight and dawn. More seriously, a much larger number of orbiting satellites will be detectable owing the highly sensitive astronomical detectors on modern telescopes. The impact is particularly dramatic for wide-field telescopes and automated surveys aimed at detecting moving objects, e.g., the COPUOS-supported International Asteroid Warning Network (IAWN). It is estimated that up to 30–40 per cent of the images taken by a wide-field telescope like the Simonyi Survey Telescope at Vera C. Rubin Observatory could be made unusable. The mitigation of the effects caused by satellite constellations requires an internationally agreed regulation, therefore it falls within the core remit of the UN COPUOS. The situation is certainly complex, both from the technical point of view and in terms of the possible regulatory aspects.

Protection of Dark Sky Oases

It is unrealistic to re-establish a pristine night sky within the boundaries of a modern city, where street illumination is mandatory for public safety reasons. However, in order to protect the right of any citizen to enjoy the vision of the starry sky, we recommend that national and local governments establish a suitable number of "dark sky oases" and protect them from excessive ALAN. In order to protect them, especially if they are located near densely populated regions, urban illumination has to comply with a number of prescriptions that can mitigate the outward diffusion of light, including reducing the level of illumination to the minimum necessary to ensure public safety and directing the light sources only toward where light is needed. Urban illumination that is not strictly needed for safety reasons should be discouraged. It is worthwhile noting that such measures result in substantial energy saving and serve to promote societal conservation of natural resourcesn, or available under an open license.

Protection of Ground-Based Optical Astronomy Sites and Related Science

In the case of the protection of existing or planned astronomical observatory sites, the mitigating measures are more stringent than those recommended for the dark sky oases, not only because the level of light pollution from ALAN has to be kept considerably lower, but also because the control of the spectral distribution is an important factor. Modern astronomical optical observatories represent large public investments, and governments have an interest in protecting a suitable area surrounding each observatory by adopting and enforcing specific regulations. In many cases, astronomical observatories that are financially supported by a given government are located in a foreign country that offers better geographic and climate conditions for astronomical observations. In these cases, it is essential that a clear assurance of enforced protection from ALAN is included in international hosting agreements. This is one of the reasons why this matter is being brought to the attention of COPUOS, which offers the best international forum in which to propose a uniform approach to the matter.

Protection of the Bio-Environment

In analyzing the impact of ALAN on astronomical observations, it was noted that the same polluting sources affect not only the night sky, but also the environment in general and in particular biological life and human health. These effects have been analyzed and a number of measures are recommended, some of which are germane to those recommended in the previous two categories. Further study of the effects of ALAN on the bio-environment is encouraged, in particular effects produced by novel light sources such as various types of outdoor light-emitting diodes (LEDs). The approach to regulating ALAN effects, however, differs substantially from those considered for sunlight reflected from satellites in large "constellations".

The recommendations for the last three categories (dark skies oases, optical astronomy and the bio-environment), even if agreed to internationally, can only be adopted and enforced by individual national and local governmental authorities, i.e., by the same authorities that regulate and finance, directly or indirectly, urban illumination. Nonetheless, if a substantial number of UN Delegations endorse the recommendations of the Dark & Quiet Skies Workshop, this would greatly enhance the chances of their local implementation.

Summary

The four categories above, plus one on Protection of Radio Astronomy Sites and Related Science, will be presented at the April 2021 meeting of the Science and Technology Subcommittee of COPUOS. The summary report for the UN and the full D&QS workshop report can be found at https://www.iau.org/publications/iau/.

Measurements for determining spectral correction factor for satellite observations and field test of light pollution maps

Theme: Measurement & Modelling

Dénes Száz,[1*] Kornél Kolláth,[1,2] and Zoltán Kolláth[3]

[1] Eötvös Loránd University, BDPK, Department of Physics, Szombathely, Hungary
[2] Hungarian Meteorological Service, Budapest, Hungary
[3]Department of Physics, Eszterházy Károly University, Eger, Hungary

szaz.denes@gmail.com
[*] presenting author

Imaging detectors of satellites like the VIIRS–DNB sensors onboard the Suomi NPP and the NOAA–20 satellites play an important role in monitoring light pollution globally. These measurements are also used to construct maps of night sky brightness like the World Atlas (2015). However, the satellite data cannot be directly compared with ground-based measurements taken with devices with different spectral sensitivity.

To estimate the error of the spectral sensitivity mismatch and to provide possible correction factors, we collect ground-based data by a spectroradiometer during light pollution surveys in Hungary. We selected locations being part of national parks at the Great Hungarian Plain, where the visibility of the light domes of the neighbouring settlements is guaranteed. The spectrum of the light-domes are measured and then compared with data of satellite detectors and then knowing the spectral sensitivity of the satellite sensor, the ratio of the observed and total radiance can be estimated. This procedure, in principle, can provide a correction factor for each settlement.

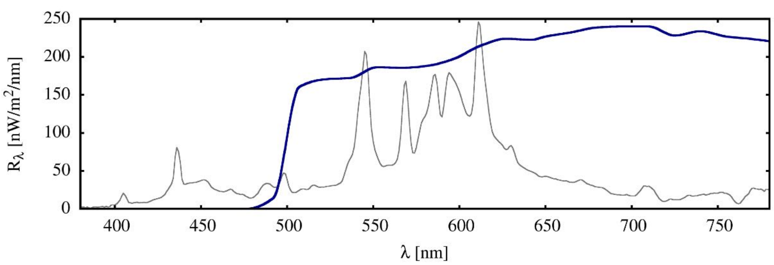


Fig. 1: Spectral radiance distribution of the light dome of Kaposvár, Hungary and the spectral sensitivity of the VIIRS–DNB sensitivity curve

With these measurements, we can give the predicted error caused by the spectral mismatch of the World Atlas data. We also collect ground-based data of whole sky imagery, which provide an additional test of light pollution maps.

Acknowledgements: The project is supported by the European Union and co-financed by the European Social Fund (Grant no. EFOP-3.6.2-16-2017-00014; Development of international research environment for light pollution studies).

Device for automatic measurement of light pollution of the night sky – test results and conditions of operation

Theme: Measurement & Modeling

Dominika Karpińska[1,*] and Mieczysław Kunz[1]
[1] *Nicolaus Copernicus University in Toruń, Faculty of Earth Sciences and Spatial Management, Department of Geomatics and Cartography, Poland*
karpinskadominika@doktorant.umk.pl, met@umk.pl
[*] *presenting author*

Introduction

Man's actions negatively affect the surrounding natural environment. Along with the more and more intensive development of civilization, we can observe an increase in environmental pollution of anthropogenic origin (Jechow et al 2019, pp. 212–223). The sky, polluted with light, is already an integral part of the landscape of the modern city. It has been proven that the excessive amount of light emitted at night has a huge impact on the development of plants and animals as well as on the functioning of the human being (Depledge et al. 2010, pp. 1383-1385, Jechow et al. 2019, pp. 212–223, Roge-Wiśniewska 2015, pp. 15-28). The described phenomenon has become an already noticed global problem, which is subject to monitoring, evaluation and research. For over a dozen years, this topic has been dealt with by an increasing group of scientists dealing with various disciplines from different parts of the world on a daily basis.

Light pollution studies have been conducted in Toruń since 2017 (Karpińska and Kunz 2019, pp. 91–100, Karpińska and Kunz 2020, pp. 155–172). Initially, the measurements were carried out by using a handheld SQM photometer in the L version by Unihedron. The research lasted one year and the selected twenty-four stations made up a measurement network located throughout the city. Currently, an automatic measurement network is being built on the same site. In principle, over thirty devices will work remotely, sending measurement data to a dedicated server where they will be analyzed.

Fig. 1. A device measuring the brightness of the sky, placed on one of the TARR buildings in Toruń (Poland) (photo by Mieczysław Kunz, 2020)

Methods

Since 2019, a portable and low-costs device has been constructed to meet the conditions of the assumed measurement network. Components that meet the project assumptions have been selected. The first tests of the two devices were successfully carried out in early 2020 (Fig. 1). Since then, another thirty-five devices that have already been tested in the field have been developed (Fig. 2). The data obtained at present will also be compared with measurements made with professional SQM devices, as well as with data obtained in 2017–2018. The designed devices carry out measurements remotely and communicate with the server in LoRa technology.

Fig. 2. Testing the cloud of devices for measuring the sky brightness in November 2020 on the terrace of the NCU Meteorological Observatory in Toruń (Poland), (photo by Mieczysław Kunz, 2020)

Conclusions

Light pollution of the night sky is a developing problem in the world today. It is necessary to monitor this phenomenon, which will allow scientists to check its condition and extent. The remote measurement network being built in Toruń will allow for an in-depth analysis of this phenomenon.

Remote data acquisition of night sky light pollution based on a network of sensors is part of Industry 4.0. Wireless communication in LoRa technology is an element of the Internet of Things (IoT) concept. It will have practical application related to Smart Environment.

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GAMBONS: A multi-band Gaia – Hipparcos map of the natural night sky brightness

Theme: Measurement and Modeling

Eduard Masana,[1*] Josep Manel Carrasco[1], Salvador Bará,[2] Salvador J. Ribas,[3]

[1] *Institut de Ciències del Cosmos (ICC-UB-IEEC), Barcelona, Spain*
[2] *Universidade de Santiago de Compostela, Santiago de Compostela, Galicia*
[3] *Parc Astronòmic Montsec- Ferrocarrils de la Generalitat de Catalunya, Àger, Spain*

emasana@fqa.ub,edu
** presenting author*

Introduction

The natural brightness of the night sky in different photometric bands is a relevant parameter for light pollution research, since it allows establishing a baseline against which to evaluate the light pollution levels experienced in urban, periurban, rural and pristine dark sites. Brightness, in this context, is a shortcut name for the spectral radiance of the sky, weighted by the sensitivity function of the photometric band, spectrally integrated over wavelengths, and angularly integrated within the field-of-view of the detector.

The brightness of the natural night sky results from the sum of the spectral radiances coming from the Moon, stars and planets, the natural airglow, and the zodiacal light. This radiance is affected by attenuation (absorption and scattering), before it reaches the observer. The natural sky brightness is not uniform over the sky dome. Besides the dependence on the line of sight of the airglow radiance, absorption and scattering, the presence of the Milky Way or other bright sky regions has a direct impact in the value of the sky brightness in a given direction. The value of the brightness is therefore a function of the location, time, observing direction and atmospheric conditions.

We present in this work GAMBONS (GAia Map of the Brightness Of the Natural Sky), a model to map the natural night brightness of the sky in cloudless nights. Unlike previous maps, GAMBONS (Masana et al., 2020) is based on the extra-atmospheric integrated starlight radiance obtained from the Gaia catalogue. The Gaia-EDR3 archive (Gaia Collaboration 2020) compiles astrometric and photometric information for more than 1.8 billion stars up to G=21 mag. For the brightest stars, not included in Gaia-EDR3, we have used the Hipparcos catalogue (ESA, 1997) instead. After adding up to the star radiance the contributions of the diffuse galactic light and extragalactic light background, zodiacal light and airglow, and taking into account the effects of atmospheric attenuation and scattering, the radiance detected by ground-based observers can be estimated. This methodology can be applied to any photometric band, if appropriate transformations from the Gaia bands are available. In particular, we present the expected sky brightness for V (Johnson), SQM and visual photopic and scotopic passbands.

Methodology

The novelty of this work is the determination of the radiance outside the Earth's atmosphere using-Gaia and Hipparcos catalogues to obtain the integrated starlight. Gaia is an extremely ambitious astrometric space mission of the scientific programme of the European Space Agency (ESA). The third catalogue of the mission (Gaia-EDR3), with more than 1,8 billion sources, was released in December 2020. It includes very high accurate positions, motions and parallaxes, as well as information about the brightness, colour and several astrophysical parameters for all these sources. Gaia is the successor of the Hipparcos ESA mission, launched in 1989. Hipparcos catalogue includes around 120.000 stars, with information about their position, motion, brightness and colours. Although the Gaia catalogue is several orders of magnitude more complete and precise than Hipparcos catalogue, Gaia cannot observe bright objects (below 5^{st} magnitude in G). For those stars, the Hipparcos catalogue address the lack of Gaia data.

As a first step, we have computed the total ISL irradiance from the Gaia and Hipparcos data in several bands arriving to the Earth. The three passbands (G, G_{BP} and G_{RP}) of the Gaia photometric system need to be transformed to the other passbands. However, a complete sky brightness model requires the modelling of the other components, as the diffuse galactic light, the zodiacal light, airglow or atmospheric attenuation and scattering. We have implemented in GAMBONS the more updated and reliable models available in the literature for those components.

Results

GAMBONS model can be used to generate all-sky maps in a given passband, as the shown in Fig.1. These maps provide a realistic description of what one can expect to observe in pristine locations free from light pollution sources, under different atmospheric conditions. The multi-band capability of GAMBONS allows generating all-sky images in several bands. The model also allows estimating the nightly and seasonal variation of the sky brightness for a given location, allowing to establish a limit value for the darkest possible sky visible from a given place.

GAMBONS is available at `gambons.fqa.ub.edu`.

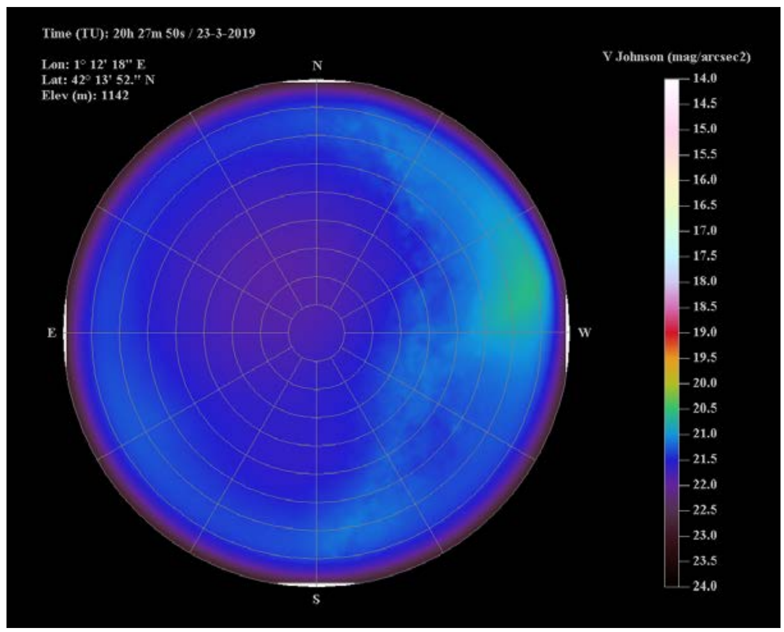

Fig. 1. All-sky map in the V Johnson-Cousins band generated by GAMBONS.

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GLOW – The Global artificial Light Ocean netWork

Theme: Biology and Ecology

Elena Maggi,[1,*] M. Aubè,[2] L. Benedetti-Cecchi,[1] I. Bertocci,[1] Z. Botterell,[3] P. R. Brooks,[4] R. Christofoletti,[5] J. Coughlan,[4] T. P. Crowe,[4] K. Dafforn,[6] D. Davoult,[7] G. Franzitta,[8] R. Gauff,[7] , N. Hubbard,[3] L. Iveza,[9] A.S. Martinez,[5] E. Marzinelli,[10] M. Mayer Pinto,[11] A. Queiros,[3] P. Quijon,[12] F. Rossi,[13] M. Trethewy,[6] F. Tuya,[14]

[1] Dipartimento di Biologia, via Derna 1 – University of Pisa, CoNISMa, Pisa, Italy
[2] Département de physique, Cégep de Sherbrooke, 475, rue du cégep, Sherbrooke (Québec), Canada
[3] Plymouth Marine Laboratory, Prospect Place, West Hoe, PL1 3DH Plymouth, UK.
[4] Earth Institute & School of Biology and Environmental Science, University College Dublin, Dublin, Ireland
[5] Institute of Marine Sciences - Federal University of São Paulo (IMar/UNIFESP) - Brazil
[6] Department of Earth and Environmental Sciences, Macquarie University, North Ryde, NSW 2109, Australia
[7] Sorbonne Université, CNRS, UMR 7144, Adaptation et Diversité en Milieu Marin, Station Biologique Roscoff, Place Georges Teissier, 29680 Roscoff, France
[8] Research Infrastructure for Marine Biological Resources Department, Stazione Zoologica Anton Dohrn, Napoli, Italy
[9] Center for Marine Research, Ruđer Bošković Institute, G. Paliaga 5, 52210 Rovinj, Croatia
[10] Faculty of Science, School of Life and Environmental Sciences, Rm 147, Edgeworth David Bldg A11, The University of Sydney, NSW 2006, Australia
[11] Centre for Marine Science and Innovation Evolution & Ecology Research Centre School of Biological, Earth and Environmental Sciences University of New South Wales, Sydney NSW 2052, Australia
[12] Department of Biology, University of Prince Edward Island, 550 University Avenue, Charlottetown, PE, C1A 4P3, Canada
[13] ECOSEAS laboratory, CNRS-UCA, 28 av Valrose, Nice, France
[14] IU-ECOAQUA, Grupo en Biodiversidad y Conservación, Departamento de Biología, Universidad de Las Palmas de G.C., Las Palmas, Spain
elena.maggi@unipi.it
[*] presenting author

The Global artificial Light Ocean netWork (GLOW) is a collaborative consortium of scientists studying the potential effects of artificial light at night (ALAN) on coastal assemblages worldwide. Established in Italy in Summer 2018, GLOW has attracted partners from several countries (Australia, Brazil, Canada, Croatia, France, Ireland, Spain, UK), where researchers are collecting data to quantify the intensity and quality of night lightings and their potential effects on the abundance of intertidal algae and invertebrates colonizing artificial structures.

Fig. 1: GLOW logo (by R. Gauff)

Why is it important to monitor the biological effects of ALAN on artificial structures? Armouring of the coastline is ubiquitous, due to commercial, residential, or touristic activities. Jetties, pontoons or pier pilings, seawalls, and riprap revetments or bulkheads are very common structures used to support human activities and assets, and all represent new habitats for a plethora of organisms. These man-made structures are usually brightly lit at night for security reasons (Bulleri and Chapman 2015). Increases in human population and global climate changes will cause coastal artificial structures to proliferate, thus replacing natural habitats with light-polluted coastal systems.

Activities of the GLOW network are based on the application of a concise protocol, that includes both diurnal and nocturnal samplings replicated twice (i.e., 2 dates) within the Summer and Winter seasons, at both lit and unlit areas, and focuses on measures of artificial lighting (by means of SQMs and light meters) as well as visual estimates of abundance of sessile and mobile organisms (including crabs). Optional activities related to sampling during additional moon phases, sampling microbial biofilm (Maggi et al. 2020) and using additional instruments to quantify properties of ALAN (LAN3; Aubé et al. 2020) are presented.

Variability observed among locations and between seasons in the difference in abundance of organisms between lit and unlit areas are discussed, by considering possible natural or anthropogenic drivers, with a focus on potential interactions between ALAN and other disturbances related to urbanization in coastal areas (Maggi et al. *in prep*, ECOlight working group - https://www.euromarinenetwork.eu/activities/emergent-impacts-coastal-areas).

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Lidar measurements of insect distributions near light fixtures with different spectra

Theme: Measurement and Modeling

Elizabeth M. Rehbein,[1] Riley D. Logan,[1] Kurt M. Fristrup,[2] and Joseph A. Shaw[1,*]

[1] *Montana State University, Bozeman, Montana, USA*
[2] *National Park Service, Natural Sounds and Night Skies Division, Fort Collins, Colorado, USA*
joseph.shaw@montana.edu
[*] *presenting author*

Introduction

The incursion of Artificial Light At Night (ALAN) into environments that evolved under geologically stable lighting conditions has disrupted the natural biological rhythms of nocturnal animals (Grubisic et al., 2018). Potential disturbances to the spatial distribution and behavioral pattern of insects in response to ALAN can result in insect injury, failure to reproduce, and death–all events with potential trophic cascades that may further alter an already disturbed ecosystem (Davies, Bennie, & Gaston, 2012; Justice & Justice, 2016). Understanding the effects of various lighting sources on insect movements will help provide valuable information to those seeking to minimize the effects of anthropogenic lighting in pristine or protected areas such as national parks. To this end, we conducted a collaborative effort to develop and use a wing-beat modulation lidar (US 2006025422A1, 2006) to noninvasively monitor insect distributions and movements in response to a broadband light source and a narrowband red light source. Our study aimed to establish the degree to which insect distributions are altered by the replacement of broadband white lights with narrowband red lights.

Methods

To begin understanding insect response to artificial lighting, we conducted a field study near Bozeman, MT using white and red light sources and a wing-beat modulation lidar to noninvasively monitor flying insects. The light source was a Signify RoadFocus Medium (RFM) designed specifically for use in ecological studies in Colter Bay Campground in Grand Teton National Park. The luminaire has a set of broadband white Light Emitting Diodes (LEDs) and a set of narrowband red LEDs to enable switching between the two spectra. We used the red and white LEDs on alternate nights and scanned a volume of nearby air with the lidar to identify insects. The wing-beat modulation lidar was developed to noninvasively and nonlethally monitor the spatial and temporal distributions of flying insects for ecological studies. It detects insects without drawing them to a trap or removing them from the study region. The lidar uses a laser beam with 532 nm wavelength and a high pulse repetition frequency to probe a test region. We analyze the backscattered light with spectral analysis to detect flying insects based on the oscillatory nature of light reflected by the insect wings.

Results and Recommendations for Future Studies

While there were no obvious distinctions in spatial insect distribution between the red light and white light nights, there was some variability in the temporal distributions. Environmental differences (e.g., temperature, wind, wildfire smoke levels) across the study period complicated our ability to draw conclusions on insect response to the two light colors while the small sample size of data inhibited our ability to account for environmental variability. Analysis currently is done manually but we are investigating automated analysis with machine learning to decrease processing times.

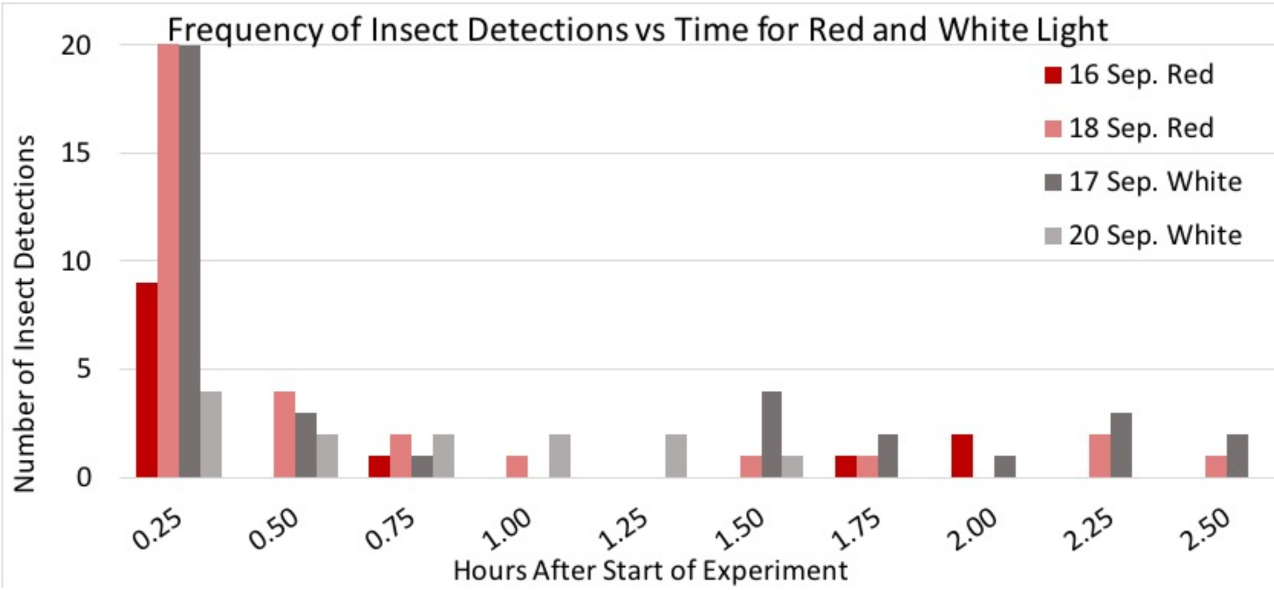

Figure 1. Histogram of insect detections on the four nights of the field experiments.

This study suggests modifications in future experiments. A longer study period will improve statistical sampling of environmental variables, and a new version of the insect lidar designed with a larger transmit beam area will improve spatial sampling of insects (and increase their time in the beam, which will lead to better-defined wing-beat spectra). The effects of weather differences between nights could be avoided by operating two luminaires simultaneously–one running the white LEDs and the other running the red LEDs. While we had only one luminaire available, access to two would enable the field team to collect data on insect distributions in response to both light spectra within the same night. We suggest setting up two luminaires, separated by a large enough distance that they are unlikely to interfere with one another, and scanning small volumes of air near each luminaire and a control area away from the lights. Future studies of this variety would improve our capacity to understand insect response to different sources of nighttime artificial lighting.

Acknowledgments

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Impact of light pollution on biodiversity: Challenges for education
(Poster presentation)

Theme: Biology & Ecology

ÉVA NAGY[1]

[1]*Neumann János High School, Vocational School and College, Rákóczi Street 48, Eger 3300, Hungary*

[1]*Eszterházy Károly University, Doctoral School of Education, Eszterházy Square 1, Eger 3300, Hungary*

ecuska79@gmail.com

Introduction

Light is an essential source of energy for plants by photosynthesis (Pénzesné et al., 2020) and it is a key factor in the orientation of some birds, movement of insects, and feeding of mammals As living organisms, people are affected through their biorhythm, as well and the learning efficiency, especially for growing children are also greatly influenced by the lights in the pre-sleep period (Mika et al. 2020).

Today, there are fewer and fewer valuable biological stages through which the idea of sustainability can be demonstrated in education, but light pollution can be presented in an educational way for the next generation. We have to make them understand today that the right view of their immediate environment and thus of the entire world's are fundamental and urgent challenge. (Nagy 2020)

Stimulating active learning can produce unparalleled results in the long term. One of the most effective ways of responding to challenges (especially for the high school age groups) is to reconstruct young people's partially acquired study materials aiming to correspond to the current state, making them more personal, contributing to the regeneration of our environment.

In connection with the participation in a light pollution project (EFOP-3.6.2-16-2017-00014), interesting conclusions can be drawn with a detailed study of biodiversity. Among the research opportunities, the study of nocturnal animals, appearing in the biology textbooks, has proved to be the most instructive part, during which it was confirmed that in the textbooks, obligatorily used in Hungarian public education, the existence of the animal species that are closely related to the theme of nightlife, is described in an unexpected number. However, in many required educational materials, the primary goal is still not to highlight the nocturnal aspects of biodiversity even if lighting would be one of the most defining conditions. (Nagy 2020) (Living Planet Report 2020) (Council of Europe – point 5 2020)

In 2021, the János Neumann High School, Vocational School and College of Eger is planning to join the Hungarian Eco-School network and our school will make a number of observations related to the school's natural surroundings. The implementation of this Eco-School project offers practical activities for night observations in the future, as well The active observation of the flora and fauna in the schoolyard, even at night, comes into the spotlight from a much more natural aspect, and the observations related to the studies are processed through innovative technological tools and methods. (Könczey 2016) A parallel project, a Bisel program, is also being implemented in our school in connection with light pollution, and it examines the effects of pollution and the biology of nocturnal activity. (https://bisel.hu/verseny)

Methods

The aim of the poster presentation is to present the researched essential elements of education in connection with the light pollution, which are currently found in all compulsory secondary school knowledge in Hungary, but are not necessarily highlighted in terms of light pollution.

Furthermore, it also presents methodological possibilities that adapt to the needs of Hungarian children through the channels they use, and thus aim to draw attention to the dangers and harmful effects of light pollution (Eco-school project, Bisel program).

Conclusions

In many cases, the drastic decline in biodiversity might happen due to the fact that, young generation does not always have access to sufficient and up-to-date information from their textbooks. However, a greater knowledge of species diversity might ensure natural sustainability for all life forms, for us, humans, as well. Considering these facts within the environmental education, its elements in the school materials were examined. (Nagy, 2020)

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Computing light pollution indicators

Theme: Measurement & Modeling

Fabio Falchi,[1, 2*] Salvador Bará, [1]

[1] *Dept. de Física Aplicada, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Galicia*

[2] *Istituto di Scienza e Tecnologia dell'Inquinamento Luminoso (Light Pollution Science and Technology Institute), 36016 Thiene, Italy*

falchi@istil.it

[*] *presenting author*

Introduction

Light pollution modelling and monitoring has traditionally used zenith sky brightness as its main indicator. Several other indicators (e.g. average sky radiance, horizontal irradiance, average sky radiance at given interval of zenith distances) may be more useful for specific purposes of night sky quality and environmental monitoring. For example, the average radiance in the first 10° above the horizon is an indicator useful to describe the impact of light pollution on the night landscape, both for humans (e.g. enjoyement of wilderness during the night) and animals (e.g. phototaxis), as for terrestrial animals the average pointing direction of the eyes is toward the horizon. These indicators can be calculated after the whole sky radiance is known with sufficient angular detail, implying even several tens thousands or more directions in the sky. This means, for each site, to integrate the contribution in each direction of the sky of each light source in the radius of hundreds of km. This approach is extremely high time consuming if the mapping is desired for a large territory and not for a single observing site. With our method, limited to the indicators that can be defined as a linear operator acting on the all-sky radiance, we can have a gain in computation time proportional to the desired number of directions in the sky (100000 directions in our case). Here we present a way to obtain maps of large territories for a large subset of useful indicators, bypassing the need to calculate first the radiance map of the whole sky in each site to obtain from it the desired indicator in that site.

Methods

For each desired indicator, the point spread function (PSF) of the sources is calculated from the whole sky radiance maps generated by a single source, at a given altitude, for a sufficiently dense number of distances from the observing site, with its altitude. Then, using Digital Elevation Maps we produce, for a given altitude of the observing site, a function describing the precise contribution of a unit-radiance source located at any arbitrary point in its surroundings, taking into account for each source altitude. Multiplying pixel-wise this function by a satellite radiance map of the light sources, and adding up the contributions of all pixels, the value of the desired indicator at the observing site is immediately obtained.

If we desire maps of the indicator(s) for a large territory, to speed up further the process, we can relax the condition to use the exact altitude of sources and sites, using transversally shift-invariant PSF, i.e. that depends only on the relative position of source and observer. In this way, we can use Fast Fourier-Transform (FFT).

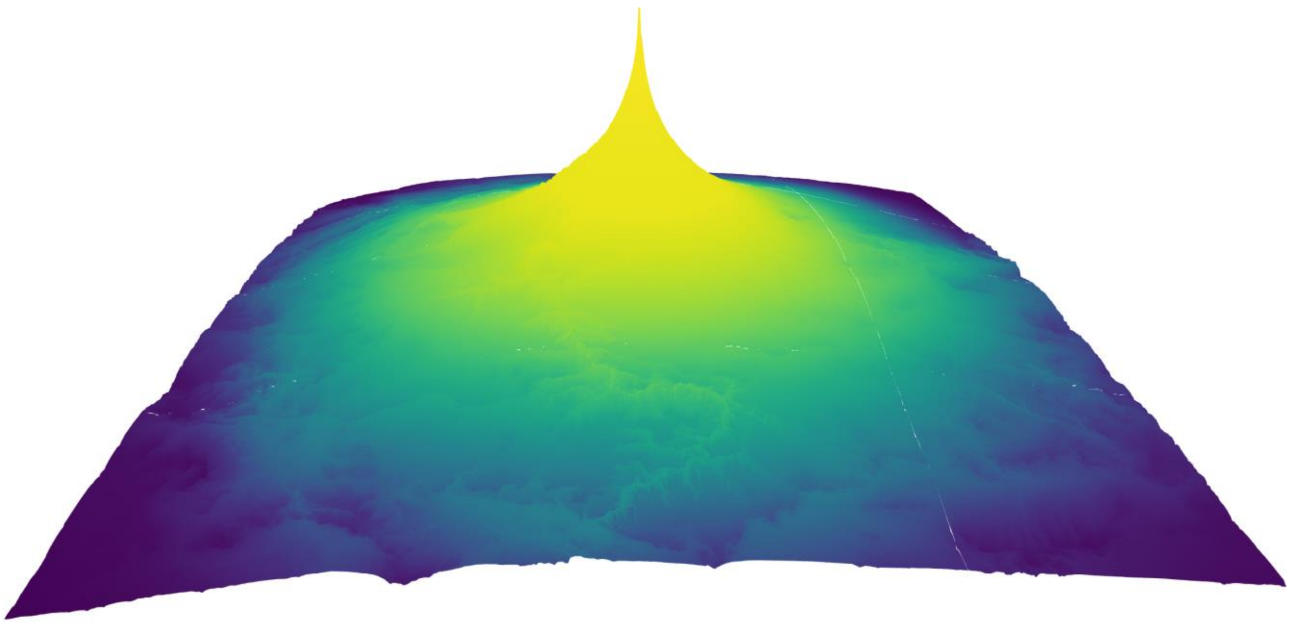

Fig. 1: Function describing the contribution to the zenith sky brightness in Moran Point Overlook (Grand Canyon National Park, USA) of unit-radiance sources located in its surroundings. The effect of the altitude of the light sources are clearly visible in this false color 3D rendering.

Conclusions

We present here a method to compute light pollution indicators that were usually attainable only computing in advance very detailed whole sky radiance maps.

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Living the Pyrenean night

Theme: Society

Fernando Jauregui[1*]

[1] Planetario de Pamplona, Pamplona, Spain
fernando@pamplonetario.org
[*] presenting author

Introduction

The European project *Pirineos La Nuit (Interreg - POCTEFA EFA233/16 PLN)* has three main areas of activity: Science, Outreach and Strategy. We present the fulldome documentary "Pirineos La Nuit" for planetarium domes as part of the outreach section of PLN. Three of the six project partners manage a planetarium in their facilities, so it seems natural to produce this audiovisual presentation as part of the project.

The Planetarium of Pamplona is producing original content for its dome since the center opened in 1993, so we have a large experience in this type of media. The arrival of digital planetariums with the first years of the new millennium allowed us to expand to new areas of interest and visual resources as the video covered the entire surface of our domes. At the same time, the progress in the quality of digital cameras (video and photography) and the evolution of 360º cameras and the software for stitching and warping give us the ability to represent the real world in our domes. Using fisheye lenses or devices with multiple lenses, we can capture 180ºx360º or even 360ºx360º images that we can project on the dome.

The fulldome show Pirineos La Nuit aims to present to the public not the perfect skies that are typical of planetariums, but the real night we discovered there. To achieve this goal, we had to capture images and sounds of the real night.

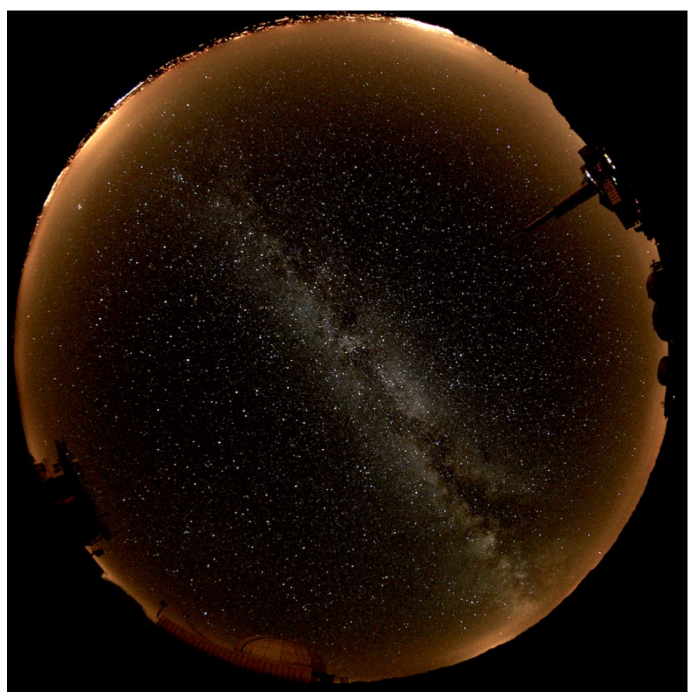

Fig. 1: One of the frames taken in the Pic du Midi Observatory. Direct light from the surrounding cities can be seen. The halos come from distant cities: Pau, Toulouse, Andorra, Girona, Barcelona, Zaragoza, Pamplona and the Basque Coast

The equipment

We started with some tests in 2016 to see if the equipment could do the job in those hard conditions. As a result of those tests we select the Nikon D850 DSLR camera to be used with the Sigma 8mm fisheye lens for dark scenes (photographic time lapses) and the Insta360 Pro for daylight and for the scenes recorded in the cities. Both cameras allow us to render 4k planetarium frames (4096x4096 pixels square frames). The Insta360 Pro can also record 3D sequences in 4k planetarium resolution.

These two cameras have been used to

capture the true night in the Pyrenees and in the cities surrounding the mountains ... and more.

The night in the mountains

For those who are used to climb mountains, it is normal to get up early (or too early) to reach the summit before noon and be safe in the valley or mountain shelter early in the afternoon. But for us, that was not the case. Our goal was to reach the point where the tripod would be placed in the afternoon and be ready to start with the sunset and stay there until dawn. This creates a new dimension of experience. The summer of 2019 (not 69) was the time for touring the Pyrenees night. The Col de Pombie, the valley of Pineta, the Brecha de Rolando, the Ibón de Llosas, the Col D'Albere, the Pic du Midi de Bigorre or Ordesa-Monte Perdido National Park were some of the places selected to shoot all night long. Some winter nights were also lived in Larra-Belagua and in the Valley of Hecho but … those were too hard nights to be narrated here.

We lived under the stars (and clouds) in some of the most spectacular places in the Pyrenees feeling the darkness, the wind, the sounds, the cold… that is, the natural conditions of the night. Above, on the summits, we saw the horizon dyed with artificial light that is perceived as pale white to the naked eye and yellowed in the photographs. But in the valleys the mountains blocked the direct view of the horizon and only the stars and the Milky Way illuminated us. There, the night's experience was complete.

The night in the cities

We also recorded the night in the places responsible for the light pollution we observe from the mountains. We shoot a full night in Pamplona and we toured the Pyrenees visiting some of the major cities: San Sebastian, Biarritz, Pau, Toulouse, Figueres, Girona, Barcelona, Lleida, Jaca, Zaragoza, Tudela and, of course, Pamplona. Most cities are still lit with HP Sodium lamps, but the tendency to use white LEDs is changing this scenario. The lighting industry is deciding for us, once again, the color of our nights.

Conclusion

Producing a fulldome documentary for planetariums that shows the real state of the night in the Pyrenees means that you have to spend many nights living and enjoying the night. The light of the cities, even the big ones located hundreds of kilometers away, can be seen from almost everywhere. Only those valleys where the mountains block the horizon line up to 40º in all directions, are free of light pollution. To the naked eye, artificial light is confused with the natural brightness of the sky because we do not distinguish colors when we are adapted to darkness. But in the photographs, light pollution produces a yellowish background that clearly differs from natural light.

We hope that the current trend of changing HP sodium lamps with white LEDs will end soon and another warmer, more amber light will be used in the near future. This should be mandatory for the villages within the Pyrenees.

Testes histo-morphological changes in laboratory rats, *Rattus norvegicus*, exposed to Artificial Light at Night (ALAN)

Theme: Health

Festus O. Kehinde,[1,*] Gabriel A. Dedeke, [1] Matthew A. Olude [1], Kehinde O. Ademolu[1], Adeyinka A. Aladesida[1] and Fatimo O. Olatunde[1]

[1] *Federal University of AgricultureAbeokuta 1, Abeokuta, Nigeria*
corresponding.festus.kehinde@pg.funaab.edu.ng
[*] *presenting author*

Exposure to artificial light at night is becoming a global phenomenon. Artificial light has been implicated in reproductive dysfunction in female rodent such as polycytic ovarian. Exposure to light at night is presently inevitable hence the need to examine its spectra effect on male reproductive function. Since the effect of light in animal is spectra specific, this study aimed at evaluating the periodic change in testicular histological and testicular weight of albino rats exposed to various light spectral at night. Albino rats were exposed to different light spectra (Blue, Green, Yellow, Red and White) at night (6 pm – 6 am) for 126 days from birth. They were also exposed to ambient light and darkness which served as the control. Compact fluorescence bulbs 11 watts were used and the light intensity maintained between 350 and 300 lux using light meter. At day 63, 91 and 126, rats was euthanized and the testes removed, weighed and fixed in 10 % formalin for histological examination. Testicular weight (TW) was significant ($p < 0.05$) with highest value under BL at days 63, 91 and 126. Rats exposed to YL has the least significantly ($p <0.05$) TW at day 126. TW increased significantly under GL (1.72±0.33 g) and significantly ($p < 0.05$) reduced under YL (0.23±0.25 g) considering the difference between day 63 and 126. Spermatozoa were recorded at day 63 under BL, YL and WL. Tubules had greatest diameter and elongation of seminiferous tubules under BL. Non-specific atrophic degeneration of seminiferous tubules under DD with age. Evidence of displacement and degeneration of the spermatogonia and pyknotic basal cells observed close to the lumen under YL at days 91 and 126. In conclusion, exposure to YL and DD seemed to pose risk to reproductive function while BL and GL enhanced male reproductive function in albino rat.

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Investigation of the spectral response of the environment

Theme: Biology & Ecology

Flóra Siska[1*], Anna Skribanek[2], Magdolna Dani[2], Zoltán Kolláth[3]

[1] Eötvös Loránd University, BDPK, Department of Physics, Szombathely, Hungary
[2]. Eötvös Loránd University, BDPK, Department of Biology, Szombathely, Hungary
[3]. Eszterházy Károly University, Department of Physics, Eger, Hungary

skribanek.anna@sek.elte.hu
[*] presenting author

A recent development in solid-state lighting technology makes it possible to perform tests on flora and fauna with different spectral distributions. We have built controllable light sources which can be used in various field experiments, e.g., to study the phototaxis of insects or in the laboratory to investigate the effect of spectral distribution on photosynthesis. LEDs are the first light sources to have the capability of true spectral composition control, allowing wavelengths to be matched to plant to influence plant development.

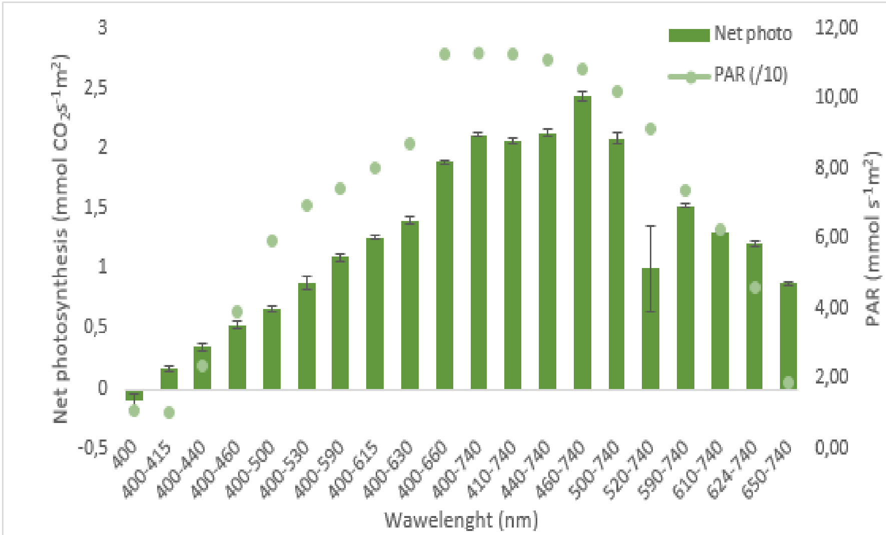
We developed a method to compare the dependence of phototaxis on spectral distribution. First, the insects are trapped to white sheet illuminated by wide wavelength band lighting. Then two other boards at the same distance but lighted with different spectral content switched on. The movement of insects is recorded with digital cameras. With this experiment source with different spectral composition can be compared in the same conditions, excluding the effect of different weather conditions.

Light is a vital source of energy for photosynthesis, and its intensity is closely related to the amount of incorporated CO_2. In the case of angiosperm plants, the synthesis of chlorophyll occurs exclusively in the presence of light, and it is also important for photomorphogenesis control. The light and dark hours can act as a resource for organisms for various physiological processes and changes in the availability of light and dark hours can have positive or negative effects. The visible light up to 700 nm wavelength is utilized in the process of photosynthesis. Spectral sensitivity of pigments involved in light absorption are different, thus there is also different in their recovery.

Net photosynthesis was measured with LICOR 6400 (LI-COR Environmental, USA) photosynthesis system at different light wavelength exposure. Measurements were made on a four-week soybean (*Glycine soja*) plant. Data were collected for 2 minutes; net photosynthesis and transpiration were evaluated. The efficiency of PSII reaction centre ($Y_{(II))}$) of the soybean seedlings grown under different lighting ((400–460 nm (blue); 500–530 nm (green); 615–740 (red); 400–740 nm (control) and natural light) *(Table 1.)* were measured with Imaging PAM-M- series chlorophyll fluorimeter.

	1	2	3	4	5	6	7	8	9	10	11	12
Wawelenght max. (nm)	395	410	440	460	500	525	590	615	630	655	690	735
Wawelenght bandwith (nm)	18	20	20	22	27	35	17	17	18	20	20	24

Table 1. Tested wavelengths with LED illumination



1: Net photosynthesis vs spectral composition

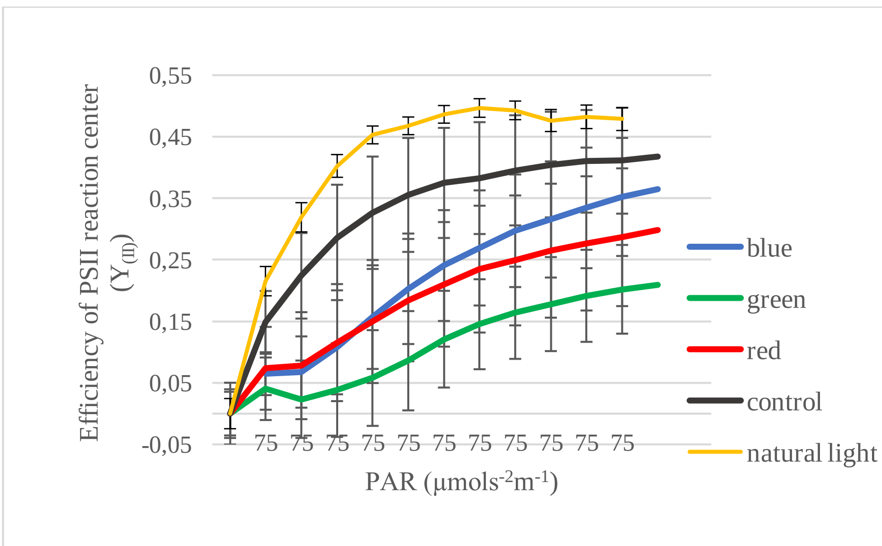


Fig. 2: Fluorescence Yields of PSII reaction centres by different wavelengths

Based on our conclusive results, the transpiration showed a strong correlation with the light intensity and wavelength. The net photosynthesis and yield of PSII reaction centre of the plant is strongly dependent for the wavelength of illumination *(Figure 1 and 2)*. We established the inhibitory effect (photoinhibition) of short wavelength blue light (under 400 nm) *(Fig. 1.)*. The net photosynthesis and yield of PSII rection centre of the plant depended on the wavelength of the illumination to a large extent *(Fig. 1.)*. The developments of photosynthetic systems showed also deviation for plants grown under different light quality *(Fig. 2.)*. The development of photosynthetic system and the efficiency of 2nd photochemical system were inhibited under green light compared to the natural light, but the red and blue wavelength illumination resulted also inhibited photochemical activity.

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Feeding of a diurnal caterpillar increased directly by artificial light at night, but not indirectly via effects on host-plant quality

Theme: Biology & Ecology

Geoffrey D. Miller,[1,*] Melissa H. Hey,[2] Lauren K. Emer,[3] Madaris C. S. Perez,[4] and Kyle J. Haynes[2,5]

[1] University of Minnesota, St. Paul, USA
[2] University of Virginia, Charlottesville, USA
[3] University of Puerto Rico, Humacao, USA
[4] Florida International University, Miami, USA
[5] Blandy Experimental Farm, Boyce, USA
mill8849@umn.edu
** presenting author*

Introduction

In recent years a multitude of pathways through which artificial light at night (ALAN) affects the individuals and populations of terrestrial insects have been identified (Owens et al. 2019). For example, under ALAN, nocturnal moths have been found to exhibit reductions in feeding (van Langevelde et al. 2017), reproduction (van Geffen et al. 2015), and predator-avoidance (Wakefield et al. 2015). In contrast, little is known about the impacts of ALAN on diurnal insects. In this study, we tested whether ALAN has direct and indirect effects (via effects on host-plant quality) on the feeding behavior and performance of a diurnal herbivore, the monarch butterfly (*Danaus plexippus*).

Methods

First, we grew common milkweed (*Asclepias syriaca*) in a greenhouse under either natural ambient light (i.e., no ALAN) or with broad-spectrum ALAN added at night, and tested for effects of ALAN on nutritional quality (water content, percent nitrogen) and anti-herbivore defense traits (trichome density, latex exudation) of plant foliar tissues. To test for indirect effects of ALAN on the feeding preferences of the diurnal herbivore, we carried out feeding trials in which caterpillars were presented with leaf material collected from experimental plants that were grown either under ALAN or ambient light. We tested for indirect effects of ALAN on herbivore performance by rearing caterpillars on diets consisting of host-plant leaves collected either from plants grown under ALAN or ambient light and comparing pupal weights. Next, we tested for direct effects of ALAN on the feeding behavior by comparing feeding frequency between caterpillars exposed to ALAN and caterpillars

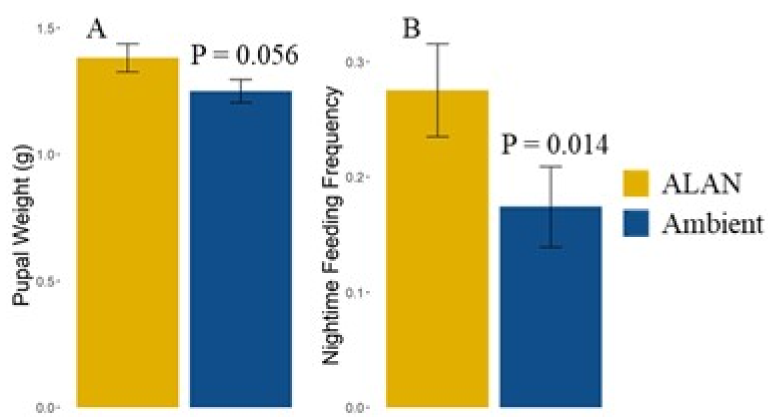

Fig. 1: Monarch caterpillars exhibited increased pupal weight (A) and frequency of feeding at night (B) when exposed to ALAN during development. Values are mean ± SE.

exposed to ambient light. Finally, we examined the direct effects of ALAN on herbivore performance by testing for differences in pupal weights between caterpillars reared under ALAN or ambient light.

Conclusions

There was no evidence that ALAN affected the growth, nutritional quality or defensive capabilities of common milkweed, nor were there indirect effects of ALAN on caterpillar preference or performance via effects of ALAN on common milkweed. However, compared to monarch caterpillars not exposed to ALAN, those directly exposed to ALAN exhibited 58% higher feeding frequency at night and showed a marginally significant 10% increase in pupal mass (Fig. 1). Our study is the first to show direct effects of ALAN on the feeding frequency of a diurnal insect herbivore. These findings suggest that exploring the impacts of ALAN on diurnal insects represents an important avenue of future research.

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Learning from Newport, Ireland

Theme: Technology and Design

Georgia MacMillan,[1,*] Brian Espey,[2] Marco Palandella[3] and Roberto Corradini[3]

[1] *Friends of Mayo Dark Skies, Newport, County Mayo, Ireland*
[2] *Trinity College Dublin, Dublin, Ireland*
[3] *Lighting Design Workshop, Casale Monferrato-San Michele al Tagliamento, Italy*
mayodarksky@gmail.com
[*] *presenting author*

Introduction

Newport, County Mayo, is a beautiful heritage town in the West Ireland. Situated at the edge of Clew Bay on the Atlantic Coastline, it is a charming rural town surrounded by natural habitats and wild landscapes. It is the gateway town to many scenic tourist attractions such as Wild Nephin Ballycroy National Park, the Nephin Beg mountains and Clew Bay.
In May 2016, a Gold Tier standard of International Dark Sky Park was awarded to Wild Nephin Ballycroy National Park, known as Mayo International Dark Sky Park (Mayo Dark Sky Park).

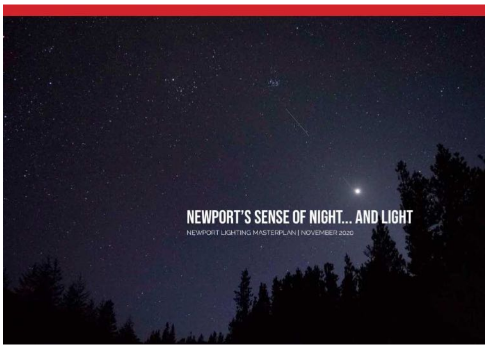

Fig. 1: Cover page of Newport Lighting Master Plan – 2020 (image by authours)

In order to safeguard the future of the International Dark Sky Park, a valuable sustainable tourism asset to the area, it is necessary to protect the surrounding area from increasing light pollution. Therefore, a lighting master plan was developed for Newport with objectives to protect the dark sky area; to enhance the nocturnal environment of the town; and to serve as an example for other sites.

To the best of our knowledge this collaborative project, initiated by the community and not by the local authorities, is the first of its kind. We will report on our approach, show some examples of our work, and provide some lessons learned from the project.

An holistic teamwork's approach

Recognising the increase in light pollution from Newport town, the Friends of Mayo Dark Skies, a community group affiliated with the Dark Sky Ireland network and a chapter of the International Dark Sky Association asked Lighting Design Workshop, to address the issue.

Thanks to the financial support of The Heritage Council (An Chomhairle Oidhreachta) the team was created in September 2020 and began a concentrated effort to research themes of relevance to the local community including biodiversity, heritage, traffic volumes, outdoor lighting, night sky observation and the development of dark sky philosophy and illumination science.

Methods

Due to the global pandemic situation, all the design and scientific work was managed and completed remotely. We firstly built a shared framework for the Lighting Master Plan and thanks to a careful planning, we held weekly online meetings with the key stakeholders in order to review research, share proposals and discuss the critical issues. An online repository (via Google Drive) was used as a tool for storing photos of sites, design sketches, scientific papers and stakeholders' contribution. The project team shared the views of various stakeholders with the intention of creating a bespoke plan for the town of Newport.

Despite working to such a short timeframe, the level of enthusiasm and dedication from the team produced some impressive results, which were submitted to the Heritage Council in advance of the agreed deadline.

Conclusions

Protecting, maintaining and improving the beauty of the night skies enjoyed by visitors to Mayo Dark Sky Park whilst also improving the quality of life in Newport's urban and rural environmental settings, was a moral imperative. The shared vision presented in this project will allow the community and visitors to safely enjoy Newport's unique architectural heritage, against a beautiful backdrop of a natural night sky, free from light pollution. Ultimately, the successful preservation of the night sky in this beautiful area will depend upon the implementation of this plan by the local authority, however, the initial response has been very positive.

The authors hope the holistic approach and the visible benefits of Newport's Lighting Master Plan could be shared with other Irish and Europeans towns.

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Dark sky tourism and the need for a new academic network

Theme: Society

Hannah S. Dalgleish,[1,2,*]

[1] University of Oxford, Oxford, UK
[2] University of Namibia, Windhoek, Namibia
hannah.dalgleish@physics.ox.ac.uk
[*] presenting author

Dark sky tourism (DST) makes use of unpolluted nightscapes while empowering rural communities and providing travellers with a sustainable, meaningful, educational, and cultural experience. DST's popularity has been ever-increasing, especially due to a desire to reconnect with nature in addition to rising light pollution, caused by urbanisation and the introduction of white light-emitting diodes (LEDs). Despite its worldwide appeal – and the increase of dark sky oases in recent years – DST has been little researched. Out of a need for more evidence and understanding behind DST, rose a desire to foster a new community. This has led to the successful creation of a dark sky tourism network, bringing academics together from a wide range of disciplines. This newfound collaboration offers a great deal of scope to contributing to academic knowledge.

Given the current pandemic and the climate crisis, it is paramount that we decarbonise tourism and find sustainable solutions (Gössling & Higham, 2020), for which DST has the potential to be a part. Of the limited scholarly output to date, dark sky tourism has repeatedly shown its relevance to several of the UN's seventeen Sustainable Development Goals (SDGs[1]; Fig. 1). Economically, DST can generate significant income for a region, creating jobs and extending tourism activity into off-peak times (Mitchell & Gallaway, 2019). Environmentally, the minimisation of artificial light at night lessens interference with freshwater, marine, and terrestrial wildlife (Davies & Smyth 2018) and reduces unnecessary carbon emissions. DST presents educational opportunities for tourists and local residents, covering topics from astrophysics to light pollution (Blundell et al. 2020), and empowers women in rural, underprivileged areas (see e.g., Astrostays[2]). Stargazing is also known to promote health, well-being and connectedness with nature (Bell et al. 2014).

The DST network initially brought together a novel and cross-disciplinary group of physical and social science experts from between the UK and Ireland[3]. First and foremost, the network is inclusive – all are welcome to join. Our goals are to pursue new and exciting avenues of research; collaborate, engage and share our findings with practitioners, the tourism industry and policy makers; and to empower early career researchers. Together, we have already identified many areas of interest, such as the potential of DST during a global pandemic; how DST is perceived and taken up by local communities versus tourists; how DST can help to preserve indigenous knowledge; and the impact of DST upon the planet. I will share this year-long journey of creating and developing the DST network as an early career researcher, despite the limitations of remote working, as well as the outcome of our inaugural meeting in April 2021.

[1] https://sdgs.un.org/
[2] https://astrostays.com
[3] Fields have since expanded to include tourism, light pollution, sustainable development, cultural heritage, environmental psychology, public health, light pollution, human geography, art, ecology, education, science communication, and astrophysics.

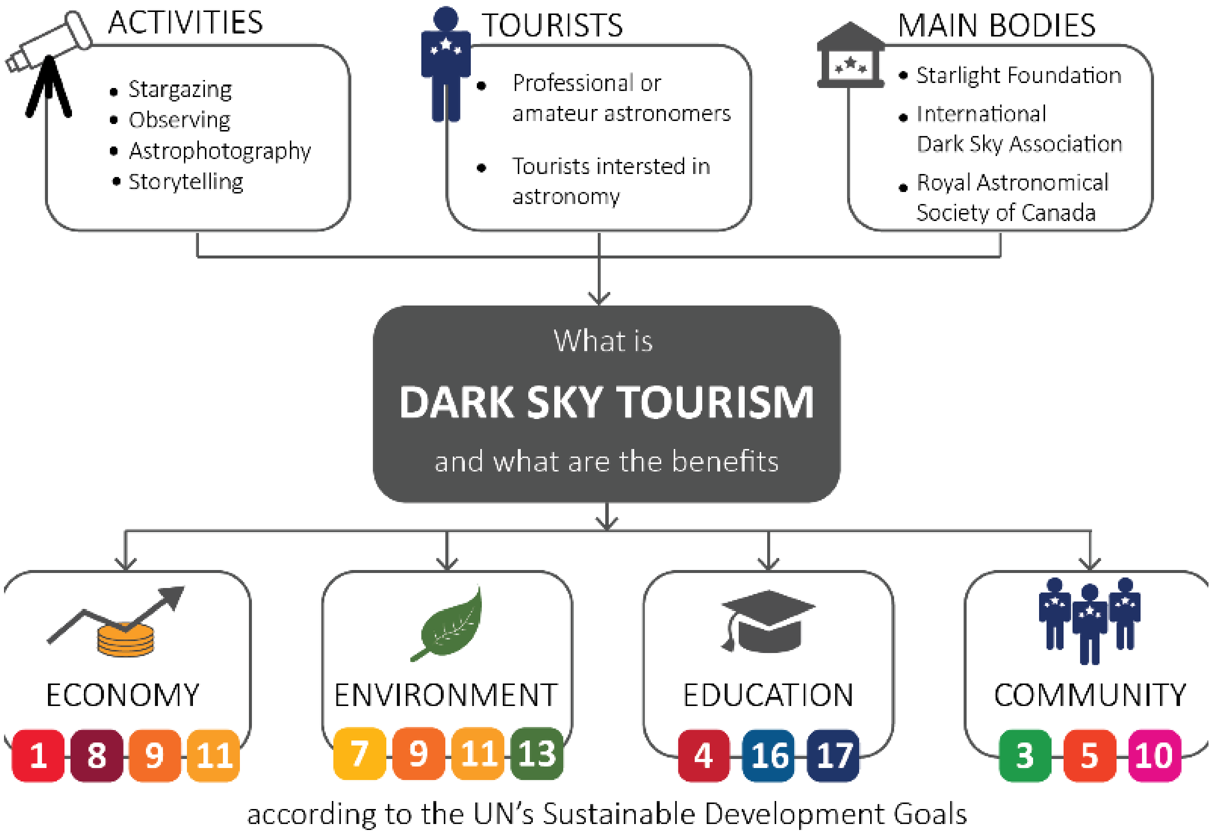

Fig. 1: Dark sky tourism has strong links to at least twelve of the United Nations' seventeen Sustainable Development Goals. Credit: Dalgleish & Bjelajac (2021)

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SkyMeAPP: a citizen science project to study light pollution

Theme: Measurement & Modeling

Héctor Lamphar

[1] *Conacyt 1, Querétaro, México*
hasolanola@conacyt.mx

Introduction

Citizen science encourages the public to collect data in a variety of habitats and locations over different periods of time. Citizen science projects have been remarkably successful in advancing scientific knowledge, and the contributions of citizen scientists now provide a wealth of data on the occurrence and distribution of different research problems worldwide. Most citizen science projects also strive to help participants learn about the topics they are observing and experience the process to conduct scientific research. Developing and implementing public data collection projects that produce both scientific and educational results require significant effort. Light pollution is a recently studied environmental problem worldwide and affects not only the performance of astronomical activities but also has biological effects on photosensitive organisms, including humans. Light pollution is spreading continuously, which results not only in high amounts of wasted energy but as well in injudicious, harmful over illumination of natural environments (Rich and Longcore 2006). To comprehend the properties of the artificial light at night (ALAN) is essential in modelling the nocturnal radiance in a diverse nocturnal atmosphere.This article describes the model for building and operating a citizen science project that is expected to contribute to the study of light pollution.

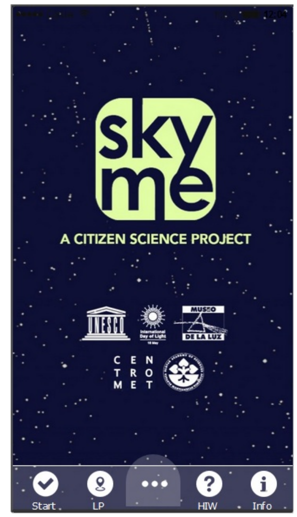

Fig 1: Main page of the SkyMeAPP.

Methods

The SkyMeAPP project is carried out to contribute to the study of light pollution worldwide through the scope allowed by citizen science. The above, through three main axes: collect information for research, generate a link between the general public and the scientific community, and generate interest from the public regarding light pollution. Two efforts are considered to support the project: a website and the creation and dissemination of SkyMeAPP for mobile devices. The application covers two main areas: the classification of georeferenced photographs and the user interface. The interface, based on the visualization of the device's geolocation, has two main objectives. The first, to lead users to work as a team and generate a community interested in using the application. The second is to tell users about the state of light pollution in their city or region in order to obtain information from different places.

Conclusions

This work addresses the importance of citizen science in modelling the emission function and all the factors involved in its characterization. In this sense, we are presenting the SkyMeAPP (fig. 1); a project that has the aim of contributing to the worldwide study of the emission function of ALAN through the advantages of citizen science. Specifically, it follows three main goals: (1) to gather data for research; (2) to generate networks among the general public and the scientific community; (3) to bring attention to society regarding light pollution.

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A methodology for a light pollution network with optimal sensor location

Theme: Measurement & Modeling

Héctor Lamphar[1], Rodrigo López

[1] Conacyt 1, Querétaro, México
hasolanola@conacyt.mx

Introduction

The design criteria for a light pollution monitoring network must meet the objectives of the environmental monitoring program that governments have defined as priorities for the different zones to be analyzed. The monitoring activities in this case should be directed to the most sensitive environment. The levels of concentration imply new conditions in the selection of sampling methodologies, number of data and frequency of sampling in addition of a good statistical management of the data to have reliable results. On a large scale, cities are heterogeneous (fig. 1). Several logics lead to a differentiation of the urban space: the economic ones that determine the value of soil, the social ones that imply a regrouping by similarity, the spatial ones, among others. The city can be considered as an element of observation and measurement. It is configured as a mosaic, as a differentiated space in areas that are characterized by their population and by the predominance of certain activities. The business center, residential areas, industrial areas, periurban area, among others. For this reason, when establishing a monitoring network these differences should be considered. Specifically, in the topic of light pollution, the monitoring network must be distributed according to the lighting needs represented by the city. In the case of images, the distribution is considered according to the poles of attraction of the city; that is, the nodes where the pixels have a higher value.

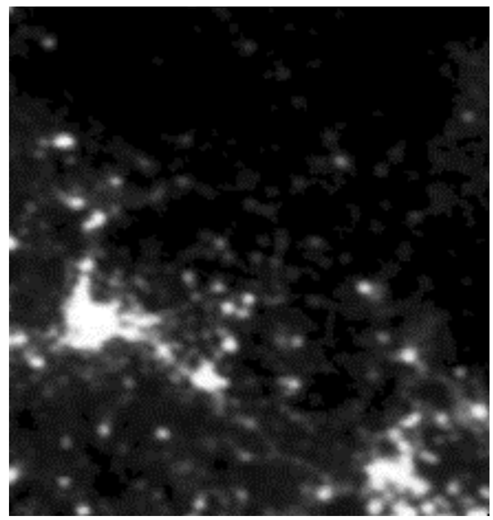

Fig. 1 Image used in the experiment.

Methods

We assume the light pollution satellite images have light concentration centers that spread the light around with certain decaying. This decaying can be modeled with a radial basis function e.g., a gaussian model. In order to find a good sensor location, we look for areas where a radial basis function model describes with certain detail level the spread of light.

The first approximation we propose, is the use a basic k-means clustering algorithm to decompose in groups a binary image, where 1 means the existence of light pollution. K-means clustering algorithm is a variant of a Gaussian mixture model, where a gaussian distribution is a kind of radial basis function assuming that the clusters we will find has the same variance for each dimension (murphy 2013).

Conclusions

Cities need to monitor the environmental problems they face. Light pollution can be theoretically modeled; However, experimental physics is necessary not only to have a constant monitoring, but to validate the theoretical models and make them more robust. The main contribution of this work is the generation of an efficient and effective monitoring model, in such a way that it is possible to use the sensors in disposal with the best likely benefit. It is important to define the scope of the monitoring devices, as well as the spectrum to be analyzed in each of them, thus achieving an efficient monitoring strategy. An advance of this work will not only determine the ideal location of the sensors, but also the decision of the variables to be monitored, the location of the stations, and the estimation of the sampling frequency.

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Sky brightness simulation with Illumina over locations from the Pyrenees Pyrenees La Nuit Project

Theme: Measurements & Modelling

Hector Linares,[1,2,*] Eduard Masana,[2] Salvador J. Ribas,[1] Martin Aubé,[3] Salvador Bará,[4] Alexandre Simoneau[5]

[1] Parc Astronòmic Montsec, Àger, Spain
[2] Institut de Ciències del Cosmos (ICC-UB-IEEC), Barcelona, Spain
[3] Département de physique, Cégep de Sherbrooke, Sherbrooke, Canada
[4] Universidade de Santiago de Compostela, Santiago de Compostela, Galicia
[5] Université de Sherbrooke, Sherbrooke, Canada
h.linares.arroyo@gmail.com
** presenting author*

Pyreness la Nuit is an international project financed by the EU that aims to protect and ameliorate the night natural darkness in the Pyrenees area. One of the major scientific goals of the project is to establish a methodology that allows to recreate the night sky dome over any location within the borders of the Pyrenees.

The team has been working on this for almost four years. The work started by simulating the artificial radiance received in the Parc Astronomic Montsec (partner involved in the project) from a mid-distance city, Lleida, using Illumina light pollution model (Aubé 2005, 2018). Then it followed by showing that the model can appreciate changes in street lighting of this city, simulating the radiance received before and after a street lighting change that took place in 2014 (Linares 2018). As Illumina is very time consuming, we needed a way to know which cities and towns affect the sky over a specific location before using the model to create all-sky maps. We used the methodology presented by Bará and Lima (2018) to create light pollution contribution maps by municipalities. These maps show the percentage of contribution from each municipality to the total artificial radiance received in the observation point. The know-how acquired working with Illumina allowed us to derive ad-hoc point spread functions (PSF) using the model. We used the PSF to create contribution maps for the Parc Astronomic Montsec in the B, V and R filters of the Johnson-Cousins system. The information of those maps was used to decide which sources had to be included for simulating all-sky maps of that location (Linares 2020).

The methodology is now applied to study the night sky over eight locations in the Pyrenees and its area of influence (see figure 1). For each of them contribution maps and all-sky maps are presented. Satisfactory levels of correlation have been achieved between simulations and measurements for the night sky brightness at each location. The typical deviation is below 0.2mag. That is of the order of magnitude of the variations observed due to atmospheric condition, Milky Way presence and other phenomena.

A new version of Illumina light pollution model has been released recently (Aubé 2020). Using some of the locations studied we present a preliminary comparison between both versions of the model.

Fig 1. Locations studied. A: Parc Astronomic Montsec. B: Centre Astronomic Prades. C: Montgarri refuge. D: Monsant Natural Park. E: Aigüestortes Natural Park. F: Orri Peak. G: Pico Larra. H: Pic du Midi de Bigorre. *Google Earth*, earth.google.com/web/.

The methodology presented is very useful to estimate with great precision the quality of the night in terms of brightness with no need of measurements, which is especially useful for remote places. It also helps identifying main pollutant sources and it allows to study the implications of changes in street lighting before they are applied, preventing this way the worsening of the quality of the night.

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Nachtlicht-BüHNE: update on the German citizen science project to create large area lighting surveys

Theme: Measurement & Modeling

Helga U. Kuechly,[1,*] Yiğit Ö. Altıntaş,[1] Nona Schulte-Römer,[2] Andreas Hänel,[3] Eva C. Weiss,[4] Normän Naboulsi, [4] Sabine Frank,[5] Sicco Bauer, [4] and Christopher C. M. Kyba[1]

[1] *GFZ German Research Centre for Geosciences, Potsdam, Germany*
[2] *Helmholtz Centre for Environmental Research – UFZ, Leipzig, Germany*
[3] *Dark Sky Working Group VdS*
[4] *Citizen Scientist*
[5] *Sternenpark UNESCO Biosphärenreservat Rhön*
kyba@gfz-potsdam.de
[*] *presenting author*

Synopsis

Nachtlicht-BüHNE is a co-designed citizen science project which investigates the proportion of different types of outdoor lighting. We are developing an app that allows citizen scientists to do lighting surveys. The two main research questions we address are: How much of the light in satellite imagery (e.g. Fig. 1) comes from which types of light sources? How does this proportion change when you change settlement context (from village to town to city center)?

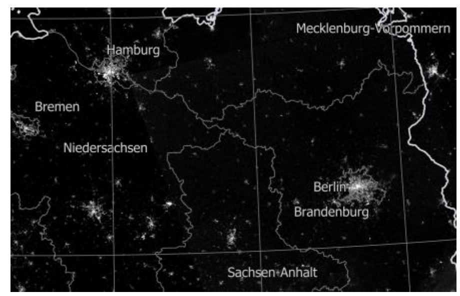

Fig. 1: Artificial lights of northern Germany, observed from Luojia-1. Image courtesy Jacqueline Coesfeld.

Background

At the moment, the relative light emissions from different source types (e.g. streetlights, advertising, façade lighting, and light escaping from windows) is not known. Several researcher groups have examined the relative fraction due to street lighting, and have come up with values ranging from 12-100% (Kyba et al. 2020). This uncertainty poses several problems for remote sensing, for example in understanding the relationship between energy and light emissions observed from space. It is also a problem for skyglow simulation, for example because light reflected from the ground and horizontal surfaces propagate in different directions.

Project overview

The app is currently in development. It is based upon initial surveys that we conducted using pen and paper in 2018 and 2019. A major challenge was to categorize the great variety of outdoor lighting into a manageable number of classes. The participation of our team of about a dozen highly-motivated citizen scientist co-designers was of great value here. Another challenge was to develop an app within a constrained budget. To avoid costly revisions after the app was already developed, the project leaders developed a detailed flowchart showing the entire app functionality, and this was improved through several rounds of constructive criticism and discussion with the citizen scientist co-design team.

During August to October, 2021, we will conduct a set of measurement campaigns in different regions of Germany covering areas ranging in size from 0.5 to 2 km^2. Within these regions, a set of street segments (generally from one corner to the next) will be predefined, based on Open Street Map data (Fig. 2). Citizen scientists will survey all of the lights visible from each of these street segments. These local campaigns will be planned and coordinated by citizen scientists, with support from the institutional scientists. These data will then be compared to satellite imagery from Suomi NPP, Luojia-1, as well as aerial photography from Cologne from the CALEC project. In order to facilitate comparison with DNB imagery, at least three of the regions will cover 2 km^2 area. Participants from around the world will also be able to use the app by defining their own transects. However, we do not plan to analyze such data.

Fig. 2: Transects assigned to a given area (right) are developed based upon Open Street Map data (left).

The project is part of the CitizenScience@Helmholtz initiative. The German word *Bühne* means “stage”, and the project name means “Network of citizen and Helmholtz researchers studying night light phenomena”. Together with a sister Nachtlicht-BüHNE project studying fireballs, we aim to demonstrate the compatibility of co-designed citizen science with the overarching Helmholtz mission to solve the grand challenges of science, society and industry.

Methodological details

We have categorized outdoor lights into a set of 18 types. For most categories, we have a second attribute, for example the level of shielding for “lights mounted on buildings”, or the size for “lit advertisements”. Illuminated areas will estimated via proportion to human dimensions (Fig. 3). An “expert mode” for the app will allow participants to report the color of the lights (white, orange, or other), as well as their perceived brightness (exceptionally faint, normal, or exceptionally bright).

Participants will need to complete an online tutorial before they can submit data, in order to ensure standardized data collection. The tutorial is currently being developed by a team of undergraduate students from Worcester Polytechnic Institute in USA, in cooperation with our team of citizen scientists. The tutorial training is based on a large set of images of each type of lamp class, taken by our citizen scientists and other contributors from around the world. These images are all released under a CC0 (public domain) license.

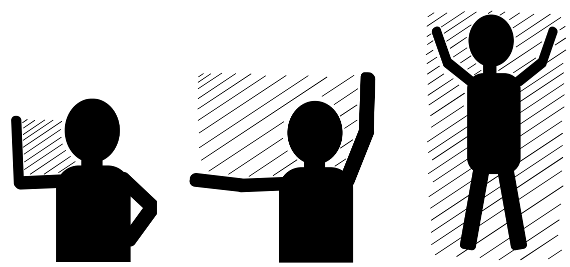

Fig. 3: Example of size classes within the app.

Acknowledgements

We thank the rest of our team of citizen scientist co-developers who chose not to be listed as co-authors. This work was funded by the Helmholtz Association Initiative and Networking Fund under grants CS-0003 and ERC-RA-0031, and from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 689443 via project GEOEssential.

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ART IN THE CITY OF LIGHT IN AN ERA OF INNOVATIVE *ÉCLAIRAGE*

Theme: Society

Hollis Clayson[1,*]

[1] Northwestern University, Evanston, Illinois, USA
shc@northwestern.edu
[*] presenting author

Interest in the aesthetics of light shaped the work of countless modern artists across the far-flung art worlds of the transatlantic. The bond between innovative art and light was especially pronounced in France, and the Paris region was at the center of this artistic fascination. But Paris light was compelling for a reason that is routinely overlooked: the capital city's prominence in the development of new illumination technologies. Indeed in order to come to grips with the connections between art and light in *La Ville Lumière* (the City of Light), *éclairage* (lighting) and *lumière* (light) must be uncoupled. Recognition of the difference is logical but also imperative because *éclairage* was a foremost characteristic of nineteenth-century Paris – one of the three largest world cities, the international headquarters of contemporary art, and *La Ville Lumière* (The City of Light). Improvements in lighting helped in fact to define the cultural and technological landscape of the French capital city during the entire course of the 1800s. For some artists enthralled by light, aesthetic curiosity about night and its artificial illuminations coexisted with the better-known love affair with the nuances of daylight. My lecture will present a sequence of Paris-based art practices, dating from the 1850s to 1890, which were guided or at least provoked by artificial illumination. Patterns of disavowal as well as artistic interest in the new lighting will be considered.

Pyrenees La Nuit: Impact of artificial light at night on nocturnal Lepidoptera in the Western Pyrenees

Theme: Biology & Ecology

Iker Pardo,[1*] Enrique Vergara[2] and Carlos Armendariz[2*]

[1] *University of the Basque Country UPV/EHU, Dept. Plant Biology and Ecology, Leioa, Spain*
[2] *Gestión Ambiental de Navarra S.A. GAN-NIK. Área de Biodiversidad, Pamplona/Iruña, Spain*
carmendg@gan-nik.es
[*] *presenting authors*

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Introduction

For nocturnal flying insects, a group with widespread flight to light behavior, ALAN is considered an important ecological threat, causing temporal and spatial disorientation, desensitization, and enhanced predation risk (Owens & Lewis 2018). The attraction of flying insect to ALAN depends to a great extent on the intensity and spectral composition of light sources (Gaston et al. 2013). Changes in outdoor lighting technologies (i.e. streetlight lamps) can therefore have large impacts on insect populations.

Fig. 1: One of the interception traps used to capture flying insects attracted to ALAN in the Western Pyrenees.

Mercury vapour (MV), ceramic metal halide (CMH) and high-pressure sodium (HPS) are among the most frequent lamps used for street lighting in Europe. Comparative studies have shown that lamps emitting short wavelengths such as MV and CMH attract more insects than HPS lamps. These conventional lamps are being replaced by more energy-efficient light-emitting diodes (LEDs). However, it is unclear whether this shift in light technology would reduce negative impacts on flying insects (Wakefield et al. 2017). Although both warm and cold white LEDs have lower UV emissions than MV and CMH lamps, they are still rich (and richer than HPS lamps) in blue and green wavelengths that are also attractive for insects (van Grunsven et al. 2020). Phosphor-Converted Amber LEDs (PC-A) that were originally developed to reduce skyglow near astronomical observatories, have an improved light spectrum with emissions concentrated towards larger wavelengths; hence these novel LEDs are expected to be more wildlife friendly than white LEDs (Ixtaina & Sanhueza, 2016). However, this remains to be tested in field conditions.

In this study we assessed the attraction of macro-moths to different types of lamps located in small villages of the Western Pyrenees, one of the less light polluted spots of the Iberian Peninsula. These villages are surrounded by similar natural habitats (conifer and riparian forests), which are home of the endangered moths *Graellsia isabellae* and *Proserpinus proserpina.* No street lighting policies have been adopted in the region so far, and as a result, existing streetlight technologies varies from one village to another, and even within a village. Most villages have begun to retrofit streetlight with white LEDs, whereas a few others have recently switched from conventional technologies to PC-A.

Methods

We monitored 6 different types of lamps (MV, CMH, HPS, warm and cold white LEDs and PC-A) over the peak of activity *of G. isabelae and P, proserpina* (May 1st to July 1st) by using flight intercept traps hanging from street lights (Fig. 1). Multiple lighting parameters were measured in the field to characterize the actual intensity and spectral composition of each lamp. We analyzed differences in the number of captured individuals and species among type of lamps by using generalized linear mixed models. This analysis was repeated for each of the most abundant Lepidoptera families and *G. isabellae* by using Zero-inflated Poisson models when necessary.

Conclusions

By analyzing 1625 specimens of 135 species of macro-moths systematically collected in 29 traps distributed across 12 villages, we found that MV and CMH attracted more macro-moths than any other type of lamp. However, differences in total captures and within most abundant families were only statistically significant in the case of PC-A. The number of captured species was also significantly lower in PC-A than in white LEDs and traditional lamps (MV, CMH and HPS). Regarding endangered species, no individuals of *P. proserpina* were captured over the study, whereas several individuals of *G. isabellae* were captured in all but one type of light: PC-A.

Taken together, our results urge to replace conventional streetlights of VM and CMH to reduce overall impacts of ALAN on nocturnal macro-lepidoptera and potential cascading effects. Our study also stresses that detrimental effects of massive deployment of LEDs on macro-moths are likely to be large unless the emission of short wavelengths (<500 nanometers) are controlled. We therefore encourage local authorities to consider existing wildlife friendly alternatives to white LEDs. The switch from conventional lamps to PC-A cannot only improve the quality night sky for observation, but as shown in this study, contribute to lessen negative impacts of ALAN on macro-moth populations, including those of the endangered G. isabellae.

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ASTMON and Sky Quality Camera: two devices and the same sky, but same results?

Theme: Measurement & Modeling

Immaculada Garrofé[1,*], Salvador J. Ribas[2,*], Ramon Canal-Domingo[2]

[1] Master en Astronomía y Astrofísica, Universidad Internacional de València(VIU)
[2] Parc Astronòmic Montsec – Centre d’Observació de l’Univers
sjribas@parcastronomic.cat
[*] presenting author

Measuring night sky brightness (NSB) has been a complicated task with some kind of instruments leading to different real methods of measurements. Nowadays the main methods to evaluate NSB, from the ground, are well identified (see Haenel et al. 2018) but sometimes the difference of what each instrument is measuring can generate confusion (see for example LoNNe intercomparison campaign reports Ribas et al 2016a or Kyba et al 2015).

One of the best methods to evaluate NSB is the use of all sky devices or mosaic techniques to reproduce all skies images (Jechow et al 2017,2018 or Kolláth et al 2017). This technique has an important problem with the calibration of data obtained. One of the options is the use of stars as calibrator; this is the proposal of ASTMON device and automatic software (Aceituno et al 2011) or some parallel developed software as PyASB (Nievas 2013). Alternatively the use of DSLR cameras has provided a good opportunity for all sky measurements and mainly they are calibrated in laboratory or by intercomparison. The data processing of DSLR data can be done by commercial software as Sky Quality Camera or by open source code like DicaLum (Kollath et al 2017).

Here we present a comparison of data obtained in six different places with both devices (ASTMON vs DSLR + Sky Quality Camera) to check the agreements and disagreements of both instruments and methods. Unfortunately a major issue with ASTMON device did not allow us to increase the database, but with the six sites we have really different setups (dark sites, light sources or clouds) so we have analyzed different situations.

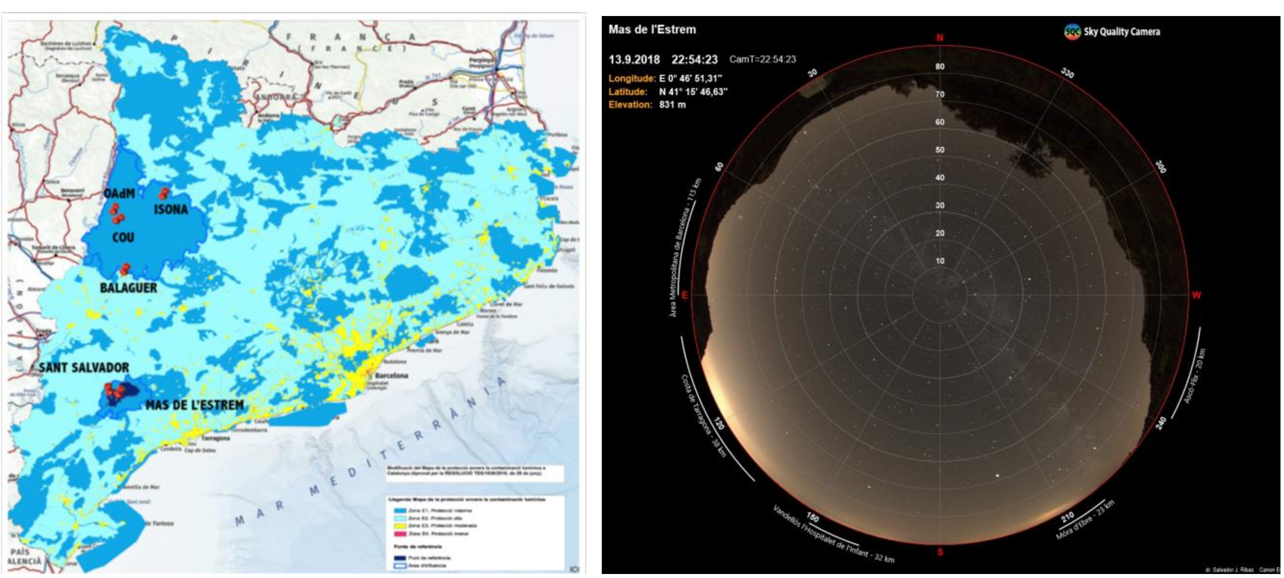

Fig. 1: Map with the position of the six used locations (left panel)
Sample image obtained in Mas de l’Estrem with DSLR camera (right panel)

ASTMON data has been processed using PyASB (Nievas 2013) and DSLR images has been processed using commercial software Sky Quality Camera SQC (Euromix Ltd). With both procedures we have subtracted night sky brightness of each image to compare and discuss the discrepancies and possible reasons.

We can conclude that both systems obtain extremely similar results at higher altitudes from horizon (60-90º) in all studied conditions. This accuracy always reduce in approaching to horizon but it is still very good in the range 25-90 degrees, and sometimes more close to horizon.

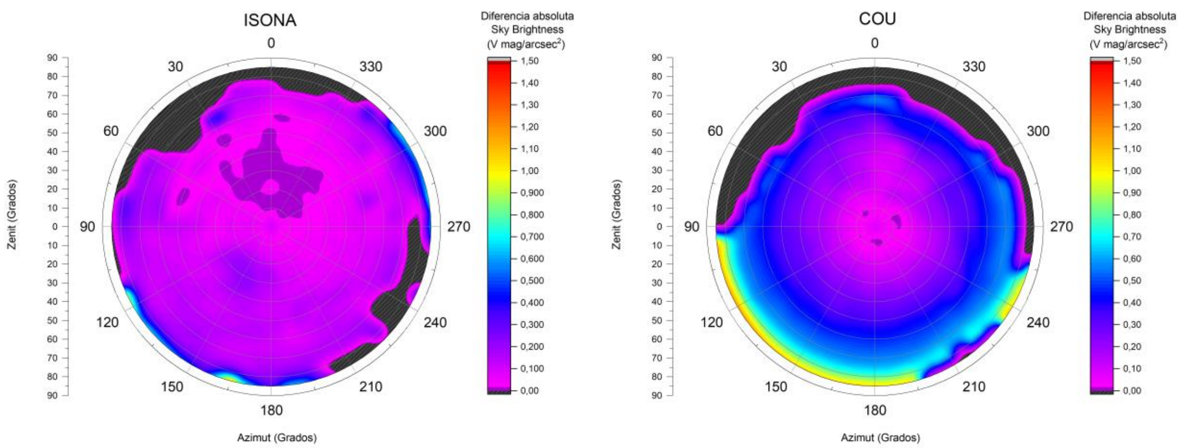

Fig. 2: Plots showing absolute differences in magnitude on two sites. The left site is very cloudy (low-mid clouds) and differences are smaller than in the right case with high clouds on the horizon.

The best fittings appears when there are not direct effect of lights in the field of view or high clouds. So in dark sites with clear conditions or with low-mid clouds seems both systems are fully compatible. The effect of the clouds in this comparison could be explained because high clouds in dark sites could be illuminated by long distance sources in front of low clouds that are darkening the sky blocking the natural sources (Ribas et al 2016b).

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AZOTEA: (Zenithal astronomy during & after the lockdown)

Theme: Measurement & Modeling

Jaime Zamorano,[1,2,3*] Rafael González,[1,8] Salvador Bará,[4] Sergio Pascual,[1,2] Jaime Izquierdo,[1,3] José Luis Navarro,[4] Ignacio Hilera,[5] Jesús Gallego, [1,2,3] Nicolás Cardiel, [1,2,3] José Robles,[1] Alejandro Sánchez de Miguel, [6,3] Cristóbal García, [8] Esteban González, [9] and Lucía García[1]

[1] Departamento de Física de la Tierra y Astrofísica, Universidad Complutense de Madrid, Spain
2 Instituto de Física de Partículas y del Cosmos, Univ. Complutense de Madrid, Spain
3 Agrupación Astronómica de Madrid, Spain
4 Departamento de Física Aplicada, Universidad de Santiago de Compostela, Spain
5 Agrupación Astronómica de Cuenca, Spain
6 Sociedad Astronómica de Alava-Arabako Astronomia Elkartea, Vitoria, Spain
7 Environment and Sustainability Institute, University of Exeter, United Kingdom
8 Agrupación Astronómica AstroHenares, Coslada, Spain
9 Ontology Engineer Group, Universidad Politécnica de Madrid, Spain
jzamorano@fis.ucm.es
[*] presenting author

Introduction

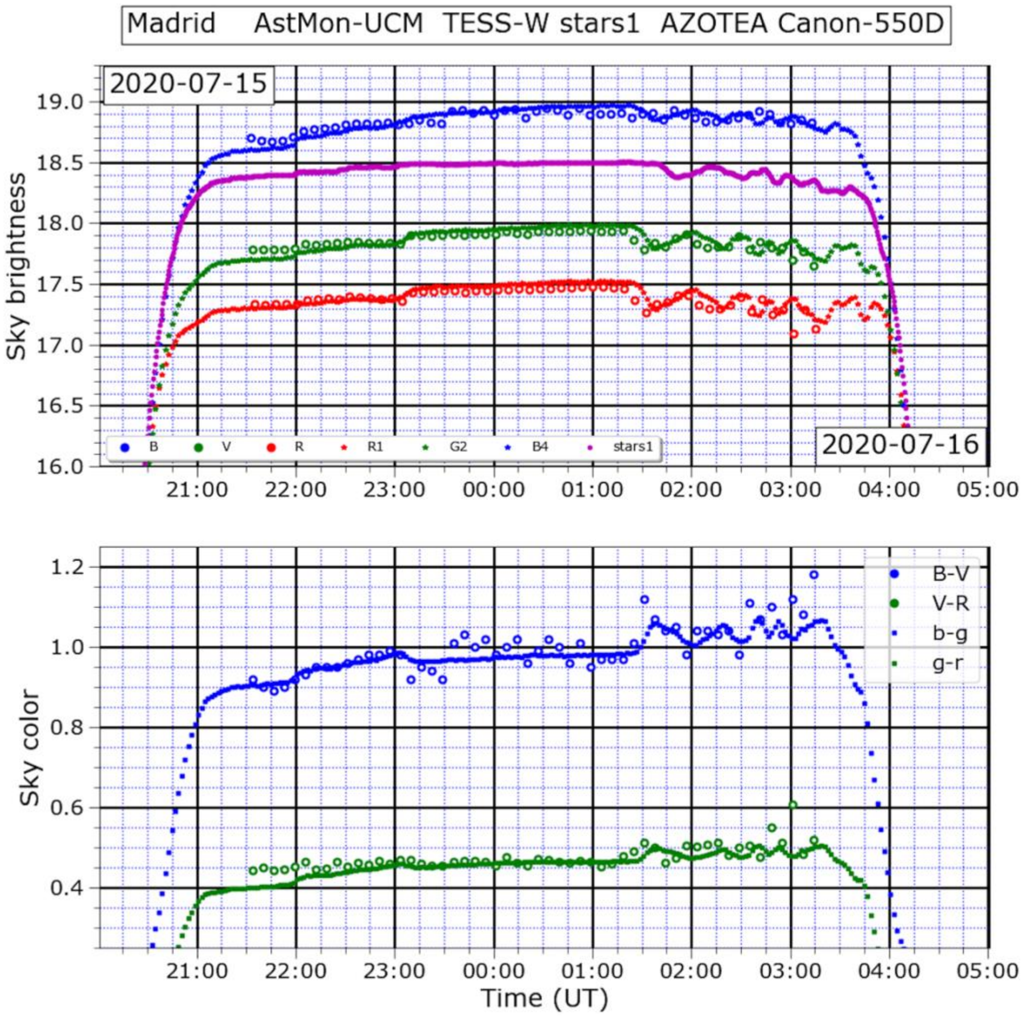
The brightness of the night sky varies depending on the lights on the street, the movement of cars and the activity of the offices. There is a sharp increase in darkness when, by law, the ornamental lights go out at 12 at night. This project tries to detect variations in this brightness produced by the lock down to stop the advance of COVID-19. From this difference the contribution by human activity in sky brightness can be estimated. This is a citizen science project of ACTION, ACTION (Participatory science toolkit against pollution) European project (Horizon 2020, SwafS programme).

Methods

Due to the self-isolation we are experience, astronomical observation activities are reduced to those that we can carry out from our home with the instrumentation we happen to have with us. This project proposes a study over time of the brightness and color of the night sky through measurements obtained at home with the help of DSLR cameras. The collaborators were requested to point the cameras to the zenith and take pictures in RAW mode along the whole night all the nights. To control the shooting they use an intervalometer or a computer. A sequence of one photo every 6-12 minutes is enough to obtaing the sky brightness variation of the sky during one night.

The pictures are uploaded to the UCM repositories where we perform the analysis using a software that we developed for this task. During the processing of the images, the information will be decomposed into R, G and B channels so the flow will be measured in counts per second of the central area. This value will be converted then into instrumental quantities that will allow the researchers to make graphic representations to show the evolution over time of the brightness of the sky and its color. All observations are processed on the fly by this free software. The resulting data is also free and can be accessed from our dedicated webpage (https://guaix.ucm.es/azoteaproject).

Sky brightness measurements of this project can be compared with those of professional instruments for the same night. The figure shows RGB measurements taken by Jaime Izquierdo with a DSLR camera at Madrid city, measurements of the Johnson B, V, R photometric bands obtained by the AstMON-UCM instrument installed on the roof of the Facultad de Físicas UCM, and also measurements taken with TESS-W stars1 photometer from the city of Coslada.



The data from the RGB channels of the camera (R1, G2, B4) adjust well to the astronomical photometry measurements Johnson B,V,R (once scaled). This indicates that after calibrating the cameras we will be able to use them to measure the evolution of the brightness and color of the night sky. The stars1 photometer data shows slightly different values as it is not located at the same place.

Conclusions

The data is still being analyzed. We have shown that the brightness and color of the nocturnal sky can be measured and monitored with DSLR cameras. We are working to improve the data acquisition using single board computers and/or cheaper cameras.

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Contrasting effects of street-light shapes and LED color temperatures on nocturnal insects and bats

Theme: Biology&Ecology, Technology&Design

Janine Bolliger[1, *], Beat Wermelinger[1], Stephan Blum[2], Jörg Haller[2], and Martin K. Obrist[1]
[1] WSL Swiss Federal Research Institute, Birmensdorf, Switzerland
[2] EKZ, Zürich, Switzerland
janine.bolliger@wsl.ch
[*] presenting author

Introduction

Among the light sources in urban and peri-urban areas, street lights make an important contribution to artificial light at night (ALAN). Indispensable to warrant the functioning of human society, ALAN intervenes mostly negatively with the ecological environment with far-reaching consequences for long-term interactions and persistence of nocturnal organisms.
Among LED characteristics, ecological impacts of LED color temperature are widely researched. A general trend in the literature shows that cold-white color temperatures have more negative effects on nocturnal biodiversity compared to warmer color temperatures. Yet, additional parameters of a light source may reduce or amplify these effects. For example, the spatial distribution of light and subsequently how bright the emitted light is perceived in the environment strongly depends on the design of the luminaire. To date, we are not aware of any ecological assessment that examines impacts of different LED color temperatures in combination with other luminaire properties and corresponding consequences of different light distributions for nocturnal insects and bats.

Fig. 1: Street-light (4000K) with an automated insect trap (Photo: Martin K. Obrist, WSL)

We provide an experimental ecological impact assessment of combined and relative impacts of luminaire shapes and LED colour temperature on nocturnal insect and bat activity addressing the following questions: (1) What is the relative role of luminaire shape with respect to light color in driving nocturnal insect abundance and bat activity? (2) Are there differences among taxonomic insect orders (Lepidoptera, Coleoptera, Diptera, Neuropterida, Heteroptera, Hymenoptera, Ephemeroptera, Trichoptera) and bat guilds (short-range, mid-range and long-range echolocators) in their response to light colour and luminaire shape? First, we hypothesize that enhancing the light distribution of LED street luminaires increases the light's visibility in the environment and thus generally attracts more nocturnal insects and bats. Second, we expect fewer insects and fewer acoustic bat signals recorded with warm-white LED color temperatures while luminaires with broad light distributions and cold-white color temperatures attract more nocturnal insects and bats.

Methods

We investigated the effects of two light treatments between May 20 and August 30, 2019 on insect abundance and bat activity at the study site of Weiningen, Kt. Zürich, Switzerland. The first treatment included three LED color temperatures (1750K, 3000K, 4000K), while the second consisted of two luminaire shapes (standard street luminaires compared to cylindrical light distributions by a modified luminaire shape). Along the study road, 29 street lights were part of the experiment. Out of these 29, 18 street lights were divided into six groups with three street lights each. Between the groups, two to three street lights with the same treatments (luminaire shape, color temperature) as the adjacent group served as non-sampled buffers between treatments. The groups were alternately equipped with luminaires with enhanced and standard light distributions. Controls were represented by two dark sites.
Flying nocturnal insects were sampled with automated flight-intersection traps (Bolliger et al., 2020; https://www.wsl.ch/en/services-and-products/media-center/biodiversity/automatic-insect-trap.html) mounted on street-light poles at a height of about 4 m. The daily resolved insect catches were stored in alcohol and sorted into nine taxonomic groups with the help of a binocular: Diptera, Coleoptera, Heteroptera, Hymenoptera, Lepidoptera, Trichoptera, Ephemeroptera, Neuropterida and 'Other'. The category 'Other' referred to infrequently trapped insects from other taxa.
A total of six batloggers (Elekon AG, Luzern, Switzerland; http://www.batlogger.com) were mounted on the central street-light pole of each treatment group at a height of 4 m. Additionally, a batlogger was installed at each of the two dark sites. The batloggers recorded echolocation calls from bats within species-specific ranges of 10-50 m.

We fit GLMMs using a negative binomial error distribution. Dependent variables were insect abundance (total insects and each insect group individually), overall bat foraging activity and bat feeding activity, each calculated for all bats as well as for recordings individual guilds (long-range, mid-range, and short-range echolocators).

Conclusions

Combined effects of luminaire shape and color temperatures showed that (1) we caught more insects at street lights with increased light distributions compared to standard shapes, and (2) luminaire shapes with increased light distribution amplified the differences in captured insects between the 1750 and 4000K LED colors. On average 92% more Diptera were caught under enhanced light distribution at 4000K, while the treatment combination of enhanced light distribution and 1750K yielded up to 40% more Coleoptera. We therefore conclude that luminaire shape is a more consistent and stronger driver for the number of captured insects than the three LED color temperatures considered here. In addition, the warmer color temperature of 1750K appears less detrimental than amber or cold-white color temperatures (3000K and 4000K, respectively).

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Impact of light pollution on human imagination

Protected (and Secured)Area for Darkness Conservation (interactive art installation)

Theme: Society

Jeanne Bloch[1*]

[1] *Independant artist, former artist in residence at Ecole Polytechnique, Chaire Art et Science, Paris, France, jeanne.bloch@ladhyx.polytechnique.fr*

Introduction

The Western world has been built upon the idea of an obscure to be cleared up outside of us, designating all forms of lights as forms of progress. Based on an artistic research and creation using dance/movement and technology, I explore light pollution impact on human imagination. I suggest that darkness is the activator of our sense of being and must be protected from indoor and outdoor light pollution. Moreover, I explore the links between the loss of imagination due to excess light and the development of a surveillance society based on computing vision.

Fig.1: Performance, Jeanne Bloch. Video capture used with permission of Jan Klein

By means of standardized experiences and consequently weaker imagination, consumer culture diminishes our perceptive skills while erasing our inner and outer darkness. We observe how over-exposure to light transforms our experience of the world into a controlled life. In his essay, *La nuit, vivre sans témoin (At night: living without witness*), the French philosopher Michael Foessel mentions the "worker for whom sunset is a non-event". Michel Foucault's *Surveiller et punir* famous book devotes a chapter to the architecture of the Panopticon: a 1791 prison design using light as a tool for subtle prisoners control. Paul Landauer, French architect and researcher, describes in *L'architecture, la ville et la sécurité*, the transition from the concept of the Panopticon to Bruno Latour's concept of Oligopticon. Landauer refers to the practice of movements' control (bodies but also data) through the observation of intersections. Art historian, Jonathan Crary, evokes in *24/7, The capitalism in the assault on sleep*, the weakening of multiple subjectivities in favor of a 24/7 production.

Protected (and Secured) Area for Darkness Conservation (artistic installation)

The artistic installation, *Protected (and Secured) Area for Darkness Conservation*, features a dark room or cabin and invites participants to wear a large cloak created by the artist. The cloak is very soft on the outside emphasizing comfort and cosy feelings. On the inside, the garment has all over its surface small video cameras embedded in the fabric as well as a few bio sensors. While wearing the cloak, participants feel on their body the technological objects. Data (such as colors, speed and rhythm variables) from images and sensors are collected during the presentation of the installation and analyzed through algorithms developed especially for the artistic project.

As a result, participants experience simultaneously various space qualities in relation to light and darkness, visibility and invisibility:

1) The space under the cloak (dark but with sensors) where participants are observed when standing in a dark room;
2) Participants stand in a dark room but free of the observational cloak. They are not seen but can't see either;
3) Participants stand in a luminous room (artificial/natural) while wearing the observational cloak. They are able to see and can be seen in different ways (in the luminous room and via the videos and sensors…) as well.
4) Participants stand in a luminous room (artificial/natural) and do not wear the cloak.

Through this artistic research, I associate the definition of intimate spaces to light and darkness. I question the ethics of being under observation versus the observer. I highlight how computing vision blur the traditional distinction between dark and light, abolishing spaces to hide, metaphorically and physically. I tempt to outline our different experiences of light and darkness as human beings, including our inner intimate vision and perception which to be clear needs some level of obscurity, far from the overflow of artificial lights.

Conclusions

We expect that artistic analyses of collected data as well as in situ observations through a dialogue between the artist and participants to serve as a creative base to understand the complexity of human relationship to artificial light, natural light, artificial darkness and natural darkness.

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BATS : WHICH TOLERABILITY FOR LIGHT POLLUTION ?
Theme: Biology & Ecology

J. LOIRET [1]*, E. LOPEZ [1], E. PONCET,[2]

[1] CPIE Bigorre-Pyrénées, BAGNERES-DE-BIGORRE, FRANCE
[2] CEN Midi-Pyrénées, TOULOUSE, FRANCE
Cpie65@wanadoo.fr
emile.poncet@cen-occitanie.org
[*] presenting study

Introduction

In 2017, as part of the ADAP'TER program, the National Park of the Pyrenees (PNP) requested the engeneering office Dark Sky Lab for modelling and mapping light pollution on its territory. The PNP later asked to cross these informations with indicatives and day-light fleeing species' behaviour. These species enjoy the darkness but avoid too bright environments. Goals are first to identify a range of light pollution below which the presence of these species would decrease and second to prioritize areas where light pollution should be reduced. As nocturnal species, bats have been selected for this study.

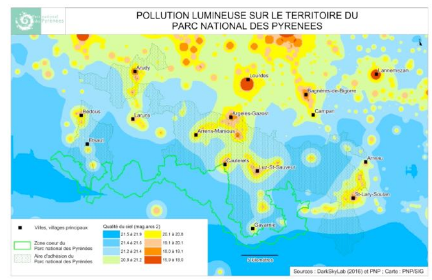

Fig. 1: Carte de la pollution lumineuse sur le territoire du Parc national des Pyrénées

This new study is financed by the POCTEFA «Pyrénées la Nuit» program which is driven in France by the CPIE Bigorre-Pyrénées. It focuses on two species: the Greater Horseshoe Bat (Rhinolophus ferumequinum), the Lesser Horseshoe Bat (Rhinolophus hipposideros) and on the genus murines (Myotis sp.). The purpose is to calculate their activity level and their probability of presence in order to compare these results with the light pollution gradient. Murines and horseshoes bats are day-light fleeing species. As a consequence, they are good indicators for the entire nocturnal wildlife.

The light pollution, or sky quality, is measured in mag.arsec² and expresses the brightness of the sky background. Brightness and sky quality are better when this value increases.

Protocole

280 listening points have been distributed over the major valleys of the National Park of the Pyrenees in the Hautes-Pyrénées department. Between 2018 and 2019, an automatic recorder has been located on each of them during two consecutive nights to recording every bats visit.

Apart from the sky quality, the altitude and the distance of the nearest water point were calculated for each point. Moreover, the rates of urban, forested and open areas have been measured into a surface of 6,25 hectares around each point.

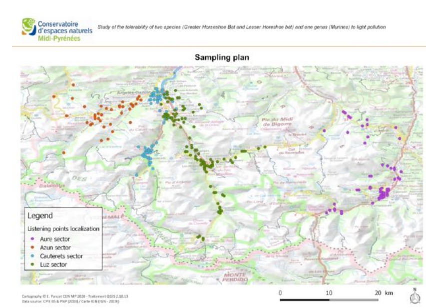

Fig. 2 : Listening points localization

Recordings have then been analyzed to determine the activity and the presence of studied species in order to compare these results with the differents measured variables.

Results and conclusions

Fig. 2 : Greater Horseshoe Bats
Sophie Bareille

- The murines and Greater Horseshoe Bat probability of presence and Greater Horseshoe Bat activity decrease for sky quality values ranging from 19.1 to 19.6 mag.arsec²,
- necessity of reducing light pollution on the areas where the sky quality is lower than these threshold values,
- Importance to ensure a good sky quality around water points, forests and opened environments. All of this landscape componants are essential for the two species and the genus studied in this work, but it is also the case for all bats.

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Dark sky advocacy in Stanley, Idaho: a case study of a rural community's dark sky friendly LED streetlight retrofit and related dark sky initiatives

Theme: Society

Jessica L. Heim[1]

[1] *University of Wales Trinity St. David, Lampeter, Wales, UK*
1502315@student.uwtsd.ac.uk

Introduction

The widespread implementation of light emitting diodes (LEDs) in exterior lighting applications has rapidly and radically altered the nighttime landscapes and skyscapes across the globe. Though often seen as a "green" solution for humanity's lighting needs due to their energy efficiency, the LED lighting revolution has resulted in a variety of unintended consequences. Many LEDs used in outdoor lighting emit a significant portion of their light in the blue part of the spectrum, which can be highly disruptive to wildlife, may be perceived as more glaring, and creates much more skyglow as compared against older lighting technologies, such as High Pressure Sodium (e.g. Pawson & Bader, 2014; Royal Society Te Apārangi, 2018; Luginbuhl et al., 2014).

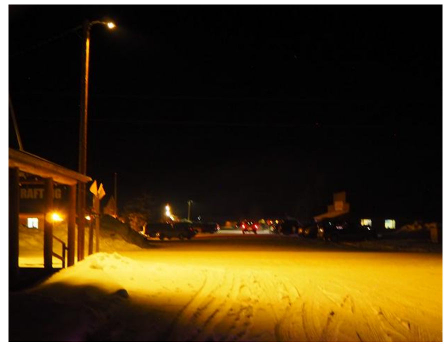

Fig. 1: Lumicana 60 Watt, 2200 K LED fixture in Stanley, Idaho.
Photo: Steve Botti
Used with permission

However, LED lighting options with minimal blue light content, shields, and other features deemed "dark sky friendly" are becoming more widely available, and some communities have utilized such fixtures in their LED conversions. One such place is the small town of Stanley in rural central Idaho, U.S.A. Dark sky advocates in this community and surrounding areas have worked to raise awareness of light pollution for many years, an effort which culminated in the successful designation of the Central Idaho Dark Sky Reserve by the International Dark-Sky Association (IDA) in 2017. The city of Stanley sought to further reduce its lighting impact by retrofitting all of its streetlights in November 2019 with low blue light 2200 Kelvin Correlated Color Temperature (CCT) LED fixtures designed to reduce backlight, uplight, and glare (see fig. 1).

In this research, I sought to obtain an in-depth understanding of dark sky advocacy in Stanley. My aim was to gain insight into the community processes which led both to the implementation of their recent LED streetlight retrofit and to many area businesses and residents voluntarily altering their lighting so as to reduce light pollution. I wanted to ascertain how this retrofit was received by the community, as well as how residents felt about dark sky friendly lighting and maintaining the area's dark nighttime skies. By conducting a case study on dark sky advocacy in this community, I endeavored to discover key elements necessary for such initiatives to be successful and to gain a richer understanding of dark sky advocates' thoughts and experiences in regard to dark skies and efforts to preserve them.

Methods

For this research, I conducted semi-structured interviews, distributed a short online questionnaire, and reviewed relevant primary and secondary source material. As I wanted to gain a deeper understanding of the experiences and actions of those most involved with the area's dark sky initiatives, in selecting individuals to interview, I sought to connect mainly with those who had been highly involved with these endeavors. Thus the majority of my interviewees could be described as "dark sky advocates." However, in distributing my questionnaire, I sought to solicit responses from the community more broadly, seeking insight into their thoughts and feelings about dark skies as well as their feedback on the new streetlights.

Findings

Overall, the streetlight retrofit appeared to be well-received by the Stanley community. While some individuals indicated a lack of interest in maintaining the area's dark skies and did not approve of the city's efforts to utilize dark sky friendly lighting, such perspectives seemed to be relatively uncommon. Many interviewees expressed that they believed one of the reasons why the municipal lighting changes were accepted with little complaint was due to the fact that the city allowed for a lengthy period of public input before making final decisions, was willing to listen to any concerns, and worked to find lighting solutions which would meet the community's needs. Additionally, those advocating for lighting minimizing light pollution made a point of being respectful of those who disagreed with them and sought to listen to others' perspectives as well as sharing their own. Also, the fact that the changes to business and residential lighting were voluntary was important - it was clear that many in the community would have opposed attempts to mandate any particular kind of lighting. While there were many reasons expressed as to why dark skies were seen to be something of value and were worth preserving, most could be summed up as the idea that the region's starry night skies contributed to the "quality of life" and "well-being" of those living in and visiting the area. Such ideas were powerful motivating factors driving advocates' engagement with this issue over the long term.

Conclusion

The implementation of dark sky friendly lighting in and around the Stanley area would not have been possible without a core group of dedicated, patient, and persistent advocates, as well as city officials supportive of these initiatives. In addition, it was imperative that these individuals were aware of the interests and concerns of others in the community, found ways that dark skies preservation might benefit various stakeholders, and were willing to work collaboratively to find workable solutions. In order for dark sky friendly practices to be adopted widely, the broader community needed to both be aware of these concepts and see how altering their lighting could benefit them or their neighbors. Essentially, they needed to care about this issue - it needed to matter to them personally if they were to support dark sky initiatives.

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Eco-linguistic analyses of knowledge transfer on the topic of artificial outdoor lightning: Are the extent and the effects of light pollution regularly underestimated? On the discussion of consequences for nature conservation and environmental protection against the background of the sustainability discourse

Theme: Society

Jochen Krautwald[1, *], Herbert Lohner[2]
[1] *Europa-Universität Viadrina, Frankfurt(Oder), Germany*
[2] *BUND-Berlin e.V., Berlin, Germany*
krautwald@europa-uni.de
[*] *presenting author*

Introduction

The research question was whether the extent and impact of light pollution are underestimated by laypersons without expert knowledge. The null hypothesis (H0) was thus: The extent and impact of light pollution are not underestimated by laypersons. The alternative hypothesis (H1) was: The extent and impact of light pollution are underestimated by laypersons. The null hypothesis would be confirmed if no substantive evidence, linguistic regularities or implications could be identified in the linguistic discourse that would indicate an underestimation. In the opposite case, i.e. if there were serious indications of underestimation, the alternative hypothesis H1 would be confirmed or at least appear to be probably correct.

Methods

As part of the eco-linguistic study, 32 experts were asked twelve questions on the topic of light, darkness and light pollution. These experts came from the fields of astronomy, biology, chemistry, medicine, sociology, physics, nature conservation as well as administration. In addition, over a period of five years, around 150 visitors of the annual public event "Long Day of Urban Nature" in Berlin were surveyed on site by questionnaire.

Conclusions

From a linguistic point of view, most experts emphasize in many ways that the entire discourse with regard to the environmental issue has the problem that light has a positive linguistic connotation and darkness a negative one. Thus, almost all idioms found on the subject of light and darkness are subject to this simple dichotomy. Accordingly, it can be assumed that due to this fact alone, the ecological dangers of too much artificial outdoor lighting at night are underestimated by many people. A weighty point in the survey of lay people here is the deeply anchored fear of darkness with regard to individual safety, which is also expressed linguistically. The experts, in turn, have long since reacted to this circumstance by developing some very interesting linguistic strategies to escape the problem described, thus making a linguistically convincing and hopefully sustainably effective contribution in the discourse against light pollution.

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An Urban Starry Sky Oasis in the Heart of the City of Sherbrooke, Canada

Theme: Society

J. Roby,[1,*] and M. Aubé[1]

[1] Cégep de Sherbrooke, 475 rue du Cégep, Sherbrooke, Canada, J1E 4K1
johanne.roby@cegepsherbrooke.qc.ca
[*] presenting author

A regional and societal educational project is underway at the Cégep de Sherbrooke. This project aims to create an urban starry sky oasis located in the heart of the city of Sherbrooke at the Mont-Bellevue Nature Reserve Park (Fig. 1). It aims to make the Milky Way visible to the citizens of Sherbrooke while protecting the natural environment and human health. This protected area will be easily accessible within the city of Sherbrooke on foot, by bike, by public transportation, or by car. Such a place will give citizens the opportunity to reconnect with a quality starry sky and a living environment respectful of flora and fauna.

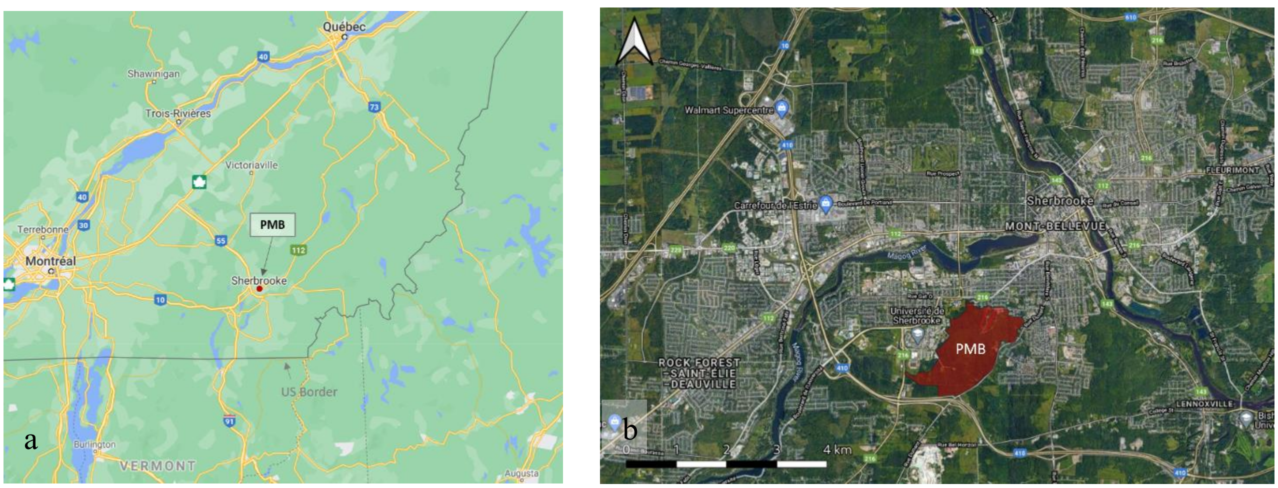

Fig. 1: a) The Parc du Mont-Bellevue (PMB) is located in the heart of Sherbrooke City ~130 kilometers east of Montreal and ~50 kilometers north of the US border. b) Satellite image of the city of Sherbrooke where the red polygon represents the land area of the Parc du Mont-Bellevue. This natural site contains an outstanding biodiversity (Images from Google Map).

The implementation of this oasis relies on the collaboration of three regional educational institutions: Cégep de Sherbrooke (CdeS), Université de Sherbrooke (UdeS) and Bishop's University (BU). The group is funded by a regional pole in higher education. The CS is the driving force of the project. The City of Sherbrooke, through Hydro-Sherbrooke (HS), the DH Éclairage lighting company and the Mont-Mégantic International Dark Sky Reserve are also partners. The networking between partners allows bridges between knowledge generators and municipal organizations. It will foster the transfer of technical information and the optimization of lighting conversions to be carried out by HS. The region is already committed to preserving nighttime integrity through its legislation and innovative lighting initiatives thanks to the implementation of the first international dark sky reserve in Mont Mégantic. In addition, a request to obtain an Urban Night Sky Place recognition from IDA is in progress.

We will present an overview of the ongoing and achieved works of this collaborative project for the establishment of a night integrity zone.

Long-term assessment of light pollution in 3 major European cities - How to overcome SQM aging and meteorological effects

Theme: Measurement & Modeling

Johannes Puschnig,[1*] Stefan Wallner[2,3]

[1] Argelander-Institut für Astronomie, University of Bonn, Germany
[2] Institut für Astrophysik, Universität Wien, Vienna, Austria
[3] ICA, Slovak Academy of Sciences, Bratislava, Slovakia
johannes.puschnig@uni-bonn.de
[*] presenting author

We present a long-term analysis of the zenithal night sky brightness (NSB) development in the three major European cities of Stockholm, Berlin and Vienna. A novel data reduction method for Sky Quality Meters (SQMs) is described, that comprises routines to select clear sky SQM readings and minimize remaining scatter via application of climatological data products that are freely available through the European Centre for Medium-Range Weather Forecasts. That way, the scatter of our clear-sky SQM measurements obtained over periods of 6-10 years could be significantly reduced.

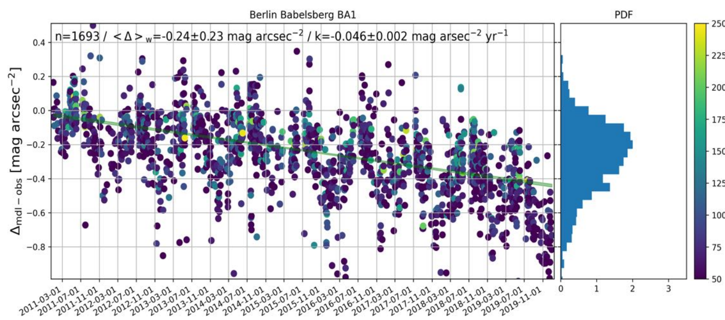

Fig. 1: The SQM aging effect, assessed from twilight observations obtained in Berlin-Babelsberg.

We further report on the quantification of the SQM aging effect, as recently published in Puschnig et al. (2021), where twilight SQM observations are used as calibrator. A linear degradation of the measurement systems (SQM + housing window) was found with the following slopes: 34±4, 46±2 and 53±2 mmagSQM arcsec^{-2} yr^{-1} for Stockholm, Potsdam-Babelsberg and Vienna. With the highest slope found in Vienna (latitude ~48°) and the lowest one found in Stockholm (latitude ~59°), we find an indication for the dependence of the trend on solar irradiance (which is a function of geographic latitude).

Taking into account the combined effects of aging and meteorological conditions on night sky brightness measurements, allows us for the first time to constrain the anthropogenic change of the zenithal NSB within the given period of time. We find that albedo, vegetation state, aerosol content and total water vapour are key parameters that impact clear-sky NSB measurements, causing a relative change of the zenithal NSB up to one magnitude.

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Pyrenees La Nuit: Influence of artificial lighting on bat activity in Western Pyrenees

Theme: Biology & Ecology

Juan Tomás Alcalde*[1], Xabier Puig [1,2]

[1] SECEMU, Alcalá de Henares, Spain
[2] GALANTHUS, Celrà, Spain
jtalcalde@gmail.com
* presenting author

The present communication framed in Project ERDF "Pyrenees La Nuit" EFA233/16, has been commissioned by Gestión Ambiental de Navarra S.A. GAN-NIK.

The technical supervision of the project by GAN-NIK has been carried out by Carlos Armendaiz. Dept. of Biodiversity, Pamplona/Iruña, Spain

Introduction

The recent technological development of human society has led to artificial lighting in many places. This change in the environment involves alterations in the behaviour of many living beings, mainly nocturnal, that have evolved over millions of years under regular conditions of darkness. Chiroptera are among these organisms. They carry out most of their activity in darkness, for which they have developed a specific anatomy and physiology. The current artificial lighting of many towns and cities interferes with natural processes of bats and can negatively affect some populations. The present study aims to know how different types of artificial lighting interact on the activity of bat species in villages of Western Pyrenees.

Methods

The bat activity has been recorded in four small villages of Western Pyrenees using ultrasound recorders and two types of experiments have been carried out:
-acoustic surveys in fixed stations were carried out in illuminated areas (streetlights) and in dark areas (natural habitats). Areas illuminated by four types of lamps have been selected: High-Pressure Sodium Steam (HPSS), Ceramic Metal Halide (CMH), Mercury Vapour (MV) and and light-emitting diodes (LED).
-vehicle itineraries on the roads that run through the villages recording bat activity.

Recordings have been subsequently analysed by means of specific programs. Several parameters have been measured to identify the species: peak frequency, initial and final frequency, duration of calls and interval between them.

Generalized linear mixed models (GLMM) have been made to determine the influence of artificial lighting and to know the effect of each type of lighting on bat species.

Conclusions

48714 bat flights have been registered and 14 taxa have been identified. The average activity recorded in the lighted areas is much higher (128,49 flights/hour of recording) than in the dark areas

(6,38 f/h). Similar differences havebeen bserved in the four villages and in the four types of lighting.

Six taxa show significantly higher activity in the lighted areas: *Eptesicus serotinus, Pipistrellus kuhlii / nathusii, Nyctalus leisleri, Pipistrellus pipistrellus, Pipistrellus pygmaeus / Miniopterus schreibersii and Tadarida teniotis*. In contrast, six other taxa show significantly higher activity in areas without lighting: *Barbastella barbastellus, Hypsugo savii, Myotis sp., Plecotus sp., Rhinolophus ferrumequinum* and *Rhinolophus hipposideros.*

Differences between the species that go to the different types of streetlight have also been observed.

In short, all types of lamps studied interfere with the behaviour of certain species of bats, although not in the same way. Some species are attracted and take advantage of the unusual and artificial abundance of insects concentrated around the lampposts, while others flee from the illuminated areas. The latter can be disadvantaged by lighting, since it attracts a part of the prey-insects of the place and removes it from its natural habitat (Eisenbeis 2006). In addition, the light can reduce the available hunting area for these species and can cause a barrier effect that prevents the transit of some bats (Stone et al. 2015).

Taking into account these results, and other studies (Voight et al. 2018), it is recommended to replace the current lighting with amber LEDs, which seem not to interfere with the behaviour of bats.

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Urban to rural nighttime light emissions observed with a simultaneous radial transect of GONet all-sky cameras

Theme: Measurement & Modeling

Ken Walczak[1,*], Geza Gyuk[1], Cynthia Tarr[1], Jesus Garcia[1], Claudia Jimenez[1], Laris Turkic[1], Jeff Wiedemann[1], Frederic Johnson[1] and Charles Roche[1]

[1]*Adler Planetarium, Chicago, USA*
kwalczak@adlerplanetarium.org
[*] *presenting author*

Introduction

To improve the understanding of emission from artificial light at night (ALAN) from urban areas it is preferable to have detailed data with spatial and temporal continuity. Proper modeling of radiance emanating from concentrated urban areas can help define its impacts in various research fields. A number of experiments have been performed to collect such information. Some of these methods include Sky Quality Meter (SQM) readings from mobile platforms (Ges et al., 2018; Zamorano et al., 2016), with synchronized regional observations (Ribas et al., 2016) or by all-sky digital single-lens reflex (DSLR) photometry (Jechow et al., 2020).

Here, we describe the Chicago radial transect experiment, a synchronized deployment of nearly twenty Ground Observation Network (GONet) all-sky cameras at regular intervals from the center of Chicago to a rural environment 140 km distant. The GONet camera is a compact, automated, all-sky nighttime imaging system designed for collecting ground-based data for light pollution research. The devices autonomously provide a set of 2π, RGB nighttime sky images every five minutes. These simultaneous and continuous observations generate a dataset with temporal and spatial definition that helps eliminate potential confounding factors in modeling such as atmospheric and environmental variations over time as seen in asynchronous experiments. This experiment is also used to demonstrate and validate the utility of the devices for ALAN research.

Results and Applications

The GONet prototype was designed using off-the-shelf electronic components with a goal of keeping unit cost at approximately $100 US while still providing data valuable to light pollution research. This experiment was performed using the prototype GONet cameras. The version 2 GONet camera will improve on the prototype with a number of design and hardware upgrades guided by the results of this experiment as well as additional testing, field use, and researcher feedback. These improvements include: higher quality camera and optics, improved user interface and options, better stability, calibration and shared data access, which will be discussed.

We use the Chicago radial transect experiment to explore the capabilities and limitations of the system as a light pollution research tool. Due to the low relative cost and ease of use of GONet cameras, they provide a number of potential applications beyond the bounds of other existing methods. We describe and provide examples of applications such as: light dome identification via triangulation, observing brightness and color variations of sky glow throughout a night or over time, inter-comparison campaigns, monitoring of transient light sources, creation of a citizen science or research database of all-sky data and multidimensional observations for radiative transfer modeling. We also describe known limitations of the system.

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Artificial Light at Night affects the timing of stridulation and locomotion behavior in the cricket *Gryllus bimaculatus*

Theme: Biology & Ecology

Keren Levy,[1,*] Amir Ayali,[1] and Anat Barnea [2]

[1] *School of Zoology, Tel Aviv University, Tel-Aviv, Israel*
[2] *Department of Natural and Life Sciences, The Open University of Israel, Raanana, Israel*

kerenlevy@mail.tau.ac.il
[*] *presenting author*

Introduction

The rhythmic changes of light and darkness are at the basis of behavioral synchronization and circadian regulation in all organisms. Artificial Light at Night (ALAN) thus disturbs the perception of this periodicity and was reported to negatively impact the natural behavior of various animals (Rich & Longcore, 2006). Specifically, exposure to ALAN may affect the daily activity patterns of many animals, including insects (Owens & Lewis, 2018).

The nocturnal field cricket *Gryllus bimaculatus* is an established model in studies of insect physiology, and also serves as a model for the characterization of the circadian clock machinery in hemimetabolous insects (Tomioka & Matsumoto, 2019). In other cricket species a shift in times of stridulation activity was demonstrated following changes in light regimes (Loher, 1972). Such light-dependent changes in courtship behavior may disturb reproduction. We studied for the first time the effect of ALAN on stridulation and locomotion behavioral patterns (simultaneously) in male field crickets.

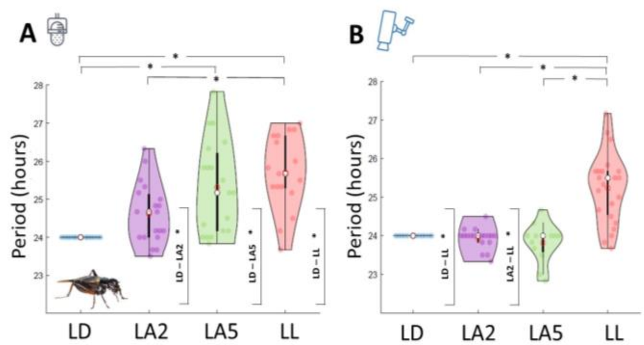

Fig. 1: ALAN intensities induce variation in the temporal behavior of **(A)** stridulation and **(B)** locomotion behavior of male crickets. The median and variance of the period (hour) under the different lighting conditions are presented. Significance of differences in medians is noted above. Significant differences in the variance of the data are noted between the data violins.

Methods

Crickets were reared under different lifelong light regimes, including ALAN. All experimental groups were exposed to 12 hours daylight (40 lux, CFL bulbs). Night conditions differed between the treatments as follows: (i) LD (complete dark nights), (ii) LA_2 (ALAN of 2 lux), (iii) LA_5 (ALAN of 5 lux) and (iv) LL (constant 40 lux). During the experiments, individual adult male crickets were housed in a custom-made anechoic chamber and monitored for a minimum of five consecutive days and nights. The anechoic chamber was equipped with day and night illumination (as above). A condenser microphone and an infra-red camera were used for simultaneous monitoring of stridulation and locomotion activity respectively. For each specimen, the periods of the daily activity rhythms were calculated. The median of the periods and the equality of variance among individuals were compared using the Kruskal-Wallis test, the Dunn-Sidak approach and the Bonferroni correction, respectively.

Results and conclusions

G. bimaculatus under LD showed a behavioral rhythm of 24h, stridulating at night and being locomotory active during the day. In the other treatments, LA_2, LA_5 and LL, an increasing proportion of the animals demonstrated free-running periods, resulting in loss of synchronized rhythmicity of the population expressed by a growth of the variance of the individual periods (Fig. 1). Accordingly, there was a significant difference in the calculated median of the period of stridulation activity between the LD conditions and the LA_5 and LL treatments (Kruskal-Wallis test, $p<0.001$). Significant light-exposure-dependent differences were also found in the calculated variance of the stridulation period of LD compared to all other three treatments (Fig. 1A, Dunn-Sidak approach with Bonferroni correction, $p<0.006$). The median period of locomotor activity differed significantly among LD, LA_2, and LA_5 compared to LL (Kruskal-Wallis test, $p<0.001$), while differences in the calculated variance were found among LD, LA_2 and LL (Fig. 1B, Dunn-Sidak approach with Bonferroni correction, $p<0.001$).

These findings demonstrate a clear effect of life-long light regimes on stridulation and locomotion activity of the individual and the population in the laboratory, and suggest that even a low ALAN intensity of 5 lux, which is encountered in proximity to street lights, may affect the synchronization of cricket communities. Moreover, our results confirm that the field cricket *Gryllus bimaculatus* is a suitable model for studying the effects of ALAN on insect behavior. Further investigation of the mechanisms of the ALAN effects are currently underway.

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Bat activity patterns may change when exposed to Artificial Light At Night (ALAN) at their foraging sites

Theme: Biology and Ecology

Léa Mariton[1,2,3*], Christian Kerbiriou[1,2], Yves Bas[1], Brigitte Zanda[3] and Isabelle Le Viol[1,2]

[1] Centre d'Ecologie et des Sciences de la Conservation (CESCO), Muséum national d'Histoire naturelle (MNHN), Sorbonne Université, Paris, France
[2] Centre d'Ecologie et des Sciences de la Conservation (CESCO), Muséum national d'Histoire naturelle (MNHN), Sorbonne Université, Quai de la Croix, Concarneau, France
[3] Institut de minéralogie, de physique des matériaux et de cosmochimie (IMPMC), Sorbonne Université, 7C Rue Guy de la Brosse, Paris, France.

lea.mariton@mnhn.fr
[*] presenting author

Introduction

Light pollution induced by artificial light at night (ALAN) has resulted in modifications of nightscapes worldwide and in alterations of natural light patterns. Such changes impact a wide range of nocturnal and diurnal taxa and modify their behaviours (foraging, commuting, reproduction) at numerous scales (Longcore & Rich, 2004). Light pollution disrupts species spatial distribution (e.g. birds (Jones & Francis, 2003), bats (Rydell, 1992), insects (Eisenbeis, 2006)) but it also impacts species temporal distribution (Gaston et al., 2017). It has been widely shown that diurnal species tend to extend their activity during night due to ALAN exposure (e.g. birds (Amichai & Kronfeld-Schor, 2019; Raap et al., 2015)). However, light pollution potential impacts on nocturnal species temporal distribution has been less studied, despite ALAN potential disruptive effect on foraging time-budget.

In particular, bats are interesting models to study light pollution impacts on biodiversity as they are particularly sensitive to ALAN and due to their place in food webs. It has been shown that light pollution affects bat spatial distribution both at local (Rydell, 1992) and landscapes scales (Azam et al., 2016; Laforge et al., 2019) by altering their foraging and commuting behaviours. It might also disrupt their activity rhythm by inducing rhythm shifts (e.g. delayed emergence from roosts (Downs et al., 2003)) which might result in a desynchronization with the peak of activity of their prey and more generally a reduced time budget for foraging. Eventually, such a curtailed time budget might lead to a decreased fitness for bat species and impact their demography. However, to our knowledge, modifications of bat activity patterns due to light pollution have been poorly studied and we do not know how much ALAN affects the nycthemeral activity rhythm of different bat species depending on their traits, their sensitivity to light and the stages of their reproductive cycle.

Methods

Thus, we assessed effects of light pollution on temporal distribution by comparing nycthemeral parameters of bat activity along a large light pollution gradient (Suomi NPP-VIIRS Day/Night Band), for more than 15 bat species. We used data from the French national citizen monitoring program Vigie-Chiro (7,500,000 bat passes, 7,000 full-night recordings on 4,000 sites across 5 years). Calls were identified at the species or group level using the semi-automatic identification software Tadarida (Bas et al., 2017). Nycthemeral parameters of bat activity studied were the time of the first and last contacts, median time of activity, shape of the activity pattern. We assessed how those parameters are shifted along the light pollution gradient using generalized linear models which accounted for the spatial and temporal data structure and the effects of environmental covariates, to disentangle and hierarchize light pollution impacts from other anthropogenic pressures and environmental factors.

Results - Conclusions

The results of this study are of utmost interest to determine how much bat species tend to shift their nycthemeral activity rhythm because of light pollution and when they are the most vulnerable if exposed to ALAN at different time scales (nights and reproduction period) depending on their traits and sensitivity to light. Hence, this study has a real applied dimension as its conclusions provide further insights on how to reduce impacts of light pollution on bats. In particular, by highlighting when lights have to be switched-off, it will allow to make measures, such as total or part-night extinction, really effective to protect bats. Furthermore, it will allow to promote land-uses that might mitigate light pollution impacts on bats due to their opposite effects on temporal patterns compared to ALAN ones.

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Leading the Natural Night Skies Stewardship and Science in the US

Theme: Measure and Modeling

Li-Wei Hung

Natural Sounds and Night Skies Division, National Park Service, Fort Collins, CO, USA
li-wei_hung@nps.gov

The U.S. National Park Service Night Skies team provides measurements, modeling, analyses, and knowledge syntheses to inform management decisions and support conservation of night skies and nocturnal light environments for all park units in the system. The Night Skies team has collected data from 126 NPS park units and 60 non-park units across the United States. Dr. Hung, the lead scientist for the Night Skies team, will review the instrumentation and analyses used to quantify skyglow intrusions into the natural night sky. These data identify priority partners for night sky preservation and restoration at each park, and they support development of geospatial models that predict sky conditions at locations lacking measurements. Recent work by the team focuses on measuring outcomes from replacing legacy luminaires with LED systems, examining relationships among summary night sky metrics, studying the effects of ALAN on wildlife, providing training for night skies visitor programs in parks, and pursuing synergetic partnerships with the Illuminating Engineering Society and International Dark-Sky Association.

Artificial light at night alters leaf litter consumption, growth and behaviour of freshwater shredders

Theme: Biology & Ecology

Magdalena Czarnecka,[1,*] Tomasz Kakareko,[1] Maja Grubisic[2] and Jarosław Kobak[3]

[1] *Department of Ecology and Biogeography, Nicolaus Copernicus University, Toruń, Poland*
[2] *Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany*
[3] *Department of Invertebrate Zoology and Parasitology, Nicolaus Copernicus University, Toruń, Poland*
mczarn@umk.pl
[*] *presenting author*

Introduction

Shredders are an important macroinvertebrate group contributing to leaf litter breakdown in freshwater ecosystems by its physical fragmentation (Graça, 2001). Previous studies showed that sunlight accelerated the litter breakdown by stimulating algal development, which increased leaf palatability for shredders (Dangles et al., 2001; Guo et al., 2016). In consequence, the shredder growth was also enhanced (Franken et al., 2005). The presence of natural night (undisturbed by artificial light) can also be important for the leaf breakdown. Many shredders are nocturnal and usually increase their activity at night, hence, some of them may consume more in darkness (Feio and Graça, 2000).

There is some evidence that artificial light at night (ALAN) affects both shredders and algal communities and thus may disturb leaf processing in urban and suburban areas. For instance, increased light levels at night modified shredder behaviour and suppressed their drift compared to unlit conditions (Perkin et al., 2014). Apart from light intensity, the spectral composition of ALAN may also be important. Hölker et al. (2015) showed that a long-term exposure to yellowish light of a high-pressure sodium (HPS) lamp (~8.5 lx, wavelength peak around 600 nm), enhanced algal growth. On the contrary, nocturnal illumination by white LEDs, emitting blue-enriched light, decreased algal biomass compared to HPS light of similar intensity (Grubisic et al., 2018). Therefore, given the potential of ALAN to affect biota, the aim of this study was to test whether nocturnal light differing in wavelength would affect leaf breakdown, shredder behaviour and algal colonisation on leaves.

Methods

The effect of ALAN on leaf consumption was tested in laboratory microcosms assigned to three light treatments, which included 12 h of mimicked daylight (~370 lx) and 12 h of night-time differing as follows: 1) dark night (0 lx); 2) night illuminated by LED light (2 lx); 3) nights illuminated by a HPS lamp (2 lx). Microcosms contained a single dried alder (*Alder glutinosa* L.) leaf (Ø 35 mm) or a microscope slide. Leaves and slides were conditioned for 21 days in water inoculated with biofilm brushed from decomposing leaves collected in a stream and 20 ml of WC medium to enhance algal growth. After 3 weeks of algal development, single specimens of gammarids: native *Gammarus jazdzewskii* and invasive *Dikerogammarus villosus*, common shredders in fresh waters, were introduced to the microcosms with leaves. The leaf consumption was measured after 2 weeks. The growth of shredders was also estimated, based on their photographs taken at the beginning and end of the experiment, using length-mass regressions.

Changes in algal biomass on the microscopic slides were estimated using high-performance liquid chromatography.

Separate tests were carried out using new gammarid specimens to observe their activity under different night conditions: in darkness, and at LED or HPS light (2 lx). Their behaviour was recorded and analysed by the video tracking software, distinguishing the following types of shredder activity: 1) total distance covered, 2) movement velocity, 3) % time spent in the shelter (under the leaf), 4) % time spent in movement.

Conclusions

ALAN affected the consumption of leaves by shredders and their growth rate. Food intake by both species was significantly greater in the LED treatment, compared to the treatments with dark night and HPS light. On the other hand, gammarids exposed to LED light exhibited a tendency to slower growth rate, which was particularly pronounced in *G. jazdzewskii*. This suggests that LED light increased the energetic demand of gammarids. This might be related to deteriorated food quality, however, our results showed that even though algal biofilm tended to be less abundant in the LED and HPS treatments, this tendency was non-significant. *D. villosus* reduced its activity and spent more time in shelter when exposed to LED and HPS light, which seemed to be associated with generally increased light level at night. In contrast, *G. jazdzewskii* did not change its activity in the presence of ALAN. However, given its significantly lower growth accompanied by increased consumption under LED light, we cannot exclude that this type of illumination was a source of stress for this species, increasing its metabolism and hunger.

This study showed that alteration of the natural day-night cycle by ALAN can potentially disturb the processing of organic matter in aquatic ecosystems. Particularly LED light, widely used in street illumination, can affect behaviour and growth rates of shredders, however, the mechanism underlying this phenomenon is not fully understood.

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Light stress - light pollution
Effect of street lights on the development of *Celtis occidentalis* L.

Theme: Biology and Ecology

M. Dani[1*], F. Siska[2], Z. Kolláth[3], A. Skribanek[1]

[1] *Eötvös Loránd University, BDPK Department of Biology, Szombathely, Hungary*
[2] *Eötvös Loránd University, BDPK, Department of Physics, Szombathely, Hungary*
[3] *Eszterházy Károly University, Department of Physics, Eger, Hungary*

kollerne.dani.magdolna@sek.elte.hu
[*] *presenting author*

Introduction

The energy of the sun (light and heat) plays a significant role in life on Earth, so many life processes and their cyclic changes are determined by the alternation of bright and dark periods.
The existence of photosynthetic plants is directly determined and influenced by light energy, so it could be believed that light pollution can only produce a positive effect, more efficient photosynthesis, more chemical energy. However, it has been reported in the literature that certain light sources (e.g.: nocturnal illumination by white LEDs) may also inhibit the growth of certain aquatic microscopic plant communities called periphyton (Grubisic M., 2018).
In plants, exposed to street lights, light pollution results in a decrease in photosynthetic activity such as the maximum photochemical quantum yield of PS II (photosystem II) (Fv / Fm), the fluorescence yield (YII) of PS II, and the degree of photochemical quenching (NPQ). Thus, light pollution is stressful for street plants (Meravi and Prajapati, 2018).
Common Hackberry is an indigenous tree in North America with a strong shading effect upon good water supply (Houle and Bouchard, 1990). It is typically planted as a roadside tree in Europe because of its ability to withstand polluted urban air, its low water demand and its ability to withstand drought.
In our study we investigated the morphological and photosynthetic physiological processes of leaves polluted with western HPS lamps compared to leaves of non-polluted shoots of Common Hackberry (*Celtis occidentalis* L.).

Methods

Shoots near the street lights (HPS lamps) and shoots farther the lights (shaded) located on the same plants (n=6) were examined. The mass, length, width and thickness of 10-10 leaves on each shoot were measured and the anatomy of the leaves was also studied on histological sections.
Various parameters of photosynthetic activity was determined through the study of the function of the electron transport chain using a Photosynthesis Yield Analyzer (WALZ Germany). Similarly orientated (east-west) leaves were used (6-6 individuals 8-8 leaves). The results were analyzed by analysis of variance and two-factor T-test in SPSS program.

Conclusions

Leaves exposed to light pollution are significantly larger in weight, longer and wider than leaves growing under non-light polluted conditions. The thickness of light-contaminated leaves is also significantly higher, on average 188.41μm $\pm$ 14.41, while the light-contamination-free leaves are 174.84μm $\pm$ 6.41.

The photosynthetic tissue (mesophyllum), of the light-polluted leaves is more developed (Figure 1). The activity of the photosynthetic apparatus can be determined from the maximum quantum yield (Fv / Fm) of the second photochemical system.
The light-polluted leaves could be characterized by significantly (P <0.01%) higher yield (0.789 $\pm$ 0.011), the quantum yield of the light-pollution-free leaves were Fv/Fm = 0.75 $\pm$ 0.038, which is between 0.75-0.82 regular values for the normal leaves of pot plants. This parameter is also a measure of the degree of stress (Björkman and Demmig, 1987).
Thus, according to our investigations, Common Hackberry utilizes light pollution of HPS lamps as a resource, the photosynthetic activity of plants increased, which was accompanied by an increase in leaf size, thickness and a change in tissue structure. Leaf fall was also shifted to a later time near the light source (Figure 2.), a phenomenon observed in other species (Škvareninová et al., 2017).

The study was carried out thanks to the support of the EFOP-3.6.2-16-2017-00014 project entitled “Developing an international research setting in the field of light pollution research”

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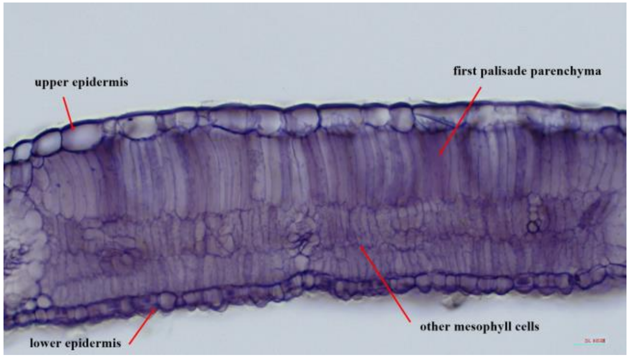


Figure 1. Leaf cross section of Celtis occidentalis

Figure 2. Common hackberry alley in December. The leaves don’t fall near the street lamp

Skyglow modifies effects of browning on benthic primary producers in lakes

Theme: Biology and Ecology

Maja Grubisic[1,*], Ivana Trbojevic[2], Franz Hölker[1], Michael T. Monaghan[1], Elisabeth Funke[1], Stella A. Berger[1,3], Mark O. Gessner[1,3,4], Andreas Jechow[1,5], Christopher C. M. Kyba[5], Gregor A. López Moreira M.[1,6], Jens C. Nejstgaard[1,3], Gabriel Singer[1,7], Sabine Hilt[1]

[1] *Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin & Stechlin, Germany*
[2] *Faculty of Biology, University of Belgrade, Belgrade, Serbia*
[3] *Berlin-Brandenburg Institute of Advanced Biodiversity Research, Berlin, Germany*
[4] *Berlin Institute of Technology (TU Berlin), Berlin, Germany*
[5] *GFZ German Research Centre for Geosciences, Potsdam, Germany*
[6] *Department of Civil, Environmental and Mechanical Engineering, University of Trento, Trento, Italy*
[7] *Department of Ecology, University of Innsbruck, Innsbruck, Austria*
grubisic@igb-berlin.de
** presenting author*

Artificial light at night (ALAN) is a disturbance for many aquatic organisms and ecosystems, yet its effects on lakes are largely unknown. Many lakes experience indirect, diffuse ALAN in the form of skyglow. Simultaneously, browning of lake water due to the increased input of humic substances is occurring in many lakes worldwide as a consequence of climate change. These two stressors can change light availability in opposing ways, thus altering this major resource with potential consequences for lake productivity and biodiversity. We performed a full-factorial experiment in 20 large enclosures (1300 m^3) to test how skyglow and browning affect benthic primary producers in lakes. We tested how white LEDs and browning agent HuminFeed, in isolation and in combination, affect biomass, photophysiology and taxonomic composition of periphyton communities, and growth of submerged aquatic plants, at five water depths after four weeks. Surprisingly, browning increased periphyton biomass in the shallow water, and skyglow alleviated this effect. Browning also reduced algal diversity and species richness in the periphyton, and these effects were enhanced by the presence of skyglow. Plant growth was suppressed by skyglow, both in isolation and in combination with browning, whereas algal physiology was only affected by browning. These results show that skyglow affects primary producers in lakes and that it can interact with other co-occurring stressors. As both skyglow and browning are globally increasing, this raises concerns about potential consequences for lake biodiversity and ecosystem functioning.

Sky Brightness Assessment in Catalonia
Theme: Measurement & Modeling

Manuel Garcia Gil[1*], Salvador J. Ribas[2], Eduard Masana[3], Hector Linares[3], Ramon Canal-Domingo[2]

[1] *Generalitat de Catalunya*
[2] *Parc Astronòmic del Montsec*
[3] *Institut d'Estudis Espacials de Catalunya*

manuel.garciagil@gencat.cat
[*] *presenting author*

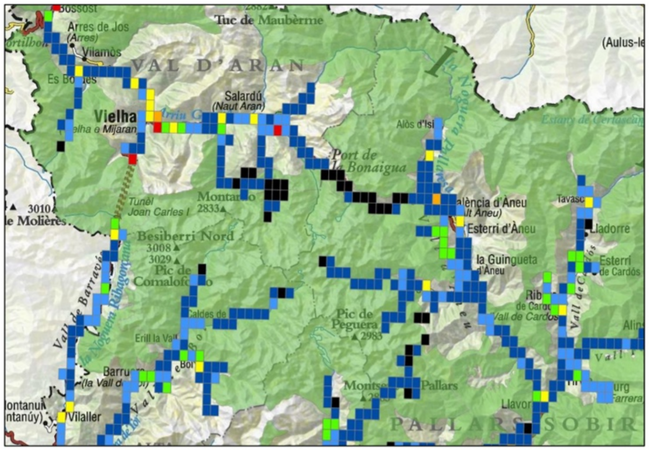
Light pollution evaluation is an essential parameter to develop environmental policies. On the one hand, this action allows knowing good and poor quality areas. On the other hand, this knowledge allows monitoring the issue, so we can know the evolution over time: for a year, a whole night, long-term…

In Catalonia, first measurements were along year 2000, within the framework of the evaluation of sky brightness, to design future regulation. They were perform with techniques that required very complex temporary and operating conditions, and a significant investment of resources :calibrated telescope and CCD camera were used in each one of the analyzed angles, for a series of typical locations (in Catalonia).

From 2012 until know, new measurements have been initiated. They have aimed to analyze the quality of the sky in natural protected areas. It has been carried out with the collaboration of different organizations: Institut d'Estudis Espacials de Catalunya (ICC-UB-IEEC), Universitat Politècnica de Catalunya, Parc Astronòmic del Montsec and Generalitat de Catalunya. Four different methodologies are included:

- Extensive analysis of the zones: Using photometer (Sky Quality Meter), on paved and unpaved road. The subsequent analysis of the data has required the adjustment and filtering by an specific software developed for this type of work.
- Temporary specific analysis: In specific points of the natural protected areas (SQM static situations).
- Punctual analysis of brightness of the entire sky: Using calibrated CCD camera (ASTMON and SQC equipment), which allows analyzing the quality of the entire dome. Besides, it permit determining the most polluting source directions.
- Pilot plan to extend a photometer network along Catalonia, which means, a long-term analysis.

All these information and measurements have provided valuable data to know more accurately the sky brightness in particular protected areas. Promoting specific lighting regulation is the target.



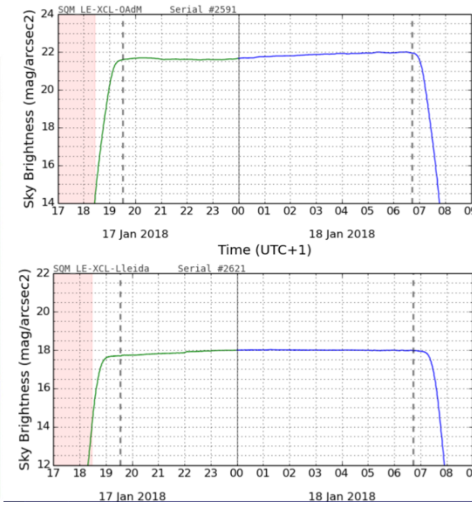


Fig. 1 and 2.. Sky brightness measurements on paved and unpaved road along Aigüestortes i Estany de Sant Maurici National Park. By Parc Astronòmic del Montsec for Generalitat de Catalunya.
Measurements by photometer net in Montsec Observatory and Lleida city. Generalitat de Catalunya network

A summary of the most representative measurements is accessible on website: http://mediambient.gencat.cat/ca/05_ambits_dactuacio/atmosfera/contaminacio_luminica/avaluacio-qualitat-cel-nocturn/.

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Modelling and Assessing Light Pollution for Environmental Planning with GIS

Theme: Society

Maria Zschorn[1,*]

[1] Institute for Landscape Architecture, Faculty of Architecture, Technische Universität Dresden, Dresden, Germany

Maria.Zschorn@tu-dresden.de

[*] presenting author

Awareness of the effects of ALAN on the environment has recently increased. Scientists and planners are looking for ways to avoid the negative impact that can result from artificial lighting (Böttcher 2001; Held et al. 2013; Rich and Longcore 2006 and many others). The task of environmental planning in Germany is to protect nature and landscape, biological diversity, the performance and functioning of the natural balance, the diversity, characteristic features and beauty of nature and landscape (BNatSchG 2009). This means that the analysis and assessment of light-related impairments is also in the field of responsibility. However, a study of landscape planning tools shows that the issue has received little attention to date (Zschorn 2018). Around 90 % of the examined examples are incomplete in the investigation of the topic. Missing recommendations and methods to analyse and assess light pollution usable for planners can be assumed as a reason. The PhD project aims to develop a methodological approach for environmental planning that can be implemented by actors in landscape and spatial planning. In the past, methods have been developed and used to model light pollution in other disciplines (Jin et al. 2017; Goronczy 2018; Jechow et al. 2019; Posch et al. 2018; Falchi et al. 2016; Kuechly et al. 2012 and others). These are to be tested for their suitability and further developed for their application in nature conservation.

An analysis of light-related impairments in landscape planning should answer the question: Where and how (strongly) does artificial light influence the values and functions of the protected issues of nature and landscape on a study area? Thus, the question with regard to existing lighting is: How and on what data basis can the area influenced by existing lighting installations be delimited? In order to achieve a correct presentation of the results, methods developed and already applied in other disciplines will be considered as possible approaches. To check their suitability for the landscape planning the following criteria must be met:

- high quality of the result (high objectivity, validity and reliability)
- low effort in the implementation (low cost and time expenditure, low complexity, little (additional) expertise required, few additional equipment necessary)
- usable result of the method (scale between 1:5.000 and 1:10.000, full area coverage for the study area, possibility of further processing in Geoinformation Systems (GIS))

The following methods, were examined as possible approaches: measurement of ground illuminance (illuminance meter), luminance measurements (luminance measurement camera), measurement of sky brightness (sky quality meter), analysis on the basis of satellite data and photos from space, measurements by airplane, drone or balloon, modeling based on the city location and size/number of inhabitants, modeling based on the current land use, modeling based on a lighting inventory, analysis by means of Citizen Science methods.

Measured against the aforementioned requirements, modeling the current lighting situation based on a lighting inventory turns out to be particularly suitable for landscape planning. However, since only a few cities have digital data on their existing lighting installations, modeling based on the current land use offers an alternative to analyse light-influenced regions (see Fig. 1).

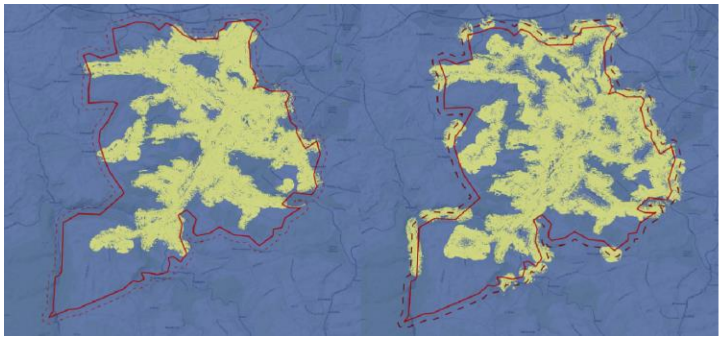

Fig. 1: Modelling of light distribution with the Viewshed2-tool in ArcGIS (ESRI) based on a lighting inventory (left) and on the current land use (right) (maps without scale, data basis: lighting inventory Freital, Corine Land Cover 2018)

The selected approaches are well suited for landscape planning, as they require a low cost and time expenditure and hardly any additional expertise or equipment from the planners. The results of the modeling cover the full extent of the study area and can be further processed in GIS. Different levels of accuracy can be achieved depending on the underlying data. The next step in the development of the method is to determine, where light influenced area overlap regions with special values and functions for nature and landscape. The final aim is to set objectives and measures for the identified conflict zones.

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Revisiting the Third Age of Light

Theme: Futures

Mark Major

Speirs Major, London
mark@smlightarchitecture.com

"London in the near future: a city in which the experience of the night is focused and autonomous, yet variable and shared. A world immersed in media and light, but where darkness once again has a tangible role. This is the 'Third Age of Light'.

In the 'First Age' we used naked flame in portable lanterns to create illumination. Technology was limited, and the glimmer of functional light barely punctuated the night.

The 'Second Age' saw the development of organised industrialised systems of gas and then electric public lighting. These ultimately resulted in a careless and wasteful use of light, leading to excessive energy use, light pollution and over-illumination, underpinned by a lack of respect for the qualities of the night.

Now imagine that, following improved understanding of our physical, psychological, biological, social and economic needs, the role of public light comes under scrutiny. Artificial light is re-elevated to a precious commodity, no longer taken for granted. A new generation of technologies and techniques begin to emerge as society looks for other ways to extend the day.

Welcome to the 'Third Age of Light'…"

Introductory text to Third Age of Light VR Experience 2017

Back in 2017, our practice Speirs Major, were invited to contribute to an exhibition in Paris that looked at how urban lighting might be experienced 50 years in the future.

We came up with a vision of the future called the 'Third Age of Light': If the 'First Age' was one in which we lit our cities and towns with primitive devices that burned, the 'Second Age' was ushered in by the industrialisation of light, first through gas and then electricity. This is the age we still find ourselves in with the further evolution of public lighting using LED, increasingly controlled by so called 'SMART' systems. We imagined however that the 'Third Age' might be one in which a combination of innovative approaches and a wide range of technologies might inform the way our cities, towns and even villages might be experienced after dark.

Whilst we were minded five years ago that the future may be driven by a response to the climate emergency and the growing awareness of the environmental consequences of using artificial light at night, the pace of change has been far quicker than anticipated. The urgent need to reduce energy use, carbon emissions and waste, minimise light pollution and prevent adverse impacts on ecologies has seen an increasing focus on the problems created by artificial light - not just its benefits. Also, interest in the relationship between light, social interaction and well-being is growing. The important role light plays in supporting the night-time economy is becoming better appreciated since recent lockdowns to help combat COVID-19.

My richly illustrated talk aims to review some of the ideas and concepts we explored as part of the Third Age of Light and examines whether our predictions still hold true, how the vision may be improved, and the likely direction of travel in the use of 'artificial light at night' in a post pandemic world.

The radiative transfer model Illumina v2.0: Added features and capabilities

Theme: Measurement and modeling

Martin Aubé,[1,2,3,*] Alexandre Simoneau[3], Julien-Pierre Houle[1], Nikki Veilleux[1], Justine Desmarais[1], Émie Bordeleau[1], Casiana Munoz-Tunon[4], Javier Castro-Diaz[4], Miquel Serra Ricart [4]

[1] Cégep de Sherbrooke, Sherbrooke J1E 4K1, Canada
[2]Bishops University, Sherbrooke, J0H 1O5, Canada
[3]Université de Sherbrooke, J1K 2R1, Canada
[4]Instituto de Astrofisica de Canarias, 38205, Spain

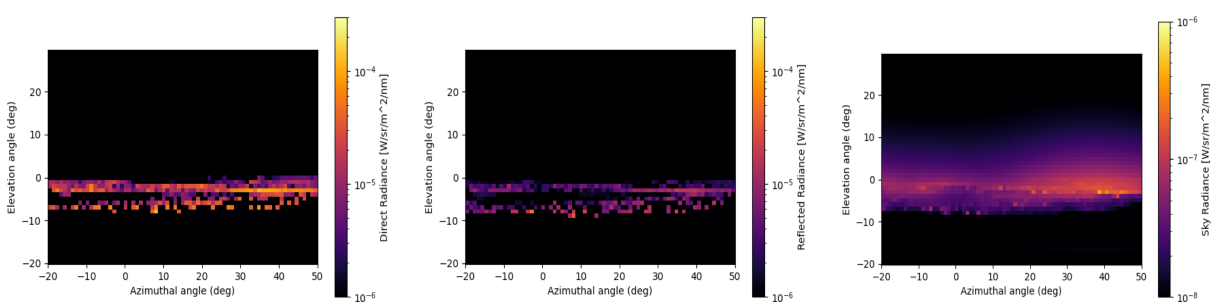
e-mail: martin.aube@cegepsherbrooke.qc.ca
[*] presenting author

Introduction

The propagation of artificial light at night (ALAN) into real environments is a complex phenomenon involving many physical processes. To properly model the phenomenon, the position, the angular photometry and the spectral properties of the lighting devices, the spectral properties of the underlying ground reflectance, the size and distribution of small-scale obstacles, the masking effect of topography, and the atmospheric transfer functions have to be taken into account. For the latter, aerosol distribution, composition and size, are of major importance because of their high variability with time and position (both horizontally and vertically). One good way to anticipate how a change in the lighting infrastructure and/or in the environment properties may affect the ALAN is to use a detailed radiative transfer model. The accuracy of the modeled ALAN relies on the implementation of the physical processes involved but also on the quality of the input data which must describe, as accurately as possible, the actual environment.

Methods

In this paper, we first describe the second version of the Illumina model. Major improvements have been made to the model, including a multiscale approach allowing a more accurate description of the lighting infrastructure and environment close to the observer. We also added the possibility of defining point sources in combination to the usual gridded light inventory. Another important addition is the calculation of the direct radiance and irradiance from the sources and reflecting surfaces, so that Illumina is not anymore restricted to sky brightness modeling experiments. Direct radiance/irradiance calculation is of major importance for studying the effect of ALAN on ecosystems and human health or even to simulate measurements made with space borne sensors.

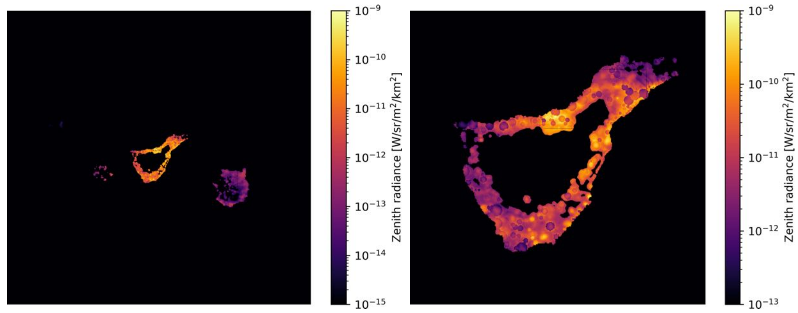


(a) (b) (c)

Figure 1 : Modeled radiance (direct and scattered) of Sherbrooke (Canada) at 550nm (integrated from 500 to 600 nm) from Mont Bellevue lookout. (a) represents the direct light from a fixture, (b) the light reflected by the ground and (c) the light scattered by the atmosphere. Note that for panel (c), the maximum level of the scale is the minimum level of panels (a) and (b). The city center is approximately located at azimuth 40deg. In panels (a) and (b), the dark horizontal stripe around -5 deg elevation correspond to the Magog river.

Results

We will show results from a diversified set of model applications including: 1- examples of direct and scattered radiance simu-lations as seen from Mont Bellevue lookout in Sherbrooke (Canada), 2- scenarios to restore the night sky darkness at Teide Observatory, and 3- an attempt to determine the flux of the lamps and their spectra by using SAVE-STARS Consulting S.L. preprocessed International Space Station color images.



(a) (b)

Figure 2 : Contribution of different parts of the Canary Islands to the zenith radiance in the Johnson's V band at Teide Observatory. The pixel color indicates the zenith radiance seen at the observatory that is produced by the sources of that pixel per units of squared km. The integral of all pixels over the image surface is equal to the zenith radiance at the observatory. Panel (b) is a zoomed view of Tenerife while panel (a) shows contributions of most islands of the archipelago. The main contributors to the Teide Observatory zenith sky brightness are sources located on Tenerife island.

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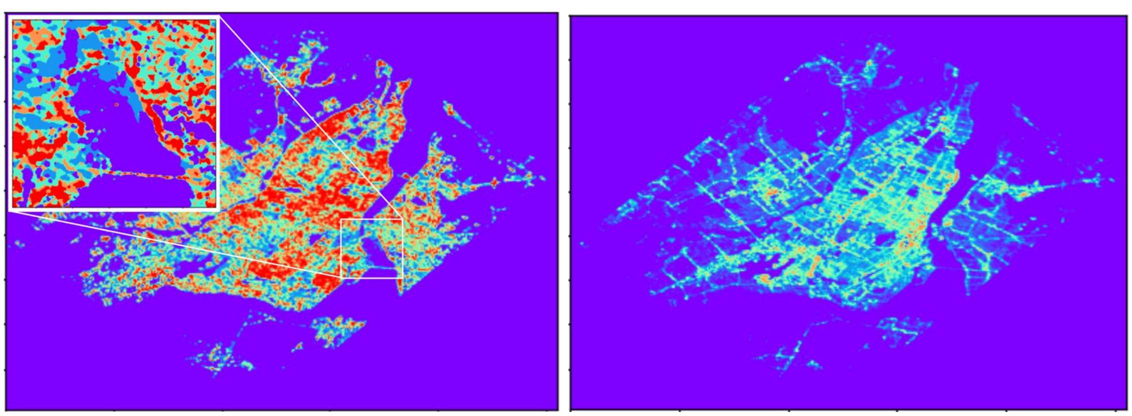

(a) (b)

Figure 3 : ISS imagery to determine the inputs of Illumina v2 model. (a) Classification of Montréal's (Canada) lighting technologies derived from ISS imagery using de Miguel *et al.* (2019) combined with some spatial and noise filtering methods. Red=HPS, Orange=PCamber and warm HPS, Cyan=Warm CFL and warm MH, Blue=Cool MH and 4000K+ LEDs, Purple=no data. Panel (b) shows the relative V band radiance of Montréal (Canada) in arbitrary units.

The impact of image resolution on power, bias, and confounding: A simulation study of ambient light at night exposure

Theme: Health

Michael A. McIsaac[1,2], Eric Sanders[3*], Theres Kuester[4], Kristan J. Aronson[2,5], Christopher C. M. Kyba[4]

1 School of Mathematical and Computational Sciences, University of Prince Edward Island, Charlottetown, PEI, Canada
2 Dept of Public Health Sciences, Queen's University, Kingston, ON, Canada
3 Dept of Statistics, University of British Columbia, Vancouver, BC, Canada
4 GFZ German Research Centre for Geosciences, Potsdam, Germany
5 Division of Cancer Care and Epidemiology, Cancer Research Institute, Queen's University, Kingston, ON, Canada
Corresponding Author: mmcisaac@upei.ca
[*] *presenting author*

Background

Studies of the impact of environmental pollutants on health outcomes can be compromised by mismeasured exposures or by unmeasured confounding with other environmental exposures. Both problems can be exacerbated by measuring exposure from data sources with low spatial resolution. Artificial light at night, for example, is often measured from low-resolution satellite images, which may result in substantial measurement error and increased correlation with air or noise pollution (Kyba, 2016).

Methods

Novel simulation studies were employed to quantify the errors that can result when measuring an environmental exposure from a source with low spatial resolution. Based on simulated epidemiologic studies in Vancouver, British Columbia, light at night exposure was the primary exposure of interest. Figure 1 presents a visualization of the range of resolutions explored. First, we assessed statistical power and bias for hypothetical studies that replaced true light at night exposure with estimates from sources with low resolution. Next, health status was simulated based on pollutants other than light exposure, and we assessed the frequency with which studies might incorrectly attribute negative health impacts to light exposure as a result of unmeasured confounding by the other environmental exposures (i.e. make a Type I error). The studied pollutants were 'all noise,' 'street noise,' *black carbon, NO, NO2, PM2.5*, and *Ultrafine Particles*.

Results

When light was simulated to be the true causal agent, the simulated studies using lower-resolution data suffered from lower statistical power and more biased estimates. In addition, correlations between light and other pollutants increased as spatial resolution decreased, although this relationship varied by pollutant. In the case of *NO*, NO_2, *PM 2.5,* and *black carbon*, the resolution of the LAN image played a clear role in the frequency of Type I errors, and using high-resolution light imagery reduced the rate of making incorrect conclusions about causality due to confounding. Other measured pollutants (noise, ultrafine particles) saw consistent Type I error rates regardless of light imagery resolution.

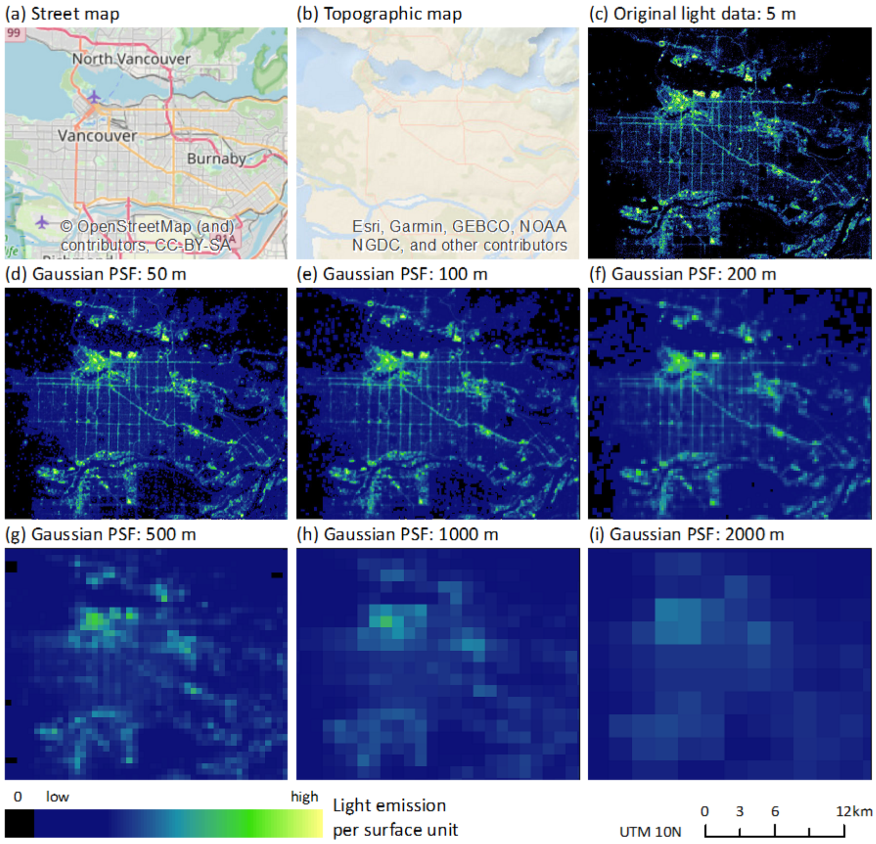

Figure 1: Street map (a) and topographic map (b) of Vancouver, British Columbia. Distribution of light at night in Vancouver as measured from the International Space Station (full resolution; c) and at calculated reduced resolutions (50m, 100m, 200m, 500m, 1000m, and 2000m; d-i) using a Gaussian Point Spread Function (PSF).

Conclusion

Studies measuring exposure to pollutants from data with lower spatial resolution are prone to increased bias, increased confounding, and reduced statistical power. Studies examining effects of light at night should avoid low resolution measures of exposure and should consider potential confounding with other environmental pollutants. This work may help explain some of the variations in results in epidemiologic studies of artificial light at night exposure as a potential cause of adverse health outcomes (Ritonja et al. 2020, Rybnikova et al. 2017).

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Moth matchmaking in moonlight: For male moths the quest to find mates is influenced by the position of the moon

Theme: Biology & Ecology

Mona Storms[1*], Andreas Jechow[2], Franz Hölker[2], Aryan Jakhar[3], Tobias Degen[1] and Jacqueline Degen[1]
[1] *University of Würzburg, Würzburg, Germany*
[2] *Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany*
[3] *School of Biology, Indian Institute of Science Education and Research Thiruvananthapuram, India*
jacqueline.degen@uni-wuerzburg.de
** presenting author*

A significant decrease in the abundance and distribution of moths has been observed in many European countries [Fox 2013, Groenendijk & Ellis 2011]. Since it is known that moths play an important role as pollinators [Devoto et al. 2011, LeCroy et al. 2013, Macgregor et al. 2015], it is important to understand the reasons for their decline. Loss and fragmentation of habitats, use of chemicals in the agriculture, climate change and light pollution are discussed as possible drivers [Fox 2013, Grubisic et al. 2018], all of them resulting in a modified environment with possible effects on behavior and orientation and therefore their reproductive success.

The most easily perceived celestial body during the night is the moon, which, however, can be more difficult to use as a compass than the sun because of its variable, temporally limited visibility [Wehner 1984]. Nevertheless, it is used by many nocturnal insects for orientation and navigation [Warrant & Dacke 2011]. However, the importance of the moon for sex partner finding and the risk potential by light pollution has not been investigated so far.

In this study we used male moths of the species *Sphinx ligustri*, which were reliably attracted by females, and analyzed the importance of the moon for their orientation.

Specially calibrated digital cameras that are suitable to measure the dynamics of night-time lighting conditions [Jechow et al. 2020] allowed us to track changes in the artificial lighting conditions and the brightness of the sky simultaneously (**Figure 1**).

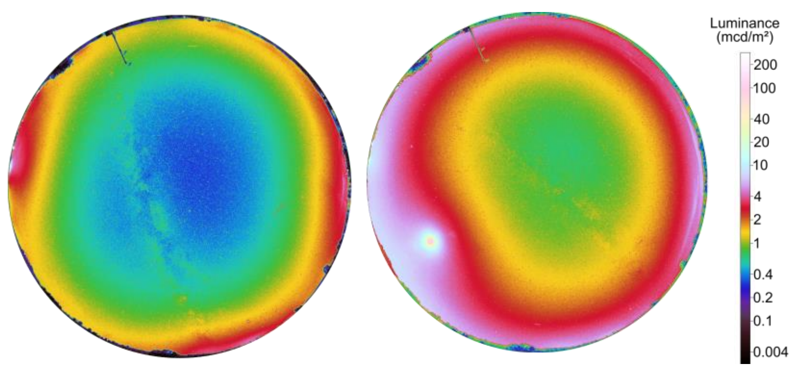

Fig. 1: Luminance maps of clear night skies. Left: The moon was below the horizon (altitude: 0°). July 23, 2019 12:25 am. Right: The clearly visible moon was 26° above the horizon. July 23, 2019 03:23 am.

The percentage of animals that arrived at the females increased when the moon crossed the horizon. Additionally, the time males needed to reach the females decreased with increasing moon altitudes – the higher the moon was above the horizon, the faster the males reached the females. This was accompanied by a reduced variance of flight durations, indicating that the rising moon generally facilitates olfactory orientation of moths. In order to determine the origin of the high variances in flight duration, the lighting conditions of the horizon were analyzed in detail. The high intensity and variability, but especially the mixing of artificial and natural light signals could be an explanation for the high variance of flight durations.

Landscapes around the world have been drastically restructured in terms of light intensity and light spectrum due to the rapid spread and increase of electrical lighting [Cinzano et al. 2001]. The final consequences are still uncertain, especially because artificial light at night is still increasing exponentially [Kyba et al. 2017].

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Simulations of light pollution over the Natural Reserve "La Primavera" in Guadalajara Jalisco México

Theme: Measurement and Modeling

Monica Lozada-Muñoz [1,*] and Héctor Solano-Lamphar [2]

[1] *Universidad del Valle de México, Calz. de Tlalpan 3016 y 3058*
Ex Hacienda Coapa,
Alcaldía Coyoacán, C.P. 04910, CDMX

[2] *Cátedras CONACyT, Av. Insurgentes Sur, San José Insurgentes, C.P. 08600, CDMX*

monica.lozada@uvmnet.edu
[*] *presenting author*

Abstract

Light pollution (LP) is an environmental problem caused by the combination of aerosols and atmospheric particles in their interaction with artificial light. It was described by Hollan (2009) as the alteration of the standard level of light night in the environment. The different devices used in cities to generate artificial light are the main factors that cause LP. This radiation is directed to the atmosphere and it is scattered by air molecules and atmospheric aerosols; causing in the night sky a characteristic color which depends on the illumination technology.

These devices are well represented by luminaires in parks, streets and different public and private spaces. In general, the use of not appropriate artificial night lighting affects not only dark skies, but also reduces the visibility of stellar objects (Crawford 1991; Cinzano 2000d; Cohen & Sullivan 2001), as well as wildlife and human beings. According to the nighttime maps of artificial luminosity by Cinzano et al. (2001), 88% of the population in Mexico lives under an artificial sky brightness 0.11 times greater than the average level[1].

There are many types of luminaries, such as the mercury vapor lamp (MC) with a strong emission in the UV spectra (Solano-Lamphar & Kocifaj 2013). These kinds are known as gas discharge lamps, since they generate light by sending an electric discharge using ionized gas. Mercury has an visible emission at 405, 435 and 545 nm. These wavelengths are important in processes such as photosynthesis, so they are used generally as growth lights. The metal halide lamp (MH) produces light using an electric arc compound by a mix of vaporized mercury and halide metals (Hordeski 2005). They have presence in almost all the visible spectra with peaks at several wavelengths, such as 385 nm, 422 nm, 497 nm, 540 nm, 564 nm, and the major amplitudes at 583 nm, 630nm and 674 nm. They are the most used in public zones because they have a strong yellow color nearly as natural as daylight. The high-pressure sodium lamp (HPS) uses sodium at an excited state to produce light. It has a major amplitude at 568 nm at green in the visible spectrum with some important peaks at yellow (near to 590 nm), orange (near to 605 nm) and finally at red (approximately at 632 nm). Their spectra are dominated by the emission line at Sodium-D (at 589 nm in the yellow range). The low-pressure sodium lamp (LPS) has a visible emission cause the emission line sodium-D at 589.3 nm, this kind of lamps are the least attractive to insects (Solano-

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[1] The luminosity average of the sky below the atmospheric level is fixed at b_n=8.61 x 10^7 V ph cm^{-2} s^{-1} sr^{-1} , which is approximately to 21.6 V mag $arcsec^{-2}$ or 252 µ cd m^{-2} (Cinzano et al. 2001).

Lamphar & Kocifaj 2013). In general, the luminaries most frequently used in Mexico are light emitting diodes (LED) this kind apparently causing adverse effects in humans and animals affecting melatonin, which is related with the exposition to blue light (Falchi et al. 2011).

The main objective of this project is to know the real affectation of light pollution at one natural reserve in Mexico. The territorial characterization was based on the study of all the factors that represent light pollution in its relationship with atmospheric optics, theoretically analyzing the predominant characteristics related to the problem of the brightness of the night sky. Rigorous light scattering and radiative transfer theories were applied to model the interaction of artificial light with an inhomogeneous atmosphere and to interpret specific optical characteristics such as skyglow typologies under high turbidity conditions.

The recovery of light pollution was carried out through the results of a theoretical development, including characterization for different climatic conditions. The calculations are based on an implementation of the Eddington approximation. Consequently, the numerical tools were based on the rigorous Mie theory to obtain the dispersion properties of spherical particles. In the case of a cloudy sky, a one-kilometer thick cloud layer with a cloud base located one kilometer above the ground was considered. The optical thickness of the cloudy layer will vary over a wide range to cause an alteration of the total atmospheric optical thickness of 5 to 10.

Aerosols can be emitted directly into the atmosphere in the form of particles, or as gases that by chemical reactions between reactive molecules form particles in the atmosphere. Another element of complexity in the analysis of light pollution is the territorial distribution of artificial light in the urban space. A large part of artificial night lighting comes from public light sources. To recover its effects on the light levels of the sky it is necessary to analyze different installations of individual lamps in the urban environment. The distribution of electromagnetic energy in the spectra of the lamp plays a crucial role in understanding the problem, as well as the intensities of the emitted glow. In the present study, the characteristics of the glow of the sky under different conditions and its effect on different natural areas near a metropolitan area were analyzed.

The results of the first analysis show that the situation of light pollution is critical in the selected places, considering the geographic center of the city, large effects near the metropolitan area were identified. Specifically, night sky patterns lose their natural structure due to significant increase in luminance amplitudes. This effect is reinforced by the increase in the color temperature of the LEDs, which have been included in the lighting system of the City in recent years. The results show that scattering effects and differences in efficiency can lead to significant impacts on the brightness of the night sky.

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Metabolic Health and Physical Development of Barn Swallow (*Hirundo Rustica*) Chicks Under Natural Photoperiod and Artificial Light at Night

Theme: Biology and Ecology

Murry L. Burgess,[1,*] Caren B. Cooper,[1] and Margaret A. Voss[2]

[1] *North Carolina State University, Raleigh, USA*
[2] *Syracuse University, Syracuse, USA*
mburges5@ncsu.edu
[*] *presenting author*

Introduction

Seasonal changes in photoperiod are ubiquitous cues used by virtually all life on Earth (Dominoni et al. 2013). Through the expression of clock genes and neuro-endocrine signals, the timing of life-cycle events and daily fluctuations in physiological processes are synchronized with local photoperiodic environments. Phenology - the timing of life cycle events - is heavily influenced by circannual light and dark (Dominoni et al. 2013). Birds rely on circannual light cues for migration and reproduction (Dominoni et al 2013; Ouyang et al. 2015) and circadian photoperiod for cueing the start (Cooper et al. 2009; Voss & Cooper 2013) and termination (Cooper et al. 2009; Voss & Cooper 2013) of laying a clutch of eggs. Songbirds lay one egg per day, so photoperiodic influences on laying can determine clutch size (Cooper et al. 2009; Voss & Cooper 2013).

Artificial light at night (ALAN) is quickly becoming a prevalent component of nightscapes worldwide (Ouyang et al. 2015; Raap et al. 2015). ALAN has several well-documented effects on birds, including altering circadian cycles (Dominoni et al. 2013; Newport et al. 2014; Ouyang et al. 2015; Raap et al. 2015), mating and reproduction (Dominoni et al. 2013; Newport et al. 2014; Ouyang et al. 2015; Raap et al. 2015), eyesight and object perception (Newport et al. 2014), orientation (Ouyang et al. 2015; Raap et al. 2015), and foraging (Newport et al. 2014). ALAN is a novel selection pressure in the human-built environment that alters photoperiodic timing cues. Artificial photoperiods can also interact with clutch initiation and termination, which ultimately determines clutch size (Voss & Cooper 2013), and can influence nutrition to affect metabolic health (Raap et al. 2015).

Under typical circumstances, sleeping chicks lower their metabolic rate at night and store unused glucose, repair tissues, and recharge their bodies (Raap et al. 2015). However, ALAN disrupts circadian rhythm, increasing the metabolic rate of growing chicks. The metabolic demand for glucose continues during the night, although the chicks are not being fed. Therefore, glucose must be converted from other sources, such as lipids and proteins (i.e., gluconeogenesis). This shift in metabolism affects developing anatomy and inhibits chick growth (Ardia 2006; Downs et al. 2009). Chicks typically have little to no fat stores; therefore, proteins are targeted for glucose production. However, protein is also needed to fuel the immune system and energetic functions, such as flight (Ardia 2006). If the feeding rate does not increase, gluconeogenic pathways can maintain high plasma glucose concentrations even though the cells themselves are not metabolizing glucose (Beauchat & Chong 1998). This can be thought of as a mechanism to spare glucose for emergency responses, such as flight from predation. In this case, we might see a shift in phenotype, such as delayed growth, as chicks exchange protein for glucose.

Hyperglycemia, high blood sugar, is symptomatic of diabetes, even in birds (Beauchat and Chong 1998; Ardia 2006). ALAN may cause avian diabetes by increasing blood glucose levels even higher above the avian norm. Because ALAN alters circadian rhythm, and blood glucose is regulated by circadian rhythm (Downs et al. 2009), daily blood glucose concentrations may similarly be altered by ALAN. In other words, ALAN may increase blood glucose concentrations thus affecting metabolic health and potentially leading to metabolic disease such as avian diabetes.

I investigated multiple research questions about natural photoperiod and artificial light at night on chick health and development: RQ1. Does chick development vary with natural longitudinal photoperiods? RQ2. How is chick development altered by ALAN? RQ3. Does parental feeding behavior change in the presence of ALAN?

Methods

During spring 2020, I researched the effects of ALAN on chick glucose levels, growth, and health through a field experiment with Barn Swallows, (*Hirundo rustica*), a common, urban-adaptable songbird found nearly globally. In a barn in Snow Camp, NC, I randomly selected half the nests for illumination with artificial lights 24 hours a day and half of the nests for controls with natural photoperiods. I collected a drop of blood from each chick to sample glucose levels at 3-day intervals throughout chick development. Similarly, I took repeated morphological measurements (mass, feather growth, wing chord length, tarsus length, and fat score) and standardized photos of pin feather tracks. When broods were 10 days old, I pooled blood from broodmates for more robust laboratory blood testing of glucose, lipids, proteins, and expression of genes that regulate glucose. I completed data analysis using mixed model regressions with random effects. Previous data was collected in 2014 and 2015 with Barn Swallows in NY using the same methods, and I was able to combine data from both locations to compare control and treatment nests across both sites.

Conclusions

Based on data analysis results, chick growth and development are impeded by ALAN and also affected by location. There was a statistically significant difference in Barn Swallow conditions between latitudes and treatments. All body measurements and glucose levels were greater in chicks from NY, while head size, wing chord, and mass were affected by the treatment. With standardized photos, I documented striking visual differences between chicks in each treatment.

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The impact of light pollution on celestial visual information invertebrates use as a navigational cue

Theme: Biology and Ecology

Nicholas W. Roberts*[1], Rochelle J. Meah[1] and Lauren Sumner-Rooney[1,2]

[1] School of Biological Sciences, University of Bristol, Bristol, UK, BS8 1TQ
[2] Oxford University Museum of Natural History, Oxford OX1 3PW
nicholas.roberts@bristol.ac.uk
[*] presenting author

Artificial light is a major sensory pollutant. While we understand how the intensity, spectral distribution and timing of light pollution can affect individual aspects of biochemistry, physiology and behaviour, the overall impact of artificial light masking visual cues used by animals for task-specific behaviours has received relatively little attention.

Light from the sun becomes polarized as it passes through, and is scattered by, the atmosphere. This results in a predictable and directional overhead polarization pattern that many invertebrates use as a directional cue. This pattern not only occurs during the day, but also at night, when the sun's light is reflected by the moon.

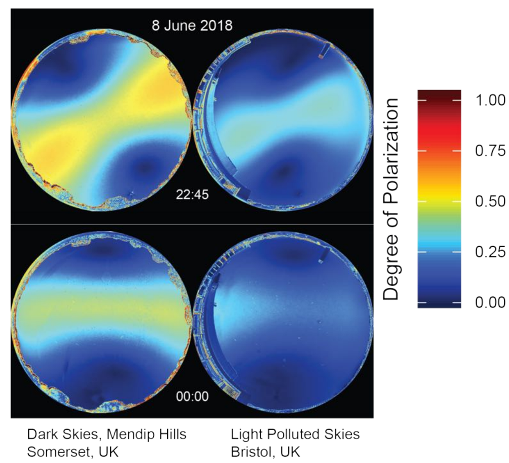

Fig. 1: The degree of polarization of the night sky under both dark and light-polluted conditions, at different times after sunset.

In a series of experimental studies, we have investigated the effects of artificial light pollution on the visibility of the night-time polarization pattern. Figure 1 shows four projections of the entire overhead hemisphere, with the false colour illustrating the degree of polarization across the night sky. Comparing the night-time polarization pattern viewed simultaneously from two sites of different levels of light pollution (the Mendip hills vs. Bristol city centre) demonstrates how ground-based artificial light masks the pattern. In particular, a significant reduction in the degree of polarization occurs approximately one hour after sunset in polluted areas. However, we should not focus solely on the changes to physical properties of the light; it is more biologically relevant to determine how those changes are seen by the visual system of the specific species or group under consideration.

Ground spiders (Gnaphosidae) are central place foragers, using the polarization pattern as navigational information to return directly to their shelter after foraging (Dacke M 1999). They have a pair of secondary eyes specialized to detect the polarization of the overhead light. The eyes are lensless; they do not form images, but each integrate incoming light over an overlapping 60-degree field of view. Polarization information is opponently processed between perpendicularly orientated photoreceptors in the two eyes. We can thus calculate the photoreceptor contrast available between these eyes in a given scene where we know the polarization pattern.

Fig. 2A illustrates the calculated photoreceptor contrast of the polarization pattern at a variety of different light pollution levels across the UK and Europe. When sampled by and integrated over the spider field of view, Fig 2B demonstrates how the contrast between the two eyes follows a strong non-linear inverse relationship with the amount of night time light produced. For these calculations we used the VIIRS measured radiance values (Earth Observation Group 2019) in order to provide a direct link between the amount of artificial light produced and the impact on the polarization pattern, without the need for correction for species sensitivity functions as required by photometric data.

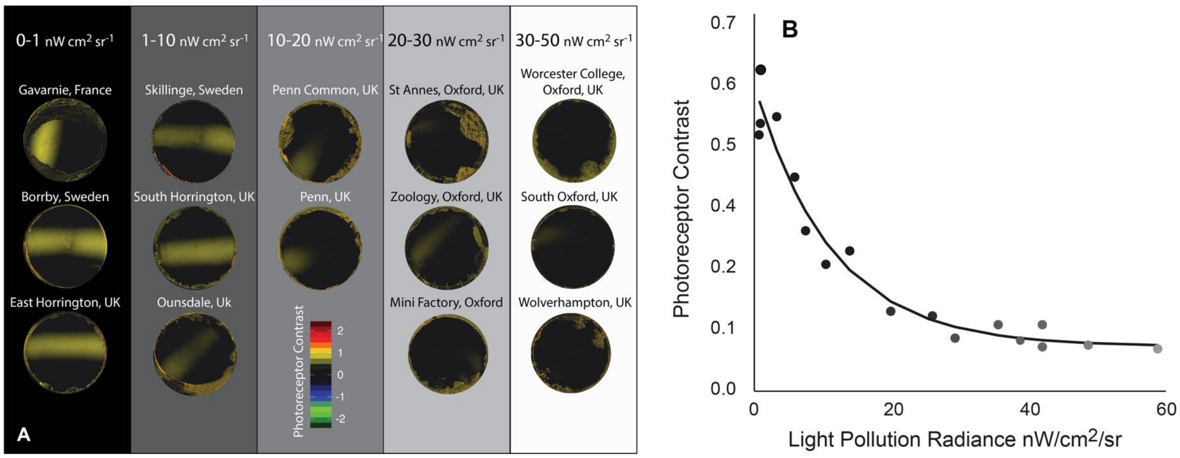

Fig. 2: A) The photoreceptor contrasts of the night-time polarization pattern, viewed at human resolution. Columns are grouped by levels of VIIRS radiance in nW cm^2 sr^{-1}. B) The functional relationship between photoreceptor contrast and the amount of light pollution produced.

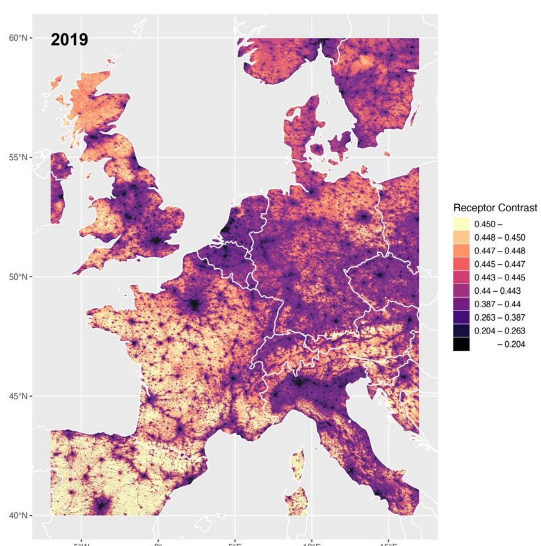

Fig. 3: The calculated levels of photoreceptor contrast of the overhead polarization pattern available to gnaphosid spiders.

Finally, we can use this relationship between the level of light pollution and the photoreceptor contrast to map how the visibility of the polarization pattern is impacted across Europe. Fig. 3 takes the 2019 yearly average of the VIIRS radiance data and recasts this as photoreceptor contrast data. This provides a unique approach by which to understand the spatial and broad scale impact of light pollution on the critical sensory information for particular groups of animals.

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Definition of a new RGB photometric system and UCM library of synthetic spectrophotometric standard stars

Theme: Measurement & Modeling

Nicolás Cardiel,[1,2,*] Jaime Zamorano,[1,2] Salvador Bará,[3] Alejandro Sánchez de Miguel,[1,4,5] Cristina Cabello,[1,2] Jesús Gallego,[1,2] Lucía García,[1] Rafael González,[1] Jaime Izquierdo,[1] Sergio Pascual,[1,2] José Robles,[1] Ainhoa Sánchez,[1] and Carlos Tapia,[1]

[1] *Departamento de Física de la Tierra y Astrofísica, Universidad Complutense de Madrid, Spain*
[2] *Instituto de Física de Partículas y del Cosmos, Univ. Complutense de Madrid, Spain*
[3] *Departamento de Física Aplicada, Universidad de Santiago de Compostela, Spain*
[4] *Environment and Sustainability Institute, University of Exeter, United Kingdom*
[5] *Instituto de Astrofísica de Andalucía, Granada, Spain*
cardiel@ucm.es
[*] *presenting author*

Abstract

One of the most challenging problems that users of high-quality digital cameras equipped with Bayer-like color filter systems are facing is the accurate calibration of their images. Although it is possible to use bright star measurements for that purpose, the available data correspond to photometric magnitudes obtained through typical astronomical filters (e.g., Johnson-Cousins UBVRI), which exhibit spectral sensitive responses that do not match with those of common RGB filters (see Fig. 1).

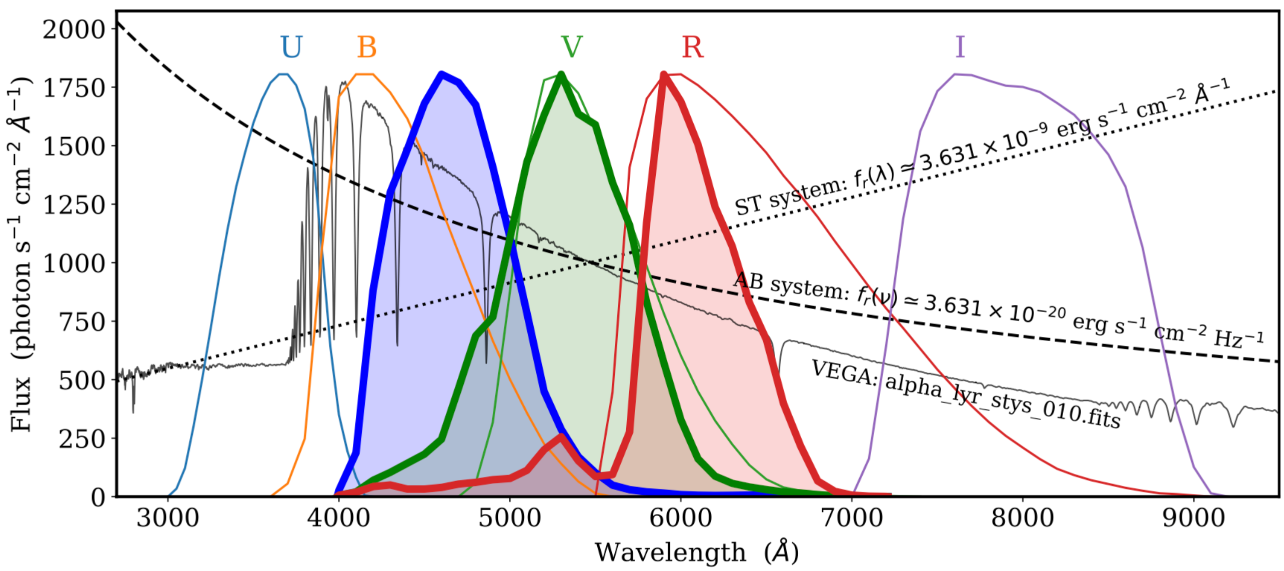

Fig. 1: Comparison of spectral sensitivity responses of the well-known Johnson-Cousins astronomical filters UBVRI (labelled thin lines) with the median RGB curves (thick blue, green and red lines with shaded regions) derived in Cardiel et al. (2021) using the compilation of 28 sets of response curves of Jiang et al. (2013). The reference flux density (in photon s^{-1} cm^{-2} Å^{-1}) employed to define the zero point for the AB, VEGA and ST magnitude systems (dashed, full and dotted lines respectively) are overplotted.

In order to solve this problem, in Cardiel et al. (2021) we have employed historical 13-color (C13) medium-narrow-band photometric data from Johnson & Mitchell (1975), Schuster (1976) and Bravo Alfaro et al. (1997), gathered with quite reliable photomultipliers, to fit the spectrum of 1346 bright stars belonging to the Bright Star Catalogue (Hoffleit 1964), using the stellar atmosphere models of Castelli & Kurucz (2003). Some representative stellar spectra are displayed in Fig. 2. The accuracy of the fitted spectral energy distributions has been checked by comparing synthetic Johnson B and V magnitudes with the corresponding data available through the Simbad database (available at http://simbad.u-strasbg.fr/simbad/), with a typical ±3σ scatter in both bands around 0.10 mag, being part of this dispersion attributable to the heterogeneous source compilation in the Simbad data. A subsample of the fits (39 stars) was compared with actual flux calibrated spectra from Kiehling (1987), providing synthetic magnitude uncertainties below ±0.05 mag. The whole set of fitted star models, that constitutes the UCM library of spectrophotometric standards, has been employed to compute synthetic RGB magnitudes and uncertainties. In addition, a new RGB photometric system, that can be used as a standard reference, has been established, by defining standard RGB sensitivity curves as the median of the corresponding curves of 28 commercial cameras (also shown in Fig. 1).

The RGB magnitudes of the UCM library of spectrophotometric standards makes the sky an accessible and free laboratory for the calibration of digital cameras, facilitating their use not only in many astronomical fields, such as the study of meteors, solar system bodies, variable stars, and transient objects, but also in the detailed monitoring of light pollution and its impact on the night sky brightness. The results of this work are publicly available at https://guaix.ucm.es/rgbphot.

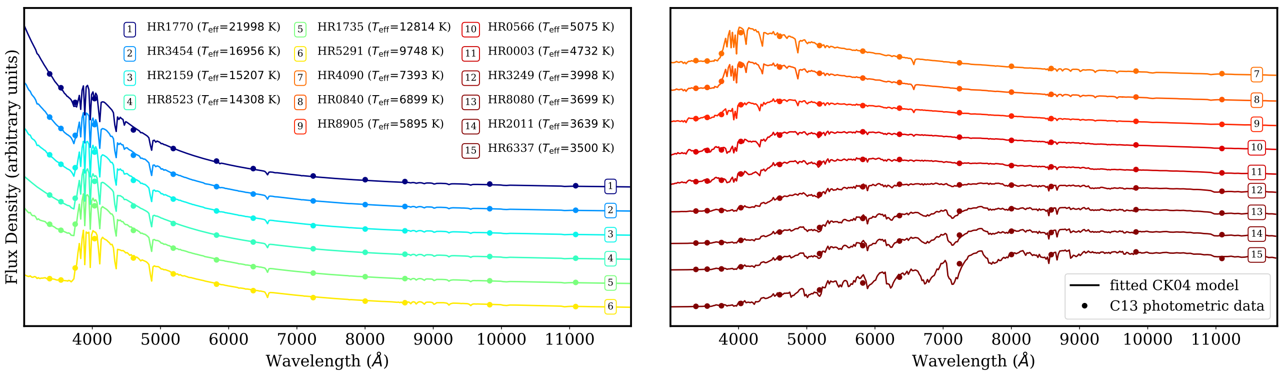

Fig. 2: Examples of spectrum fits to stars with different effective temperature. The filled circles correspond to C13 photometric data from Johnson & Mitchell (1975). The continuous lines are the fitted Castelli & Kurucz (2004) models. The spectra have been numbered by decreasing effective temperature.

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Mapping the Melatonin Suppression Index with the International Space Station colour images

Theme: Measurement & Modeling

Nikki Veilleux,[1,*] Justine Desmarais,[1] Émie Bordeleau[1], Martin Aubé,[1,2,3] and Alexandre Simoneau[3]

[1] Cégep de Sherbrooke, Sherbrooke, Canada
[2] Bishops University, Sherbrooke, Canada
[3] Université de Sherbrooke, Sherbrooke, Canada
martin.aube@cegepsherbrooke.qc.ca
[*] presenting author

Introduction

Recently, many studies have started linking the increasing exposure to artificial light at night to the rate of hormonal cancers, such as prostate and breast cancer. Suppression of the melatonin hormone may be the cause of this link that happens when people are exposed to light at night, especially for visual light of short wavelengths. This suppression happens naturally in the morning, as the sun rises, causing the end of the sleeping state. Although this response is essential to our well-being, it may become damaging when it gets triggered at the wrong time. Indeed, it is believed that the production of melatonin during sleep helps to inhibit the reproduction of cancerous cells.

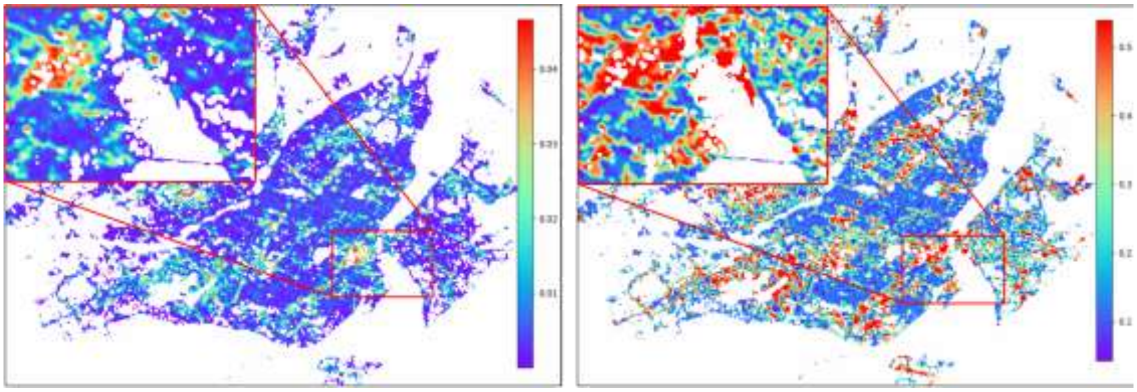
The Melatonin Suppression Index (MSI) is an interesting metric to use to study this particular link. It depends mostly on the shape of spectral emissions of the various light sources. International Space Station (ISS) colour images of light emitted towards the sky during the night could be an efficient tool at mapping the Melatonin Suppression Index.

Methods

We will present the steps undertaken in order to obtain a clean and representative MSI map of Montréal, Canada. We present manipulations that were needed to eliminate aberrant data and noise coming from a preprocessing of the images from the ISS as executed by SAVE-STARS Consulting S.L. We also show our process in obtaining approximate MSI from the classification of the type of light sources present in the area of Montréal, Canada.

Conclusions

We present a map of the different kinds of technologies illuminating Montréal at night as well as two maps of the Melatonin Suppression throughout the city: one relating the absolute MSI and one taking into account both the visual radiance and the MSI in the quantification of the melatonin suppression.



(a) (b)

Figure 1: P Melatonin suppression maps derived from ISS imagery using Sanchez de Miguel *et al.* (2019) and combined with some spatial and noise filtering methods. Panel (a) shows the absolute MSI assigned according to the different lamp technologies of Montréal's (Canada). Panel (b) shows the MSI relative to the V band radiance of Montréal (Canada).

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Poisoning the web: Effects of artificial light at night and pesticides on urban spiders

Theme: Biology and Ecology

Nikolas J. Willmott[1,*], Kathryn B. McNamara[1], Bob B.M. Wong[2], and Therésa M. Jones[1]

[1] The University of Melbourne, Melbourne, Australia
[2] Monash University, Melbourne, Australia
nwillmott@student.unimelb.edu.au
[*] presenting author

Introduction

The world is facing an environmental crisis, as anthropogenic stressors are increasingly permeating every ecosystem on Earth. While the effects of individual stressors, such as artificial light at night (ALAN), are increasingly well understood, there are several key gaps in the literature. This includes knowledge gaps for certain taxa (Luck & Smallbone, 2010), or how these impacts are mediated by interactions with other stressors (Piggott et al., 2015). Additionally, while most research rightly focuses on negative consequences for animals, many species appear to thrive under these conditions, and this has important implications for ecosystems broadly (Lowry et al., 2013). Little is known about the extent of potential fitness benefits for these species or how long these benefits are likely to last in the future.

Fig. 1: An adult female Australian garden orb-weaving spider (*Eriophora biapicata*). These spiders are large and nocturnal, and are found in a wide range of natural and anthropogenically disturbed habitats across southern Australia. Photo: Nikolas J. Willmott

Pesticides are pervasive across a wide range of environments, and they affect many target and non-target species (Pekár, 2012). Among their many physiological impacts, they can increase oxidative stress, allowing an interaction with ALAN, which reduces anti-oxidant capacity (Jones et al., 2015). Additionally, some insects show a circadian rhythm in susceptibility to pesticides (Yang et al., 2010). Despite this, there has been no experimental research looking at the interactive effects of ALAN and pesticides on invertebrates. Both of these pollutants can affect spiders, which are among the most diverse, abundant, and ecologically important terrestrial predators on the planet. Pesticides can have both lethal and sublethal effects on spiders, and trace pesticide exposures can increase foraging activity and growth (Pekár, 2012). In the field, ALAN increases foraging success for some spiders (Willmott et al., 2019), but chronic exposure to ALAN in the absence of foraging benefits can accelerate development and reduce adult body size and fecundity (Willmott et al., 2018).

In my PhD, I am investigating the potential for animals to exploit anthropogenic change, and the balance of costs and benefits associated with this exploitation. I will illustrate this by looking at the effects of ALAN and the insecticide imidacloprid on development, foraging, physical performance, and mating in the Australian garden orb-weaving spider (*Eriophora biapicata*), which is large, nocturnal, and prevalent in anthropogenically disturbed habitats.

Methods

To understand the scope of exploitation of anthropogenic change, I conducted a literature review of research showing a benefit of anthropogenic change for animals across taxa and biomes. In this review, I highlight the benefits, but also describe potential costs, and discuss how the balance between apparent benefits and costs will affect ecosystems in the future.

To investigate the impacts of artificial light at night (ALAN) on spiders, I reared orb-weaving spiders (*Eriophora biapicata*) from egg to adult under a natural LD cycle or under chronic ALAN exposure (cool white LED, 20 lux at night), and measured development and growth rates, mortality, and fecundity. I also conducted field experiments to compare prey capture rates of spider webs in dark sites or comparable sites experimentally illuminated with cool white LED lights.

I have also tested the combined effects of ALAN and the neonicotinoid insecticide imidacloprid on climbing performance in *E. biapicata*. Climbing performance is an important trait reflecting spider health and morphology, and is a potential predictor of foraging and mating success. I exposed spiders to ALAN (as above) for several weeks in the lab, and performed repeated pesticide exposures, and measured climbing speed before and after each exposure.

Conclusions

Numerous animals can exploit a suite of anthropogenic stressors, and this has important consequences for the compositions of urban communities, and thus for the health of ecosystems in an increasingly urbanised world. Artificial light at night (ALAN) and pesticides have a number of negative impacts on many species, but under certain conditions they have the potential to benefit species, either directly or indirectly, particularly through shifts in interspecific interactions. Urban spiders face a wide range of anthropogenic stressors, but many, at least in the short term, appear to be coping with and thriving under these conditions. While current evidence suggests that individual stressors can have either positive or negative effects for these spiders, our understanding of their impacts may change as we investigate interactions between stressors. Understanding these impacts on spiders will improve our understanding of ecosystem-level effects of pollutants, better informing future management practices for the conservation of native invertebrate fauna.

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The light for the value of the night.
Are the basic principles for interior good lighting design not present in the night of our cities?

Theme: Technology and Design

Paulina Villalobos

DIAV / Noche Zero, Santiago, Chile
villalobos@diav.cl

Introduction

According to Lou Michel there are 7 relevant factors of visual balance such as Lighting levels, Lighting distribution, Shades, Reflexion, Glare, Colour of light & consideration of Textures and surfaces to check if a space has good lighting for visual comfort. Those principles are some of the basic factors considered in a professional lighting design process. If we randomly chose any city around the world it would not pass the test of visual comfort in lighting, I don't know any city! Most of them will fail if we test the lighting distribution and the glare control, both linked directly to light pollution. So why is the public realm not taking in consideration the good quality of life related to visual comfort for the outdoor lighting?

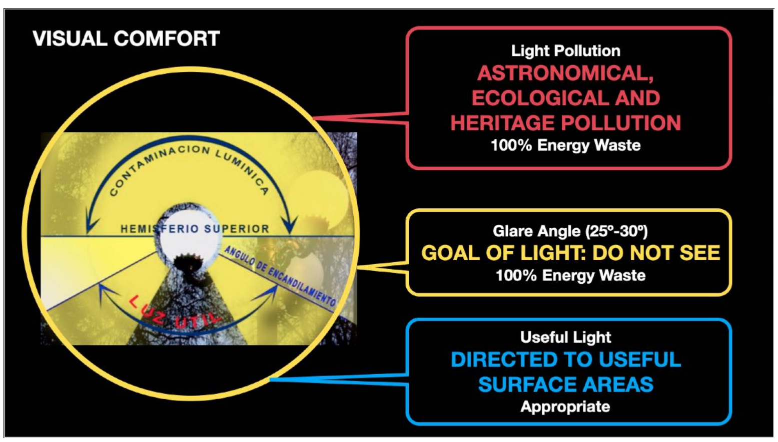

Figure 1: Standard luminaire graphic showing the luminous flux distribution and different types of light pollution. This graphic was made for the Ministry of Energy from Chile, public administration and politics.
This is a single lighting solution for the space and not a unit of a good lighting design project.

by Paulina Villalobos 2018 (Ciluz / NocheZero for Minergia).

I propose that the absence of "design" in the lighting solutions for the outdoors is the key, normally the solution for *put* light would solve the problem of lux required in a surface plane that probably is for the car only. Also we have to take in consideration that lighting design is a "new" field and with few exceptions it is still not recognised as a profession yet in most of the countries. Hence "design the night" could be one of the solutions, not just for light pollution but for the urban quality in general, because the design process use a different route to achieve a good result, were creativity, the visual balance, life quality, the respect for the environment, glare and light pollution free spaces, energy responsible decisions, security and safety are "by default" part of the outcome of a XXI good lighting design because are part of the basic factors to consider in a design process.

The inclusion of the "design process" in the lighting planning of our cities and new regulations or guidelines to design the night will help to solve the problem of light pollution and recover the value of the night, not just for astronomical reasons but also to recover the sky as a human heritage and natural ecological environment.

Design for the night

The presentation will show some of the lighting projects I have designed for the night with my team at DIAV. A park, an interactive square and a façade, a bridge and an art installation.

Through those projects and their different scales the design process will show how the factors of visual balance and I will introduce the time and the sequence as a new factor to include in the lighting design for the night.

Fig. 2: Fluvial Park in Santiago. DIAV by M.Cirano

Fig. 3: Square of light and art at Artequín Museum. DIAV by M.Cirano

Fig. 4: Artequin Museum Lighting Façade colour sequence of 2 minutes.

Fig. 5:Malleco Bridge. 800 lighting sources RGA of 8º pointing down and programmed to tell the story of the construction. DIAV by V. Urra.

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Instrument verification and atmospheric phenomena in relation to the NSB time series

Theme: Measurement and Modeling

P. Fiorentin[1*], S. Cavazzani[1,2,3*], S. Ortolani[2,3], A. Bertolo[4], and R. Binotto[4]

[1] *Department of Industrial Engineering, University of Padova, Italy*
[2] *Department of Physics and Astronomy, University of Padova, Italy*
[3] *INAF-Osservatorio Astronomico di Padova, Italy*
[4] *Regional Environmental Prevention and Protection Agency of Veneto, Padova, Italy*

pietro.fiorentin@unipd.it
(*) presenting author

Introduction

The long-term trend of the night sky brightness (NSB) in relation to artificial light at night (ALAN) is very important for the multidisciplinary effects on astronomical observations, biology, ecology and medicine. Different trends have been shown by Sky Quality Meter (SQM) and camera networks for different sites, they can present an increase of the readings or a drift to show darker sky [1-4]. Trends could be influenced by variations of the instruments in the nets, those could be caused by their ageing. Some ageing effects on the SQM components are here considered by detailed laboratory analysis, then links with the trends are looked for. An attempt of describing the causes of the time trends for two sites, Asiago (Italy) and La Silla (Cile), are presented considering also satellite data. The described algorithm provides these results with the NSB analysis measured by common SQMs.

Methods and results

The spectral response of some SQM components are obtained during laboratory measurements; in particular different kinds of external protecting windows and internal IR blocking filter are considered. Both new and aged components are studied. The analysis shows difficulties in detecting on protecting windows an ageing effect due to their outdoor use. On the contrary a clear deterioration of the IR blocking filter appears when comparing a 9-years-old one versus a new one: its transmittance changed more than 30% at the shortest visible wavelengths. This decay can clearly affect the SQM response (Fig. 1), but the amount of the variation depends on the spectrum of the considered light.

Figure 1 presents also the distributions of the radiation from the night sky in 2018 and 2020, any function in figure 1 has the area normalized to unit. The normalization of the radiation means supposing the same total power emitted by the sky. Considering at the same time the decay of the SQM and the variation of the night sky spectrum, the SQM reading reduces by 0.18mag/arcsec², showing an increase of the sky brightness. With the same the spectrum variation

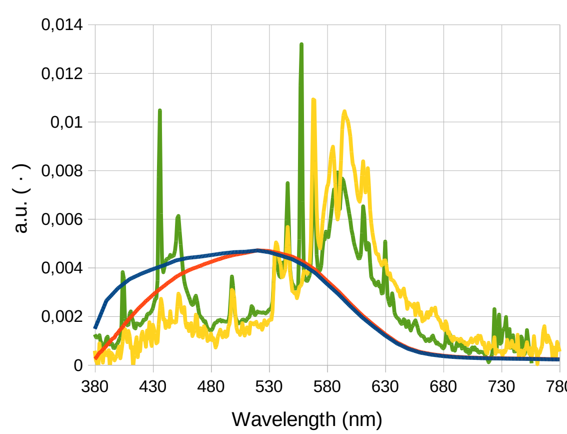

Fig. 1: SQM spectral response: blue curve represents a new device, red curve an aged device. Spectral distribution of radiation from the night sky for two years: 2018 in yellow, 2020 in green

a new SQM should show a larger reduction of the SQM output, about 0,25mag/arcsec^2.

The analysis of the decay of the external protecting windows shows very small changes, often the variation is within the dispersion among new components. In any case the changes do not explain reduction in sky brightness.

For the analysis of the trend in the two sites we make use of data provided by the satellites Aqua/MODIS and NPP/VIIRS [5-7]. Finally, the VIIRS data provide the mean monthly magnitude in clear sky conditions [8]. We compare the NSB time series in an uncontaminated site and one contaminated by ALAN: La Silla (European Southern Observatory) and Asiago (Ekar observatory) respectively. We demonstrate the aerosol concentration detected by the satellite influences the Visible Infrared Imaging Radiometer Suite (VIIRS) satellite data and the sky quality meter (SQM) ground measurements in opposite ways for the two sites. The aerosol concentration increase blocks the natural contribution of the night sky brightness (NSB). The aerosols make the sky darker at an ALAN uncontaminated site, while they make the sky brighter by diffusing the ground radiation at an ALAN contaminated site.

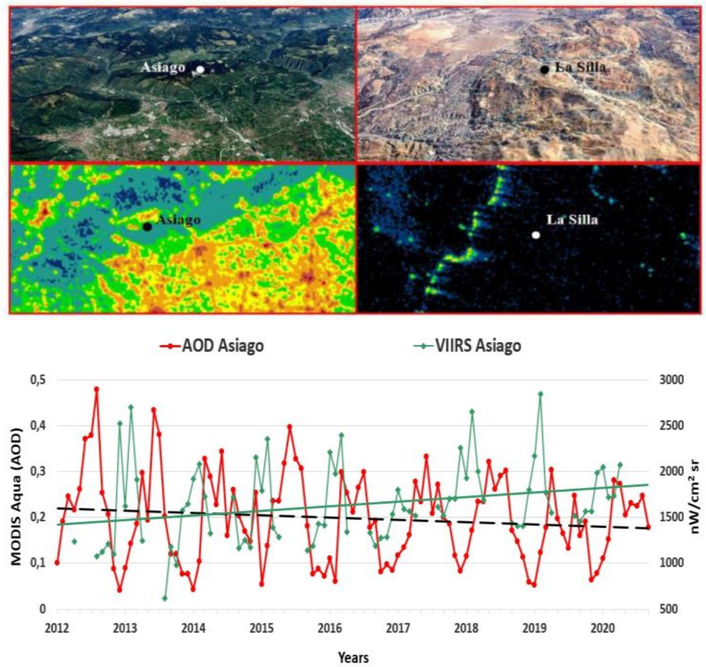

Fig. 2: Location of the analysed site. The top left panel shows the topographical characteristics of Asiago, the point indicates the Ekar observatory, the bottom left panel shows the average light emission in 2018 for the Asiago area. The panels on the right show the same characteristics for La Silla observatory.

Conclusions

The analysis of the decay of the considered SQM components can not be the sole explanation of the long-term trend of the night sky brightness. Aside it was demonstrated the aerosol concentration can influence both satellite and SQM data. The results suggest going both ways to find a more complete answer to explain long time series of Night Sky Brightness.

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Light pollution and nocturnal navigation using the lunar polarization pattern in a spider

Theme: Biology & Ecology

Rochelle J. Meah,[1,*] Lauren Sumner-Rooney,[2] and Nicholas W. Roberts[1]

[1] University of Bristol, Bristol, United Kingdom
[2]University of Oxford, Oxford, United Kingdom
r.meah@bristol.ac.uk
[*] presenting author

Introduction

Light pollution conceals and obscures the visual cues used by nocturnal arthropods for navigation at night. The lunar polarization pattern, concentric bands of polarized light formed in the sky when moonlight enters and scatters in the Earth's atmosphere, is one such navigational cue used by many polarization-sensitive arthropods (Zeil *et al.* 2014; Warrant & Dacke 2016). Light pollution reduces the availability of this cue and diminishes its reliability within an animal's celestial compass. Research on cue hierarchies, cue-clashes and cue impairment show that directional precision is reduced when celestial cues are removed, substituted, or altered, but little focus has been given to the effects of light pollution on polarization-guided navigation in nocturnal arthropods (Wehner, 1997; el Jundi, *et al.* 2015; Dreyer *et al.* 2018).

Fig. 1: i) *Drassodes cupreus* (photo credit: Mike Bok, used with permission), ii) *Drassodes cupreus* on the spherical treadmill used to test the effect of light pollution on navigation using the lunar polarization

Drassodes cupreus is a central-place forager; unlike web-hunting spiders, this spider leaves and returns to its nest following foraging bouts. To successfully make its homeward journey, the spider has a pair of skyward-facing secondary eyes responsible for the detection of the lunar polarization pattern, which it uses as a compass cue to orientate homeward (Dacke *et al.* 1991). Light pollution threatens the availability of this cue as a navigational aide and its impact on nocturnal navigators, such as *Drassodes cupreus*, is likely to increase as it spreads geographically and increases locally (Kyba *et al*. 2017). To investigate the potential impacts of light pollution on polarization-guided navigation, we tracked the trajectories of *Drassodes cupreus* on a spherical treadmill under an artificially polarized and unpolarized 'sky'.

Methods

Figure 1 shows *Drassodes cupreus* magnetically tethered on top of a rotating trackball. This set up allowed us to track the fictive trajectory of the spider as it walked whilst remaining stationary on the trackball (Fig.1). Above the spiders was a filter stack arranged such that that one face transmitted polarized light (degree of polarization=0.67) and the opposite face transmitted unpolarized light (degree of polarization=0.02). The angle of polarization was fixed and uniform across the diameter of the filter stack.

The spiders walked on the trackball for one minute before being exposed to three stimuli and a control in a pseudo-random order: 1) 90° rotation of the polarized 'sky', 2) 90° rotation of the unpolarized 'sky', 3) flip of the filter stack from polarized to unpolarized 'sky' and a feigned flip of the filter stack (control). The spiders were filmed continuously from above and the fictive paths of the spiders were tracked using FicTrac (Moore *et al*. 2014). Several metrics such as mean direction, directedness (r), speed, distance, and tortuosity of the path were calculated. Figure 2 shows an example of the walked distance and heading of a spider over time following rotation of the polarized and unpolarized stimuli. The plotted paths of the spiders were manually scored to compare turning responses between stimuli.

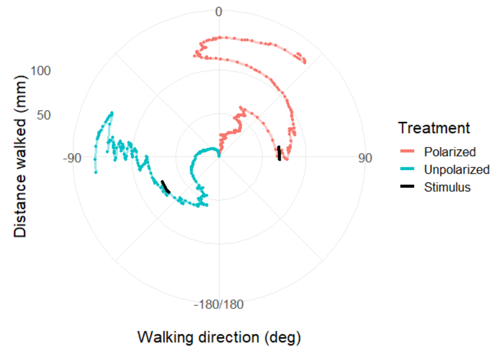

Fig. 2: An example of the paths of *Drassodes cupreus* exposed to a 90° rotation of the polarized (red) and unpolarized (blue) 'sky'. The black line indicates the time of rotation.

Future work

Future investigations using the same experimental assay are planned for 2021 to determine the detection threshold of *Drassodes cupreus*, i.e., the lowest degree of polarization required for the perception of the lunar polarization pattern. This detection threshold, coupled with real-world measurements of the polarization pattern in differentially light polluted areas, allows us to quantify what magnitude of light pollution reduces the perceptibility of the lunar polarization pattern below the detection threshold of *Drassodes cupreus* and other similar species. Thus, providing evidence of a behavioural mechanism that is disrupted by light pollution and potentially contributing to the widespread impacts of artificial light on nocturnal arthropods.

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When light and timing matters for circadian health

Theme: Health

Rol MA[1,2*], Bonmatí-Carrión MA[1,2], Madrid JA[1,2].

[1]*Chronobiology Laboratory, Department of Physiology, IMIB-Arrixaca, University of Murcia, Spain.*
[2]*Ciber Fragilidad y Envejecimiento Saludable, 28090 Madrid, Spain*
angerol@um.es
[*] *presenting author*

Circadian rhythms and sleep, which are fundamental biological imperatives, are often challenged by environmental changes, and unhealthy behaviours, including inadequate light exposure, leading to chronodisruption (CD) or a prolonged impairment of physiological, behavioural and biochemical rhythms within the organism[2]. CD constitutes a risk factor for several life-threatening pathologies. Epidemiological studies show that CD is related to an increased risk for metabolic syndrome, cardiovascular diseases, cognitive impairment, affective disorders, some cancer types and aging among other disorders. But still specific biomarkers for its "computing" are missing. This is part of our focus: looking for specific circadian biomarkers for several health threatening conditions in sensitive populations in order to boost preventive strategies.

Inadequate exposure to light, due to both insufficient daylight and excessive light at night, seems to be one of the main causes of CD. Light is detected by rods, cones, and also melanopsin-containing intrinsically photosensitive retinal ganglion cells (ipRGCs), that show a sensitivity peak around 460-480 nm. Thus, acute non-visual light effects on the circadian system, including melatonin suppression, are stronger when light contains a greater proportion of blue light[5].

The development of wearable multisensorized devices (e.g., electronic physiological records) that allow gathering a huge amount of data in combination with artificial intelligence and big data analysis may lead to implement new and effective tools to accurately quantify sleep and circadian disruption (including individual light exposure), both in clinical and nonclinical environments. This will help to strengthen healthy habits and design successful interventions, while providing feedback to users according to the recommendations set by the clinicians.

In this sense our group has developed a wrist worn device, Kronowise, and its version for bedridden patients, Kronobed, together with a software in collaboration with the Artificial Intelligence Group from the University of Murcia, implemented in the online analysis platform Kronowizard (https://kronowizard.um.es) that currently stores sleep and chronobiological data from 7500 subjects. Both devices allow us to record total, melanopic and infrared radiation[1] together with skin temperature, motor activity, body position and inferred sleep-wake pattern. All this technology is ready and provides useful (and huge, since 23 million of data per subject are processed) information from individual physiology to accurately assess, among others, circadian phase, chronotypes or chronodisruption [5, 6, 7].

Given that the light-dark cycle is the main synchronizer of circadian rhythms, a part of the research effort of our group has also focused on the implementation of different types of light that dynamically modulate the spectrum and intensity of light to adapt it to daylight and nightlight in order to allow intervention. We have also demonstrated the usefulness of pupillometry for assessing the activation of ipRGCs as well as the relationship or pupillary light reflex with rhythmic variables measured with our ambulatory circadian monitoring systems[4].

In relation with this topic, our group has demonstrated that light spectrum can be modified dynamically to entrain the behavioural rhythms in a diurnal species with photopic vision, *Octodon degus* when submitted to a 24 h DL:NL (diurnal light:nocturnal light) cycle (with the same irradiance for both) while failed to do so in nocturnal rats[3], demonstrating the importance of considering diurnal (and not only nocturnal) animals when extrapolating data on light research to humans.

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Light Pollution in Selected Philippine Metropolitan Areas using Radiance Measurement from VIIRS

Theme: Society

Ryan Manuel D. Guido,[1,*] Ernest P. Macalalad,[2]

[1] *Center for Astronomy Research and Development Rizal Technological University, Mandaluyong City, Philippines*

[2] *Department of Physics Mapua University, Manila City, Philippines*

rmdguido@rtu.edu.ph

[*] *presenting author*

Introduction

Based on several studies, light pollution in other countries which shows significant and relevant detriment towards health (Falchi, et al 2011; Hu, et al 2020), urbanization (Schirmer, et al 2019; Operti, et al 2018) insects and animals (Falchi, et al 2019). In the Philippines, it is almost not recognized environmental concern. This study aims to evaluate light pollution using the night-time light emissions in radiance using the Visible Infrared Imaging Radiometer Suite (VIIRS) over Metropolitan Cebu and Metropolitan Davao, Philippines from 2012-2019. This measurement is compared with some the demographical indexes such as population, population density, regional domestic product growth percentage, number of buildings, and number of residentials.

Methods

This study utilizes satellite imagery data to provide evidence of increasing light pollution radiance in Metropolitan Cebu (10.3425° N, 123.8411° E) and Metropolitan Davao (7.1426° N, 125.4782° E) Philippines. Satellite data images and radiance data (10^{-9} W/cm^2*sr) from Visible Infrared Imaging Radiometer Suite (VIIRS) at the lightpollutionmap.info to identify the extent of light pollution radiance in the sites from 2012 -2019. VIIRS data were set at an overlay at 85 transparency level for a hybrid basemap at an altitude of 100 km to cover the least perimeters of the metropolitan area.

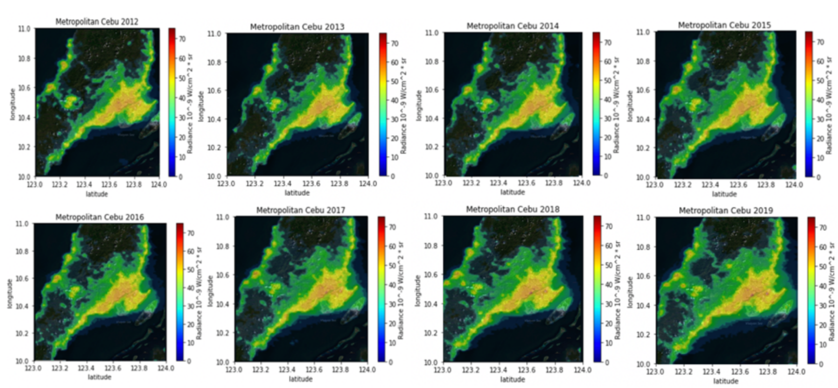

Fig. 1: Light Pollution in Metro Cebu (image credit Jurij Stare, www.lightpollutionmap.info, Earth Observation Group, NOAA National Geophysical Data Center)

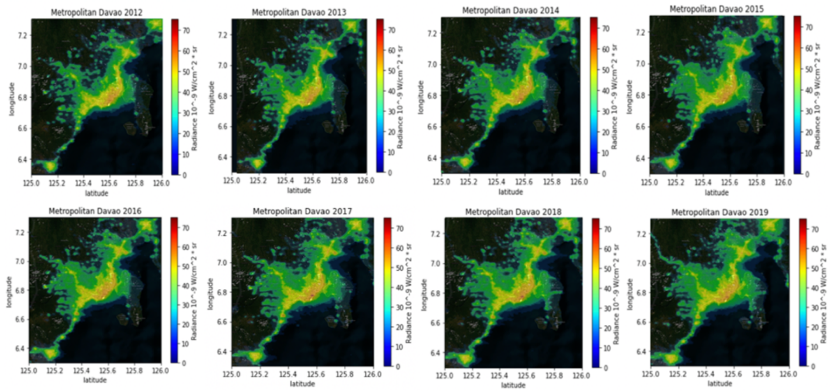

Fig. 2: Light Pollution in Metro Davao (image credit Jurij Stare, www.lightpollutionmap.info, Earth Observation Group, NOAA National Geophysical Data Center)

Conclusions

Results clearly shows that light pollution is spreading as time goes from 2012 to 2019. The expansion expands from Metro Cebu towards its western side of the island. The concentration of light pollution exists over the Cebu City and Mactan Island, while Metro Davao also extends the light pollution towards the western side of the region. Concentration happens at the Davao City. With the demographics of the metropolitan cities applied in this study. It has been found that (i) employment rate, (ii) regional domestic product growth rate, (iii) number of buildings, (iv) number of residentials, and (v) population density are all directly correlated to the amount of radiance of both Metro Cebu and Metro Davao. Despite there is a decrease in population in Metro Davao, the extent of light pollution still increases in the region.

The extent of light pollution in the metropolis can be a determining factor towards the demographics used in the study. Satellite images that represent radiance values provide evidences not only to determine the extent of light pollution but can be used also to determine the demographics of a metropolitan area. The effects of light pollution towards the environment, health, urbanization, insects and animals should also consider for further investigation and extend to other promising regions in the Philippines as there are very limited researches available in the country.

Acknowledgments

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Are the "years of peace" over?

Theme: Society

Salvador X. Bará

Facultade de Óptica e Optometría,Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Galicia (Spain, European Union)
salva.bara@usc.gal

The last two decades have witnessed a profound commotion in the lighting world. After almost one century of steady development, dating back to the pre-WWII era, the lighting sector was shaken by the onset of solid-state lighting technologies. The well established practices for outdoor lighting based on gas-discharge lamps were not directly transferable to the new LED sources, and this gave rise to some degree of unrest when some early adopters found the new installations wanting of quality or performance. Three key processes arose or were reinforced in parallel to (and partly driven by) this technological breakthrough:

(i) a huge transfer of resources from the public budgets to the lighting industry via strongly subsidized government programmes for outdoor lighting remodelling, as part of the global strategy for reducing greenhouse gas emissions,

(ii) the accumulation of a growing body of knowledge about the detrimental effects of artificial light at night in fields as diverse as ecology, human health, intangible heritage or scientific research (ALAN_DB, 2021), and

(iii) the emergence of a still weak and often somewhat diffuse, but transversal and highly distinctive social awareness about issues related to the the quality -and not only the quantity- of public lighting.

The discomfort experienced by the lighting sector as a consequence of the emergence of these new stakeholders and new quality requirements has been summarized in a brief but deeply illustrative editorial piece by P. Boyce (2019).

Contrary to some widespread discourse, the harmful effects of light pollution do not seem to be solvable by mere technological improvements. Deep social choices are needed to decide which one of the possible, probably incompatible nights will be part of our lives in the near future. In this talk the steps that led to the present situation are briefly revisited, exploring some potential future scenarios, and outlining the main challenges they may pose to the research community.

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The relationship between night sky brightness and remote sensing data: Preliminary result from Luojia-1 and the International Space Station

Theme: Measurement & Modeling

Shengjie LIU,[1,*] Chu Wing SO,[1] Nok Yan Janet CHANG,[1] and Chun Shing Jason PUN[1]

[1] *Department of Physics, The University of Hong Kong, Hong Kong SAR, China*
liusj@hku.hk
[*] *presenting author*

Nighttime remote sensing (RS) data has been widely used for environmental, urban and light pollution studies. Despite its multifaceted applications, the nature of nighttime RS data and its connection with the ground truth are still under investigation. In this study, based on field measurements in Hong Kong and Macau from the Globe at Night – Sky Brightness Monitoring Network (GaN-MN), we analyzed the relationship between the RS data and night sky brightness (NSB) data measured from the sky quality meters (SQM). Our analysis was based on two sets of medium-resolution nighttime imagery from the Luojia-1 satellite and the International Space Station (ISS). One challenge of using RS data to study nighttime emission was that images taken even within seconds could widely differ in the observed intensities (around 10% in urban areas for images taken 10 seconds apart), likely caused by different light transmission paths due to changes in satellite positions. We found good correlations between field measurements and the RS data (R = 0.81 – 0.99 for the RGB channels of the ISS images and R = 0.73 for Luojia-1). We further analyzed the distribution of light intensities in the RS data based on land use data in Hong Kong. As expected, around-the-clock facilities such as port and airport recorded the brightest emission, and commercial areas are in general brighter than the residential areas. Furthermore, we observed different characteristics of lighting from different applications, such as the dependence colours on land use: the redder emission from airport and port facilities and bluer emission from commercial districts.

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ARTIFICIAL LIGHT AT NIGHT (ALAN) DISTRUPTS SLEEP BEHAVIOR IN ZEBRA FINCHES

Theme: Biology & Ecology

Stan Moaraf [1, 2, *], Inon Scharf [1], Abraham Hefetz [1], Anat Barnea [2]

[1] School of Zoology, Tel-Aviv University, Tel-Aviv 6997801, Israel
[2] Department of Natural and Life Sciences, The Open University of Israel, Ra'anana 43710, Israel
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 behavioral patterns, such as song and sleep (Dominoni et al., 2013), causes birds to be active earlier in the morning, and increases their reproduction (Raap et al., 2016). However, not much is known yet about the overall effect of ALAN on sleep behavior in birds.

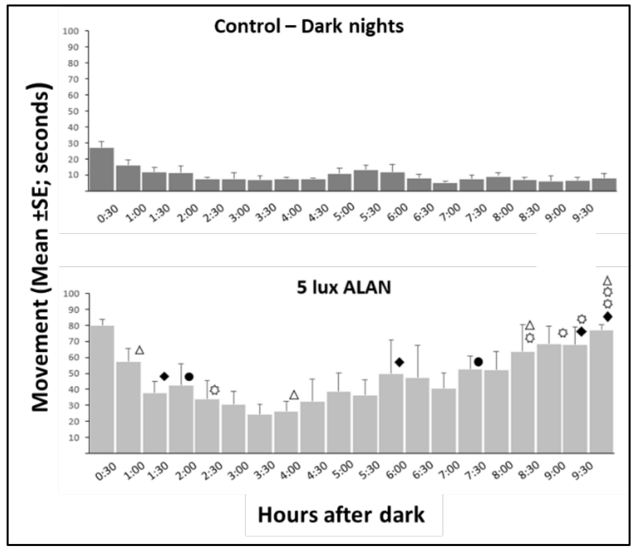

Fig 1: Movement during the night (seconds ± SE) in control and ALAN 5 lux groups (N = 8 birds / group) after 6 weeks of either dark nights or ALAN exposure. Each symbol represents a feeding event of an individual bird. The two groups differed significantly ($F_{(1,16)} = 9.33$ $P = 0.0058$).

We recently showed that ALAN affects brain plasticity in birds (zebra finches; *Taeniopygia guttata*) by increasing cell proliferation and recruitment of new neurons in some brain regions (Moaraf et al., 2020a,b). One of these regions is the medial striatum (MSt), which is a part of the avian basal ganglia and receives input from regions involved in somatosensory and motor function (Wild, 1993; Veenman et al., 1995, Kuenzel et al., 2011). This finding led us to suggest that the modifications in the MSt are induced by changes in the birds' sleeping behavior, assuming that ALAN causes the birds to be more awake and active during the nights. Accordingly, in the current study we investigated this question by examining the nocturnal activity of birds under ALAN.

To do this, we monitored the sleeping behavior of two groups of adult zebra finches that were kept under 14:10 L:D indoor isolated rooms, under controlled conditions. During the first three weeks, birds in the Control and ALAN groups were exposed to complete dark nights. Then, for additional six weeks, the Control group remained under dark nights, while the ALAN group was exposed to nightlight of 5 lux intensity. We chose 5 lux because we already found that nocturnal exposure to this intensity affects brain plasticity (Moaraf et al., 2020a,b), and because it is ecologically relevant (e.g., it is comparable to light intensities during the night in urban areas). We recorded the nocturnal activity of birds with a motion detection infrared camera at three time points:

1) at the end of the first three weeks of dark nights; 2) at the end of the first three weeks of ALAN exposure; and 3) at the end of the six weeks of ALAN exposure. We also recorded feeding events during the nights and monitored body mass every 10 days.

We found that the birds showed little locomotion activity during the dark nights, and that this activity was more obvious during the first hour after dark. However, under ALAN conditions, the birds increased their locomotor activity throughout the night, and this activity was more obvious during the first hour after dark and then before lights were turned on (Fig. 1). Moreover, nocturnal locomotion intensified with the duration of ALAN exposure (three vs. six weeks), indicating a chronic effect. In addition, birds in the Control group did not eat during dark nights, while under ALAN the birds were observed to eat several times during the night. Finally, chronic exposure to ALAN significantly increased body mass by 6%. Taken together, our study adds to the growing body of evidence of the ill-effects of ALAN on the behavior and physiology of birds.

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Sky Quality Meter vs. 'Reality' -
Investigating the true effectiveness of SQMs during lighting conversions in Vienna

Theme: Measurement & Modeling

S. Wallner,[1,2*] J. Puschnig[3], F. Binder,[1] and M. Kocifaj[2,4]

[1] *Institut für Astrophysik, Universität Wien, Vienna, Austria*
[2] *ICA, Slovak Academy of Sciences, Bratislava, Slovakia*
[3] *Argelander-Institut für Astronomie, Universität Bonn, Bonn, Germany*
[4] *Department of Experimental Physics, Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovakia*

stefan.wallner@univie.ac.at
[*] *presenting author*

Due to being low-priced and providing data in a satisfactorily accurate precision, the Sky Quality Meter (SQM) is the most used device for characterizing the impact of artificial light at night on the sky brightness. Since they enable the possibility of working remotely, such instruments are used globally to create monitoring networks and create long-term studies. However, past studies have shown that compared to known photometric bands, the spectral response suffers due to being insensible in higher wavelengths while also at shorter wavelengths outcomes can be influenced significantly. Considering the global trend of converting outdated (street) lighting systems to state-of-the art LEDs, observations done by SQMs are impacted in such way that comparisons of various lighting technologies are nearly impossible and values could be interpreted incorrectly. Additionally, not only the emission of light sources play a major role, since also the instruments themselves show aging effects, which exerts influence on long-term studies in particular. Consequently, readings from SQMs need to be characterized in further detail to take a closer look on the true effectiveness of these devices.

While past studies quantified this problem by mostly modeling approaches solely, we present a work which bases on a comparison between in-situ observations and simulations for the city of Vienna, Austria. It was chosen due to the fact that the local urban management provides one of the most detailed listings of used outdoor lighting types. Such information enables the most effective way of modeling near-realistic condition of the city emission function, especially its spectral composition. Since 2017, Vienna changed a third of all existing street lightings to 4000K LEDs which concludes the initial tranche of conversions. On the basis of continuous spectral measurements of Vienna's night sky performed over the past years, it is possible to include accurate spectra as observed into the city model.

The model itself will be evaluated in different approaches, e.g., by varying the thresholds of wavelength ranges to the visible or beyond, and by including the spectral sensitivity and monitored aging effects of SQM devices. The aim is to characterize, what amount of light is truly detected by the instrument, particularly before and after the LED conversion. In order to compare simulated results to real-life conditions, data of SQMs located in and outside of Vienna will be evaluated.

Results of this work shall specifically be used for long-term studies of Sky Quality Meter observations, especially to increase the accuracy when comparing data before and after LED conversions.

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Economic motivation study of dark sky astrotourism in Thailand

Theme: Society

Sze-leung Cheung,[1,*] Surachai Tuamsomboon [1], Jessada Keeratibharat,[1]

[1] *National Astronomical Research Institute of Thailand, Chiang Mai, Thailand*
cheungszeleung@narit.or.th
[*] *presenting author*

Astrotourism is very new and a growing idea in Thailand through the promotion of the National Astronomical Research Institute of Thailand, and Tourism Authority of Thailand. Economic impact of COVID has helped to escalate the idea of having astrotourism to drive domestic travels and therefore bring in economic benefits to the country. Thailand has also recently launched a national dark sky places scheme to promote dark sky awareness, in addition to the astrotourism idea.

This is a qualitative study to understand the economic factors that are associated with 2 proposers who make decision to apply for dark sky places, mainly for astrotourism purposes. One from a hotel point of view, another one from a community point of view.

The study will understand the traffic, operation costs, investment costs, revenues and also difficulties they faced during the process.

Light Touch: A Design Strategy for Responsible Urban Park Lighting

Theme: Technology & Design

Taylor Stone[1,*]

[1] Delft University of Technology, Delft, The Netherlands
t.w.stone@tudelft.nl
[*] presenting author

This presentation will introduce an ongoing research and design project focused on innovative and responsible (sub)urban park lighting. The project, currently in the research and planning stage, is a collaboration between the author and lighting design firm Atelier LEK (www.atelierlek.nl/), with contributions from Delft University of Technology students and in close collaboration with local stakeholders. The presentation will primarily focus on the methods of analysis and outcomes from the first phase of the project. Further, the case offers a secondary contribution via outlining the challenges and successes of a transdisciplinary ALAN research project in practice (see Pérez Vega et al. 2021).

The Delftse Hout park – largely designed from reclaimed farmland in the 1970s – is a multi-functional space in Delft, The Netherlands. It includes green areas, walking and cycling trails, sports fields, restaurants, and a camp ground (fig. 1a). In the decades since its creation, tens of thousands of homes have been built in surrounding neighborhoods, putting increasing pressure on the park's services and paths. As a further consequence, cycling paths through the park have become commuter routes (fig. 1b). Currently there is minimal artificial lighting in the Delftse Hout, and local stakeholders have identified public lighting as a priority for improving safety and wayfinding. However, it has also been recognized that any future lighting installations should preserve the dark spaces of the park (fig. 1c). As a park within an increasingly urbanized region, the need to maintain the green (and dark) spaces of the park and the social and ecological services they provide is crucial. The identified goals for the Delftse Hout thus present a challenge, and possible conflicts between competing values. Yet, it also offers an opportunity to envision solutions that can satisfy supposedly competing goals. We thus set out with following research question: *can the innovative use of new lighting techniques, as well as a careful consideration of when and where illumination is truly needed in the park, allow us to create a space that is accessible but also preserves (or even enhances) the darkness of Delftse Hout?*

Towards this goal, we initiated an interdisciplinary research approach aimed at establishing innovative design and policy strategies for urban park lighting. First, the theory and method of *design for values* (Stone 2018; van den Hoven et al. 2015) was utilized to investigate the underlying values that both artificial illumination and darkness offer for the space. The practical manifestation of these values (and value conflicts) were then examined via in-depth site analysis of the programs and routes, existing lighting, and ecological services (fig. 1), as well as the insights of key stakeholders. The result was a report articulating a *light touch* approach, arguing for strategic and restrained lighting, as well as the preservation of a central *dark habitat* (Stone & Atelier LEK 2020). The proposed *light touch* design strategies focus on creating a unique atmosphere within the park, and include:

- **Nature-inclusive lighting**: the development of dynamic lighting that is responsive and adaptive to users, changing ambient conditions, and daily/seasonal local ecological needs. Combined, we see this as offering the potential to improve social safety and wayfinding, keep (ecological) light pollution at a minimum, and create a novel aesthetic experience for park visitors.

- **Nightscape revitalization:** one area of particular concern is two highway underpasses connecting the city center and the park, which currently serve as both a physical and perceptual barrier. Taking inspiration from the planning strategies of urban acupuncture (Lerner 2014; Stone 2021) and creative placemaking (Meagher 2020), we have proposed an art installation to initiate a process of urban renewal – improving social safety with minimal artificial lighting.
- **Regional light pollution ordinance**: the Delftse Hout is situated in one of the brightest regions in Europe, due largely to greenhouses in the surrounding region. By striving for the International Dark-Sky Association's Urban Night Sky Place certification (www.darksky.org/our-work/conservation/idsp/unsp/), our hope is to use the park to draw attention to the region's light pollution problem. In doing so, it can ideally serve as a catalyst for regional action to curb light pollution.

To conclude, the presentation will reflect on how the proposed concepts, as well as the research methodology developed for the Delftse Hout, could serve as generalizable approaches to (sub)urban park lighting.

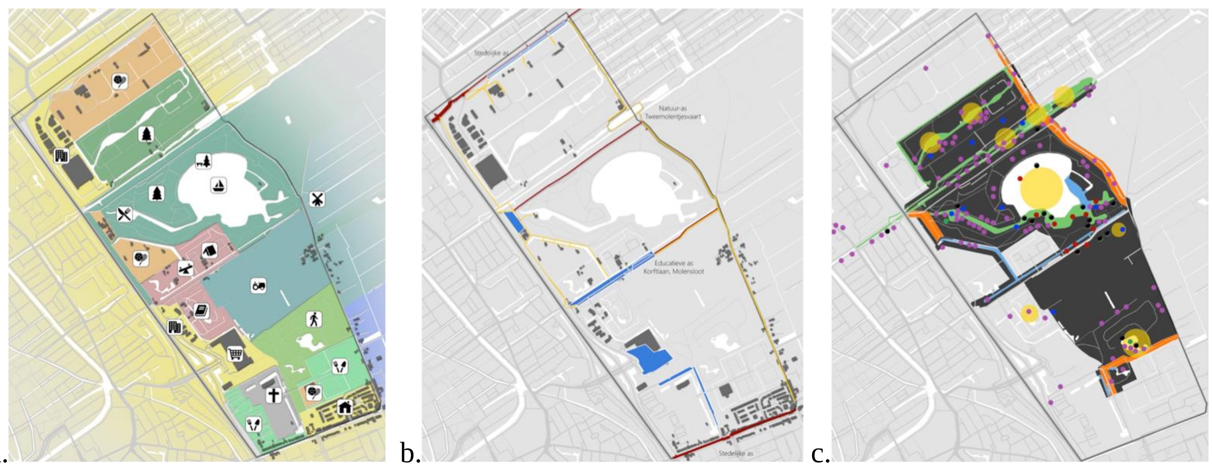
a. b. c.

Fig. 1: site analysis of the Delftse Hout park in Delft, The Netherlands, identifying a) the distinct programs and uses within the park; b) cycling routes (red), vehicle routes (yellow), and parking lots (blue), and; c) the existing dark spaces of the park overlaid with the foraging sites of different bat species.

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The impact of the night sky brightness on the water quality indicators in the Dobczyce Reservoir, Poland

Theme: Biology & Ecology

Tomasz Ścieżor[1,*]

[1]*Cracow University of Technology, Kraków, Poland*
tsciezor@pk.edu.pl
[*] *presenting author*

The Dobczyce Reservoir is the main source of the water supply of Krakow. In 2014-2016 the research of the changes of the water quality indicators was done at the three levels of this reservoir in parallel with measurements of the night sky brightness. This study verifies the thesis on the correlation of these indicators, particularly the concentration of chlorophyll *a* in the surface layer of the reservoir, with the brightness of the night sky. The analysis of the weekly internal reports of the Municipal Water and Sewage Company SA in Krakow led to notice of a clear monthly periodicity of the concentration of several biological indicators, such as chlorophyll *a*, phosphates, phosphorus and phyto- and zooplankton. It seems that moonlight is the only periodic external factor with a similar period, possibly affecting the value of these indicators. In the same three-year period were done the continuous measurements of the night sky brightness above the reservoir. It turned out that illuminance of the reservoir surface by the Moon is comparable to the one by artificial skyglow, one of the aspects of light pollution. Analysis of the problem showed the clear linear correlation between the monthly averaged brightness of the night sky and the content of chlorophyll *a* in the water during the growing season. It was suggested that the brightness of the night sky is one of the factors affecting the water quality, so far not taken into consideration.

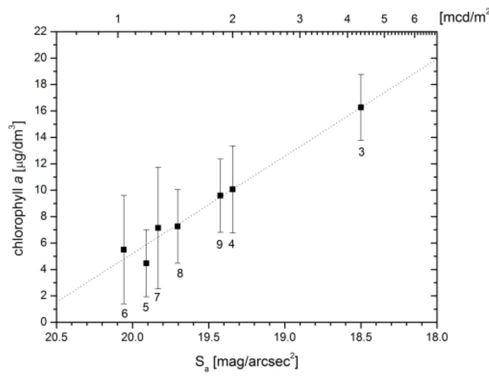

Fig. 1: The concentration of chlorophyll *a* vs. night sky brightness in the Level I of the Dobczyce Reservoir during the growing season of 2014 (numbers indicate month).

Brightening of the night sky is connected both to the Moon, as well as to the artificial skyglow, derived from faulty constructed light sources. This means that the correct lighting of the water intake areas can reduce the eutrophication of reservoirs and, in perspective, can also reduce the cost of water treatment.

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The deregulation of glucose metabolism after exposure to dim light at night in rats

Theme: Health

Valentina S. Rumanova,[1,*] Monika Okuliarova,[1] and Michal Zeman[1]

[1] *Department of Animal Physiology and Ethology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovakia*
rumanovavalentina@gmail.com
[*] *presenting author*

Introduction

The light-dark (LD) cycle is an important environmental cue synchronizing the central clock of the circadian system located in the suprachiasmatic nuclei of the hypothalamus with prevalent environmental conditions. The molecular machinery generating circadian oscillations is based on the transcription-translational feedback loop consisting of positive (CLOCK and BMAL1) and negative (PER and CRY) elements, which inhibit the activity of CLOCK:BMAL1 complex, hence they inhibit their own expression. The LD cycle is recognized as a very stable signal, which is weakened only in modern age. During the day, people working in offices are exposed to much lower illuminance in comparison to sunlight and after the sunset they are exposed to artificial light at night (ALAN). The level of light pollution has been increasing dramatically over last decades (Falchi et al., 2016) and recent studies suggest, that it can have negative consequences on human health (Fleury et al., 2020). Among them deleterious effects on metabolic diseases are frequently stated. Indeed, experimental studies show impaired glucose tolerance and glucose levels in rodents (Dauchy et al., 2015; Russart et al., 2019) exposed to dim light at night. We have found higher insulin levels and decreased expression of *glut4* in spontaneously hypertensive rats that are insulin resistant, implying further deterioration of their metabolic health (Rumanova et al., 2019). Another our study in healthy Wistar rats showed increased hepatic *glut2* expression after dimALAN exposure (Okuliarova et al., 2020). Most of those studies are based on two-point studies sampling of experimental animals during the daytime and night-time. Because of possible shifts of measured rhythms, as a consequence of ALAN, the assessment of complete 24-hour profiles is needed. Therefore, the aim of this study was to evaluate the changes in daily rhythms of glucose and genes involved in the control of glucose metabolism after dimALAN exposure. Glucose entering the liver via GLUT2 needs to be phosphorylated by glucokinase (GCK) to be processed in glycolysis, glycogenesis, or pentose pathway. The molecular clock has an important role in the regulation of glucose metabolism. Cryptochrome (CRY) proteins inhibit gluconeogenesis via the inhibition of FOXO1, the important gluconeogenetic transcription factor. Moreover, the CRY cascade can be inhibited by sirtuin 7 (SIRT7) in the liver depending on the body temperature (Liu et al., 2019).

Methods

Adult male Wistar rats were exposed either to the standard lighting regimen 12L:12D (CTRL) or the dimALAN (~2 lx) during the whole dark phase for 2 weeks. Samples were collected every 4 hours throughout the 24-h period, with sampling starting at ZT6. Plasma glucose levels and hepatic glycogen concentration were measured by spectrophotometry using diagnostic kits. The hepatic expression of glut2, gck and foxo1 were assessed by real-time PCR. The western blot method was used to measure the protein expression of SIRT7 in the liver.

Results

All the measured parameters in the control group were rhythmically expressed with peaks during the night (active phase) when nocturnal rats predominantly consume their food. Plasma glucose levels in the dimALAN group lost their daily variation and the amplitude of hepatic glycogen concentration was lower compared to controls due to higher concentration at the beginning of the active phase. The rhythm of *glut2* expression was phase advanced after the 2 weeks of dimALAN exposure. Glucokinase gene expression in experimental rats was higher in the middle of the light phase and the beginning of the dark phase in comparison to the control group. Expression of gluconeogenetic transcription factor FOXO1 also lost its rhythmicity after dimALAN exposure and protein levels of SIRT7 were increased in the middle of the dark phase.

Conclusions

In conclusion, changes in expression of *glut2* and *gck* after exposure to dimALAN can reflect higher uptake and processing of glucose in the liver resulting in the increased hepatic glycogen concentration during the active phase. Despite the higher expression of gluconeogenetic factor *foxo1* during the resting period and SIRT7 in the middle of the active phase, we did not observe an increase in glucose levels. The lost rhythmicity of plasma glucose and *foxo1* expression in the liver, as well as phase advance of *glut2* could be caused by changes in food intake in experimental animals, which was observed in rodents after dimALAN exposure (Fonken et al., 2010; Stenvers et al., 2016). In conclusion, the observed circadian deregulation of glucose metabolism after the exposure to dim light at night could be a possible risk factor for the development of “civilization diseases”, such as type 2 diabetes and obesity.

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Neutrophil response to lipopolysaccharide under dim light at night in rats

Theme: Health

Viera Jerigova,[1,*] Michal Zeman,[1] and Monika Okuliarova[1]

[1] *Department of Animal Physiology and Ethology, Faculty of Natural Sciences, Comenius University in Bratislava, Slovakia*

jerigova4@uniba.sk

[*] *presenting author*

Introduction

An exposure to artificial light at night is an increasing phenomenon during last decades. Appropriately timed light information is essential for alignment of environmental cycles and endogenous circadian rhythms. In our previous studies, we showed negative consequences of low-intensity artificial light at night (ALAN) on cardiovascular as well as metabolic parameters (Rumanova el al., 2019; Okuliarova et al., 2020). Moreover, we reported that ALAN can weaken circadian control of daily variation of main leukocyte subsets in the circulation and affect immune and redox homeostasis in the kidney (Okuliarova et al., 2021).

In rodents, leukocytes (Le) and their major subpopulations peak in the circulation at the beginning of the light phase and reach a trough at the beginning of the dark (active) phase (Pick et al., 2019). Leukocyte oscillations play an important role in the control of immune functions and contribute to the time-of-day-dependent immune responses. It is generally known that organisms display higher susceptibility to immune challenge at the transition point between their rest and active phase as compared to other times of the day (Halberg et al., 1960; Marpegan et al., 2009). Neutrophils (Ne) are key components of the innate immune system and major first-line mediators of anti-microbial defense. For example, in process of respiratory burst Ne produce high quantities of reactive oxygen species (ROS) to eliminate pathogen.

In our study, we investigated whether ALAN can affect time-of-day-dependent immune response to lipopolysaccharide (LPS) in rats. We focused on Ne and analyzed the functional activity of blood Ne, the numbers of Ne in the circulation as well as Ne infiltration into the renal cortex.

Methods

Male Wistar rats were housed either under control light/dark (LD) cycle of 12:12h or exposed to low-intensity ALAN (L ~150 lux, D ~2 lux). After 2 weeks of ALAN, animals were i.p. treated either with sterile saline or LPS (1 mg/kg) at the beginning of the passive (ZT2) or active (ZT14) phase, respectively. Zeitgeber time (ZT) zero is defined as the beginning of the light phase. Blood was collected from a lateral tail vein 24 hours post-LPS challenge and total Le count as well as the number and functional activity of Ne were analyzed using flow cytometry. Eight days after first LPS challenge animals were i.p. treated with the second LPS injection. Three hours later animals were sacrificed and kidneys were used for immunofluorescence analyzes. The Ne infiltration in the renal cortex was evaluated as the number of myeloperoxidase (MPO)-positive cells.

Results

The daily variation with higher levels at ZT2 than ZT14 was observed in both the circulating numbers of total Le and Ne in control animals, while two-week ALAN exposure eliminated this variation. The number of total Le decreased after LPS injection at ZT2 and conversely increased after the stimulation at ZT14. Animals exposed to ALAN did not respond to LPS stimulation by changed number of total blood Le. As expected, LPS treatment led to significant neutrophilia and increased ROS production in Ne in both control and ALAN-exposed rats. Interestingly, LPS stimulation at ZT2 primed respiratory burst of Ne in ALAN group but no priming effect of LPS was detected in controls. Moreover, ALAN-exposed rats showed higher MPO-positive cell counts in the kidney than controls at ZT2, and LPS challenge promoted Ne infiltration in the renal cortex in both control and experimental animals. Rats exhibited lower Ne infiltration in response to LPS stimulation at ZT14 compared to ZT2.

Conclusions

Our results demonstrated that two-week ALAN exposure affected daily variation of blood Ne, and promoted Ne recruitment into the renal cortex during the passive phase. Peripheral neutrophilia and renal Ne infiltration in response to LPS challenge was not affected by ALAN but LPS stimulation at ZT2 primed respiratory burst of Ne in ALAN rats, indicating a risk of excessive inflammatory response in tissues. Together, our data suggest that ALAN can interfere with timing of innate immune mechanisms and chronodisrupted immune response can represent an important link between light pollution and human health.

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Mapping the risk of the degradation of sky quality and the potential biological effects at dark sky places and protected area

Theme: Measurement & Modelling

Zoltán Kolláth[1,*], Kornél Kolláth,[1,2] Dénes Száz,[3] Flóra Siska,[3] Alexandra Pusztai-Eredics,[3] Andrea Pozsgai,[3] and József Vanyó[1]

[1] *Eszterházy Károly University, Department of Physics, Eger, Hungary*
[2] *Hungarian Meteorological Service, Budapest, Hungary*
[3] *Eötvös Loránd University, BDPK, Department of Physics, Szombathely, Hungary*

zkollath@gmail.com
[*] *presenting author*

The increasing level of ALAN, especially the blue-rich lighting in the neighbourhood of the protected area, increases the risk of degradation of biodiversity and sky quality. We developed a method for fitting radiation transfer models to ground-based and satellite measurements. The model can then be used to predict the level of skyglow, especially the strong light domes of the strong emitters for different weather and atmospheric conditions.

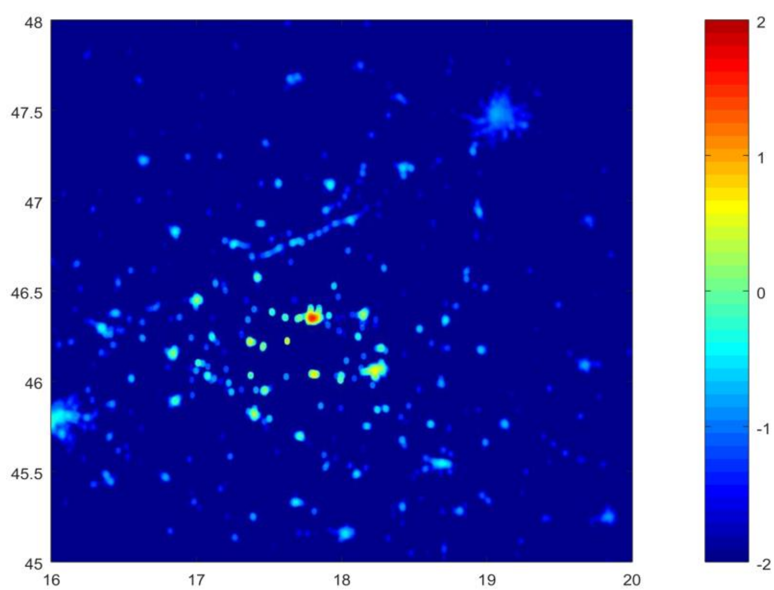

Fig. 1: Weighted emission map representing the contribution to the artificial sky brightness at the Zselic Starry Sky Park. The colour bar is on a logarithmic scale in relative units. Normal atmospheric conditions. The axes are labelled with the GPS coordinates.

We measured the spectrum of the dominant sources' light domes by a spectroradiometer and then used these data in the radiation transfer evaluation independently for all significant sources. It is also possible to use different light emission intensity distribution functions for each settlement or other light sources. The sky radiance modelling is based on a Monte Carlo radiation transfer code that does not limit the scattering and reflection events. The model results can be calculated for different spectral action functions; thus, it is possible to calculate risk maps for various species of other applications.

There are several possible applications of our maps, for example:

- predicting the effect of planned lighting installations,
- predict the variability of risks or sky quality conditions for different weather or atmospheric conditions,
- SWOT analysis based on real conditions and trends.

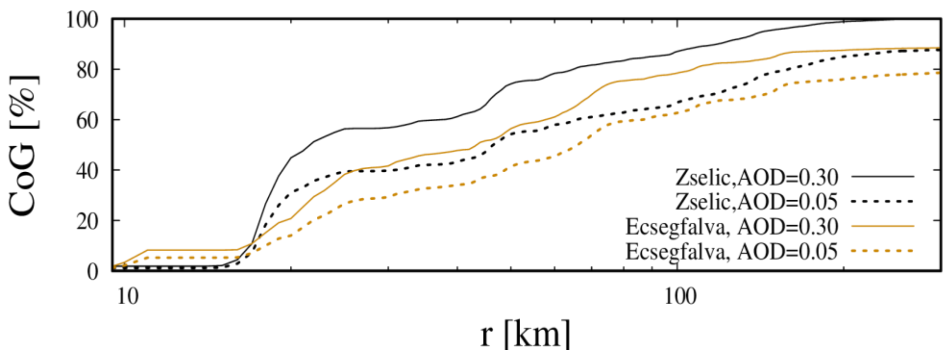

Fig. 2: Curve of growth: the contribution of sources to zenith brightness as a function of distance. Relative units normalized to the maximum in the set.

As a side product, it is also possible to calculate a "curve of growth", a representation of how the actual radiance of the sky builds up as more and more sources are included with increasing distance. Figure 2 displays the curve of growth for two different locations and atmospheric optical depth. At the Zselic site, the primary source is Kaposvár, a neighbouring city. It is responsible for the growth at 16-20 km, which provides 40-60% of the sky radiance. The next significant step in the curve is another city at a distance of 45 km. There is no large city in the adjacent region; thus, the curve is flatter.

We plan to use or method mapping all the Hungarian national parks and major protected areas to provide a wavelength, weather, and atmospheric condition-dependent data for research in biology, nature conservation, and landscape planning.

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