ALAN 2023

Artificial Light at Night

Calgary, Alberta

Cowboy Statue, Cochrane.
Photo Credit: Travel Alberta

Conference Abstract Booklet

ALAN2023
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Calgary, Alberta

Cover image: Cowboy Statue & Comet, Cochrane Ranche, Cochrane.
Photo Credit: Travel Alberta

Booklet editor: Annette Krop-Benesch

Dear ALAN participants,

When my daughter was about six years old, we travelled into the countryside about 85 km east of Calgary to watch the Perseid meteor shower. Under the dark and moonless sky, we sipped hot chocolate, counted meteors, learned about the constellations, heard coyotes yipping and howling in the distance, and listened to the wheat rustling in the occasional slight breeze (or was that unseen, nocturnal animals?). Eventually, we packed up and began to drive home. My daughter gazed out the car window, silently watching the stars fade into the sky glow of Calgary. After a while she quietly said, “good-bye stars”. To this day her comment motivates me.

The use of artificial light at night continues to increase, intensifying the impact on human and natural environments. The need to understand, innovate, and educate about artificial light at night has never been stronger. The ALAN conference series is dedicated to examining all aspects of artificial light at night, including its effects on humans and nature (e.g. ecology), how light is produced (e.g. technology and lighting design), where it is present (e.g. remote sensing), how it is perceived by the public (e.g. perceptions of safety and security, and cultural expectations), and how the benefits and detriments of artificial lighting can be balanced by regulations, standards, and laws.

The intention of the ALAN 2023 conference is to foster discussion amongst the scientists, practitioners, regulators, and users of artificial light at night. To widen participation, the conference has two main events, a virtual-only event on July 21 and 22, during which posters will be discussed, and an in-person event August 10 – 13 in Calgary, Alberta, Canada. The in-person event will also be livestreamed to delegates and includes invited and contributed talks, posters, and social activities.

Both events will bring us together, connecting inquisitive minds and new ideas, enabling us to renew friendships and forge new connections. The ALAN 2023 conference **values** equality, diversity, and inclusion because every person has a right to equal treatment, and we are strengthened by the diverse backgrounds, perspectives, and experiences of all those participating. Share, discuss, and learn earnestly and respectfully.

The Royal Astronomical Society of Canada and the University of Calgary, Department of Physics and Astronomy, are honoured to co-host the 8th International ALAN conference. I would especially like to thank all the authors for their contributions, the volunteers and staff who have devoted so much time to organising the conference, the members of the International ALAN Steering Committee for their guidance and support, and our sponsors for their financial contributions.

Whatever your motivation and whether you attend ALAN 2023 in person or virtually, we look forward to you joining the discussion, sharing your ideas, and networking with colleagues and friends from around the globe. Welcome!

Sincerely,

Bob King
Chair, Local Organising Committee
ALAN 2023

Dear ALAN participants,

10 years ago, I was on a train with Christopher Kyba, when he said: "I have an idea for a conference, what do you think…" And then he told me about an interdisciplinary conference on light pollution. Needless to say, I loved the idea, so I spoke to Franz Hölker at IGB and to some people at the German Ministry of Education and Research (BMBF) and – fortunately for us – they liked the idea too. So, with BMBF money and IGB support, Chris and I organised the first ALAN conference in 2013. It wouldn't be the last.

Today, ten years later, I'm compiling the abstract booklet for the 8th International Conference on Artificial Light at Night, ALAN2023. Again, it is a booklet with many different topics, and this is what I love so much about the ALAN community. We are people from different disciplines, different countries, different cultures, and we come together for a common goal: the protection of darkness at night and the creation of better, less-polluting lighting in places where ALAN is needed.

This community has grown considerably. While light pollution was hardly known by ecologists in 2006, when Travis Longcore and Catherine Rich published their book, today we have a compelling pile of studies showing nature's need for natural darkness. And our knowledge is growing: Scientists from all disciplines study the growing brightness at night and its consequences. Activists find together to call for less light pollution, because nocturnal darkness and starlit skies are part of our culture, spark creativity and hope, ease pain, and are fundamental for our health. A few months ago, the *Science* magazine dedicated an entire special issue to light pollution.

But not only scientists are concerned about the growing amount of ALAN. Many lighting designers also see the dark side of artificial light at night and call for a more balanced, responsible way to use it. They ask scientists for guidance and cooperation to create better lighting. For it is clear that we can't and won't switch off all the lights. But we need to understand the full costs of artificial light at night, and we need to find ways to keep the costs low while having the benefits we need.

The ALAN conference series has played an important role in bringing together scientists and practitioners from all over the world. After the pandemic and to entirely virtual conferences, we come together in person again in Calgary. However, the world has changed and many of us can't travel long distances for conferences anymore. The need to reduce air travel is another reason to meet virtually more often. We have therefore decided to hold ALAN2023 as a hybrid conference. This is a new experience for most of us – certainly for us organisers, and things did not go as smoothly as hoped. I would like to thank Bob King, Phil Langill, and the rest of the organisational team from University of Calgary and the Royal Astronomical Society of Canada for hosting this conference. It was everything but easy to organise a hybrid conference, but together we made this happen. I'm still sure that we will have a great conference with lots of discussions, inspiration, and fun during our two meetings virtually and in person.

So, thank you for joining us to ALAN2023!

Sincerely,

Annette Krop-Benesch
Co-chair of ALAN steering committee

Dear ALAN participants,

After two online conferences we have decided to do a hybrid conference. This is a new experience for all of us and has been sometimes confusing. Most surprising might be our decision to have the poster sessions three weeks prior to the original date.

We were concerned that if we only enabled virtual attendees to listen in to the talks via Zoom, we would have two groups of attendees who did not interact much with each other. We also assumed that attendees who travelled to Calgary would not want to spend too much time online, but rather use this time for in-person meetings. For this reason we came up with the idea of virtual-only poster session. To make sure that people aren't travelling to Calgary at that time, we decided on a date three weeks prior to Calgary. We know that this might clash with other appointments, but if you can't make it to the poster sessions on July 21/22, enter the virtual conference venues at your leisure and meet with other attendees.

The hashtag for this year's conference is **#ALAN2023**. 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.

Our attendees come from all over the world and very different time zones. For this reason, we might never all be together in the virtual room, and you might not have the chance to attend all poster sessions. Some of us will not be able to present their poster during the July session at all. If you can't catch up with a presenter during the

We all live under one sky, and though we might be different in many ways, the ALAN community has always been a place of respect and cooperation. We are looking forward to another conference that will be diverse in terms of disciplines, people, and surely ideas. We all learn and grow for each other. No matter if you join virtually only or if you will join us in Calgary in person, we wish all an inspiring, enjoyable conference.

Annette Krop-Benesch & Diane Turnshek
Co-chairs
On behalf of the ALAN steering committee

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The Royal Astronomical Society of Canada

Mr. Roland Deschesne
The Royal Astronomical Society of Canada

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ALAN Online 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/

VIIRS DNB overpass time predictor https://www.ngdc.noaa.gov/eog/viirs/ predict/

World Atlas of sky brightness floating point data
http://doi.org/10.5880/GFZ.1.4.2016.001

Find astronaut photographs http://citiesatnight.org/

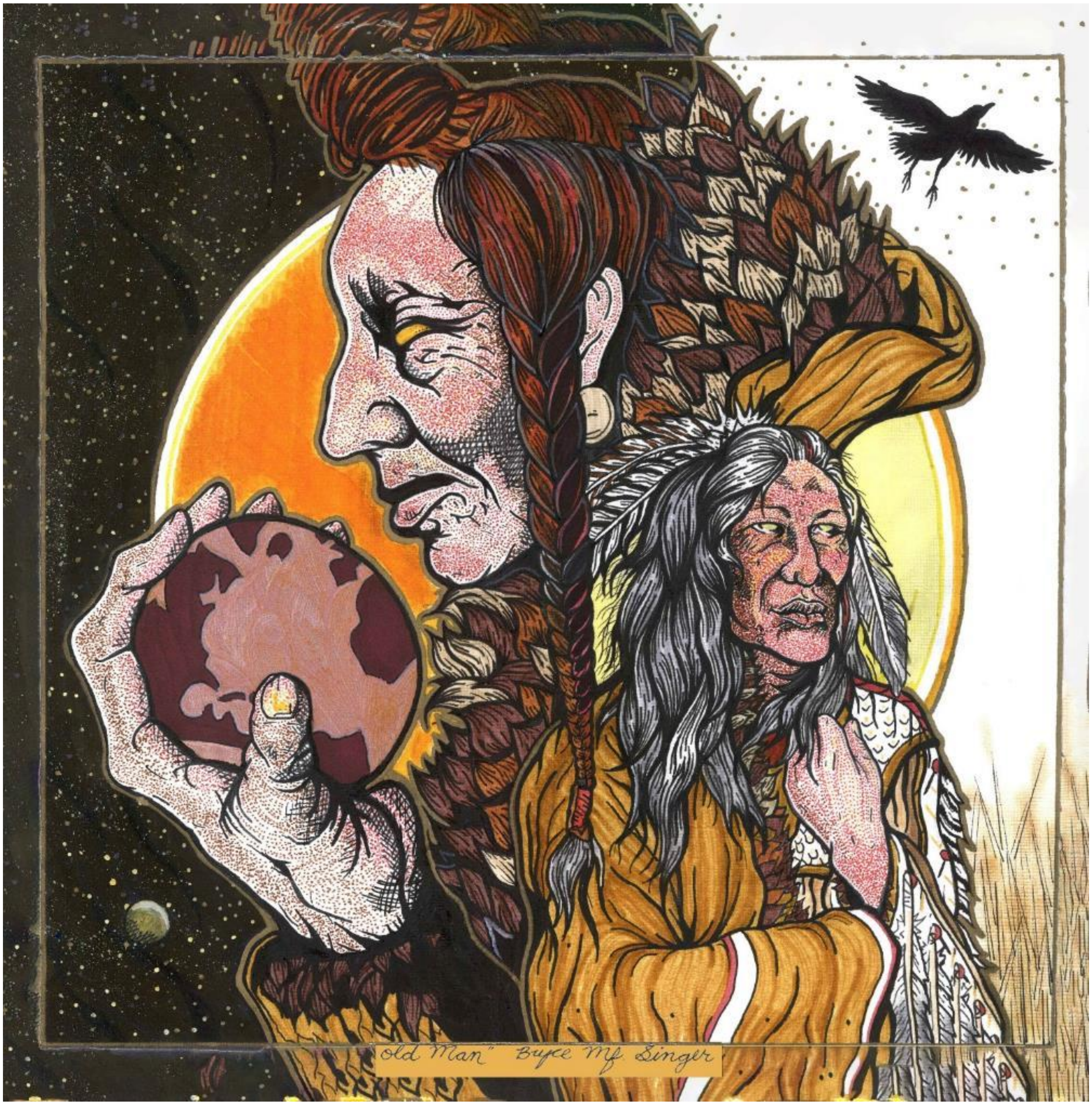
Viewing/accessing Globe at Night data http://www.myskyatnight.com/

Sunrise/sunset calculator https://www.timeanddate.com/sun/

Moonrise/moonset calculator https://www.timeanddate.com/moon/

Save the date:

Invited speakers



Old Man Napi by Bryce Singer

Rothney Astrophysical Observatory

Supplied by Jennifer Howse

Invited Banquet Speaker: Jennifer Howse

Rothney Astrophysical Observatory
jihowse@ucalgary.ca

Jennifer Howse is the Education Specialist at the University of Calgary's Rothney Astrophysical Observatory. She has been creating original experiential programming at the RAO for over 17 years, connecting students to the Earth, the Sky, and the universe beyond.

She is well respected in the local science, technology, engineering, arts, and math (STEAM) community, and is a published author. Jennifer is the director of IDA's Southern Alberta Chapter and is the liaison between the RAO and its local dark sky partners. She has presented at numerous conferences including the Open Cultural Astronomy Forum, International Dark-Sky Association, the Association of Experiential Educators, and the Palliser and Calgary Teachers' Conventions.

Jennifer is a member of the Metis Nation Region III, and her focus of research and personal interest involves the tradition and scholarship of Indigenous Ways of Knowing and scientific knowledge and discovery.

Reclamation under Alberta Skies

Jennifer Howse will share her experiences with communicating the impact and relevance of light pollution to diverse learners at the Rothney Astrophysical Observatory outdoor experiential programs. Creating land sky connections of meaning and relevance in multi sensory context along with tools of metaphor and storytelling are methods of introducing the negative implications of overuse of lighting as out of balance with the natural world. She will share approaches to Indigenous Astronomy and methods of respecting Two Eyed Seeing Scientific education and finding our place in traditional skies.

Website and social media

Instagram https://www.instagram.com/rothneyobservatory/

Facebook https://www.facebook.com/rothney.observatory

Twitter https://twitter.com/RAOastronomy

RAO website https://science.ucalgary.ca/rothney-observatory

RAO YouTube channel https://www.youtube.com/channel/UC1W1WQYhENypx-VNTTuvP2Q

Invited Closing Speaker: Brian Pincott

Executive Director of a nation cycling advocacy organization, and consults on housing policy, active transportation, and urban growth issues
Winnipeg, Calgary
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Brian Pincott first saw the light in university when, while a pre-med student, he discovered theatre. He began concentrating on lighting within theatre immediately upon switching programs. He subsequently had a twenty-year career in Canadian theatre as an award-winning lighting designer in theatres from St. John's to Victoria and all points in between. His lighting design career led him to move to Calgary from the east coast. Becoming involved in environmental and civic issues in Calgary inevitably led him to leave theatre and enter politics.

Brian served as a Calgary City Councillor for 10 years until 2017. While on City Council his interest in the environment and lighting led him to spearhead several issues, such as re-lamping of streetlights, bird friendly lighting policies, and changes to land use that would reduce the effects of light pollution. He proudly was referred to, by local media, as the "Prince of Darkness".

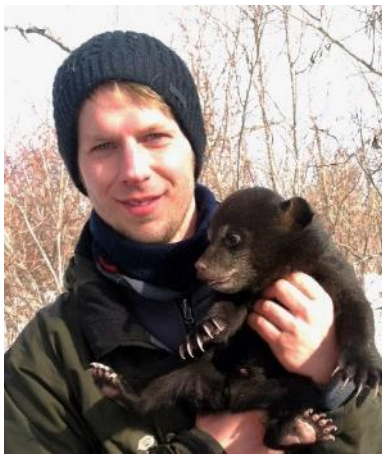
Brian, now living in Winnipeg, has since worked as the Executive Director of a nation cycling advocacy organization, and consults on housing policy, active transportation, and urban growth issues. He continues to make his yearly pilgrimage to his favourite Dark Sky Preserve in the Cypress Hills of Saskatchewan.

Title of his talk – well…

Brian bravely agreed to give a wrap up of the conference in the very last speaking slot, so we will wait excitedly for his impressions and thoughts on all he will hear during ALAN2023.

Invited Plenary Speaker: Mark Ditmer

U.S. Forest Service - Rocky Mountain Research Station , Fort Collins, CO, USA
Colorado State University, Fort Collins, CO, USA
mark.ditmer@usda.gov



Dr. Ditmer is a research ecologist with the U.S. Forest Service's Rocky Mountain Research Station. He has expertise in quantifying the impacts of anthropogenic disturbances on wildlife typically through analyses of animal movements and physiological biologger data.

Throughout his career, Mark has sought to integrate novel sources of data and technology into research that assesses wildlife responses to habitat alterations, including leading studies with black bears, cougars, wolves, moose, deer. His previous work incorporated remotely-sensed estimates of ALAN into wildlife studies to quantify behavioral changes across levels of exposure to ALAN, and he has applied ALAN to better quantify and track the dynamic human footprint. Currently, with the Rocky Mountain Research Station, he has continued to research how sensory pollution from recreation impacts wildlife and user experiences on public lands.

Integrating Sensory Ecology into Wildlife Studies Is a Bright Idea

The illumination of the landscape by artificial light at night (ALAN) has been shown to disrupt ecological processes and impact populations. Yet, a majority of ecological studies of ALAN have occurred within the lab or at relatively small spatial scales – often restricting the kinds of species involved in the studies. The use of remotely-sensed products to quantify and map changes in the dynamic footprint of ALAN now enable the assessment of impacts on resource use and movements of wide-ranging, highly mobile large mammals at large scales. Through the incorporation of ALAN data with traditional metrics of human land-use, such as road and housing density, isolating the contribution of ALAN to anthropogenic change is possible. Yet, despite the heightened understanding of the impacts that sensory pollutants can pose to species, and the availability of fine-resolution data globally, few conservation plans and studies of free-ranging wildlife account for the expanding sensory footprint of the Anthropocene. This talk will cover a variety of ways in which I have integrated ALAN data into studies of wildlife to better understand predation and movement behavior, functional connectivity, account for the human footprint, and provide targeted recommendations to wildlife managers. As a research ecologist with the U.S. Forest Service, my aim is to promote awareness of sensory pollutants into wildlife studies and management considerations for public lands throughout the American West.

Invited Plenary Speaker: Russel G. Foster

CBE, FRSB, FMedSci, FRS
Director, Sir Jules Thorn Sleep and Circadian Neuroscience Institute (SCNi)
Head, Nuffield Laboratory of Ophthalmology (NLO)
Nuffield Department of Clinical Neurosciences
Fellow, Brasenose College
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His research has focused upon how circadian rhythms and sleep are regulated by light. A key finding has been the discovery and characterisation of an unrecognised photoreceptor system within the eye that regulates circadian rhythms and sleep and, most recently, the translation of these findings to the clinic with the development of new drugs to correct for circadian rhythm disruption in the blind.

He was elected to the Fellowship of the Royal Society in 2008, the Royal Society of Biology in 2011 and the Academy of Medical Sciences in 2013. Russell was honoured by being appointed as a Commander of the British Empire (CBE) in 2015 for services to Science. He has been a member of the Governing Council of the Royal Society and he established and led for six years the Royal Society Public Engagement Committee. Russell has published over 290 scientific papers and has received multiple national and international awards, including most recently the Daylight Prize for Research.

Lighting for Human Health – Can We Make Recommendations for Circadian Entrainment?

With an increasing shift of the human population from outside to inside spaces, and a detachment of individuals from the natural light/dark cycle, artificial lighting regimes are being designed to replicate the light signals that regulate the circadian system (photoentrainment) and promote sleep. However, this is not an easy task. Photoentrainment is based upon a complex set of sensory interactions. For example, there is a dynamic relationship between stimulus duration and intensity. Laboratory studies have shown that light in the evening in the 50 to 100 lux range will modulate the circadian and sleep systems, but it requires stimulus durations of many hours. And significantly, the effects of dim light in the evening can be abolished if the individual has been exposed to moderate levels of light (~500 lux) for several hours during the day. Furthermore, light exposure at dusk will delay the circadian system, whilst early evening light exposure will advance circadian rhythms. These key factors, along with the wavelength of the light signal; ill-defined photoreceptor interactions between melanopsin-based photosensitive retinal ganglion cells (pRGCs), rods and cones; the age of the individual; the rate at which light intensity changes, the metrics used to measure impact (e.g. melatonin vs sleep/wake behaviour), and an individual's light history, illustrate the fact that attempts to develop evidence-based "Human Centric Lighting" to enhance circadian entrainment and promote sleep is, to say the least, a complex task. Recommendations for optimal light exposure are emerging. However, the practical value of the current recommendations is uncertain. These issues will be discussed within the context of what we actually know, what we don't know and what we need to know for advanced artificial lighting design for the promotion of circadian and sleep health.

Invited Plenary Speaker: Nona Schulte-Römer

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Dr. Nona Schulte-Römer has studied light in cities since 2008 when she began her social scientific research on the introduction of LED street lighting and festivals of light.

In recent years, her focus has shifted from innovation in lighting to public discourses and controversies about the undesirable and harmful effects of artificial light at night. In 2018, she published the results of an international inquiry Light Pollution – A Global Discussion with Dr. Josiane Meier and Etta Dannemann (lightpollutiondiscussion.net) while working in the sociology department at UFZ – Helmholtz Centre for Environmental Research in Leipzig. Since 2019, she has worked with Dr. Christopher Kyba in the international citizen science project Nachtlichter at GFZ – German Research Centre for Geosciences (https://nachtlicht-buehne.de/startseite/nightlights/). In her current research, she explores how people, both scientists and non-scientists, perceive and assess the environmental and health risks of electromagnetic radiation, including light and mobile radio emissions.

Prior to her work as a social researcher, Nona has studied theatre, politics and journalism and worked in art festivals and online journalism.

Better safe than sorry? A social-scientific reflection on light and security

The relationship between light and safety is a notoriously controversial issue in public debates about artificial light at night. Objective security is often equated with a subjective sense of safety. At the same time, it cannot be denied that dark and shady public spaces can evoke feelings of insecurity and that unevenly illuminated roads pose a traffic safety risk.

The relationship between light and safety seems even more complex if we account for the fact that nicely illuminated public spaces might attract more visitors after dark increasing people's trust in social control, while dark and abandoned public spaces often appear unruly and populated by 'shady' characters.

Seeking to disentangle the complex relationship between light and safety, I differentiate between physiological, social and psychological aspects and focus on three domains that are particularly relevant for decisions about light and darkness: 1) Traffic safety after dark, 2) Nighttime crime as a security issue and 3) the lack of perceived safety in 'spaces of fear'. This social-scientific reflection is based on historical accounts, the instructive, but inconclusive scientific evidence on the topic of light and safety, and my own ethnographic research on urban lighting.

However, these domain-specific considerations on light and safety seem outdated in the face of biodiversity loss, energy crises and discussions about 'light pollution' in the Anthropocene. To be more precise, security-oriented lighting strategies of the 20th century appear to follow a 'better safe than sorry' principle. Moreover, domain-specific, human-centered precautionary approaches seem too narrow to meet the systemic challenge of mediating conflicting societal, economic and ecological goals in the 21st century. While suitable technical solutions are on the market and sufficient expert knowledge is available, these conflicting goals raise much broader political questions of democratic deliberation. I conclude with a 'cosmopolitical proposal' (Stengers, 2015) an invitation to accept the tensions of protecting dark skies while still meeting human demands for light and safety. Let's better reconsider our sense of safety and not be sorry in the future.

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Invited Plenary Speaker: Diane Turnshek

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Diane's research focuses on measuring the light of cities with drones, aircraft, satellites, and astronauts aboard the International Space Station for use in designing ordinances for the reduction of light pollution, for example, Pittsburgh's 2021 Dark Sky Ordinances.

She earned an International Dark Sky Association's Defender Award and founded the Pennsylvania chapter of IDA. She has given over one hundred light pollution talks (including one for TEDxPittsburgh), curated a series of space art galleries, and is the editor of the genre anthology Triangulation: Dark Skies with twenty-one starry night short stories. She has recently been interviewed by the New York Times, PBSNewsHour, NPR Morning Edition, Canada One Radio, Chinese Global Television Network, Newsy.com, NBC, Sky & Telescope, and dozens more news outlets worldwide.

Diane started teaching astronomy and doing community engagement in Pittsburgh in 1981, where she coordinates the long-standing astronomy lecture series at Pitt's Allegheny Observatory. She instituted a summer CMU light pollution undergraduate research class called SKYGLOW and hosted a CMU Dark Skies Conference. She is a committee member of the International Astronomical Union (IAU) B7–Inter-Division B-C Commission Protection of Existing and Potential Observatory Sites and an affiliated member of the new IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (IAU CPS).

Persuasive Measurements for Environmental Justice

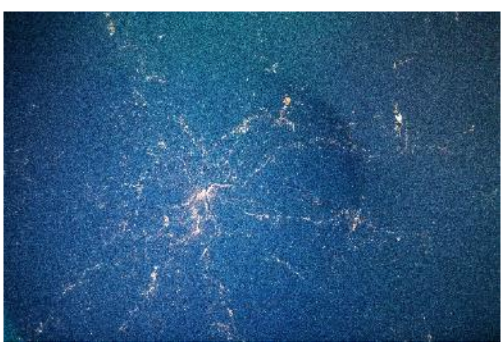

Fig. 1:. Fig. 1: ISS065-E-214151 Pittsburgh, PA, US Image credit: Earth Science and Remote Sensing Unit, NASA Johnson Space Center https://eol.jsc.nasa.gov/SearchPhotos/photo.pl?mission=ISS065&roll=E&frame=214151

President Bill Clinton signed an executive order in 1994 to document and address the way federal agencies expose people living below the poverty line to environmental pollutants known to be dangerous to human health. The list of researched pollutants has expanded to include more than just toxic waste; studies have documented contamination of clean air and water, noise and plastic pollutants, ease of access to healthy food and green spaces, flooding risk, reliable energy, and more (Chakraborty, 2016).

Adding night lights are an obvious way to show that money has been spent in a neighborhood, but people have been made vulnerable and put at risk of poor health by inadequate government policies. In some urban areas, residents can't enjoy stars or even a peaceful evening outdoor experience. At Pittsburgh's latitude (40°N), the trees are stressed by budding 7.5 days early in the spring (ffrench-Constant, 2016) native nocturnal pollinators suffer from light traps sending uneasy ripples through the ecosystem, and dawn song is a pale reflection of what it once was. Documenting environmental justice issues is the first step to correcting them.

Evidence is mounting that artificial light at night is a risk factor for human health due to melatonin level reduction and chronodisruption (circadian rhythm alteration) (Nadybal, 2020). Spatial resolution and spectral characteristics of satellite remote sensing are sometimes inadequate at night for the finetuning needed to differentiate light levels between census tracts.

The goal is to make a high resolution city map of Pittsburgh's 90 neighborhoods in such a way that the procedure can be replicated at low cost at similar or smaller scales. Not only will this bring awareness to environmental justice issues and drive policy, but it will provide a temporal base layer to local researchers studying bird migration, firefly populations, algal blooms, human health, fish feeding depths, and more. In 2021, Pittsburgh's Dark Sky Ordinances were put in place for streetlights and public property, including all the institutions that sit on city property, when large-scale renovations or new buildings are put up. Within a year, the company The Efficiency Network (TEN) will deliver a dark sky compliant design for the replacement of approximately 44000 HPS streetlights by LEDs, a retrofit process that will be completed in two years. An urban nighttime high resolution map will bring awareness to the possibility that, unless an environmental study is done, equality may not be served by the LED streetlight switch.

Preliminary systematic measurements with an All-Sky camera at Allegheny Observatory, TESS-W photometers, SQM-Ls, the DarkSkyMeter phone app, and Globe@Night have yielded mixed results. After astronomical twilight, skyglow at the zenith was recorded in the darkest places in each census tract: open fields in playgrounds, parks, cemeteries, and expansive private properties. The 500-foot elevation change within the city limits affects light levels in a different way than level grid cities, and the city has over 33,000 street trees and 3600 acres of public parkland. This also changes the way light is scattered and spread.

Concurrently, readings were taken from above: with drones (Mavic 2 Pro UAVs) at 400 feet, a Sony CyberShot DSC-RX0 II mounted under a Cessna aircraft that was moving slow and low at an altitude of 500 feet, with a helicopter and a low-light Sony A7SII DSLR at approximately 800 feet in elevation, and by astronauts aboard the ISS taking photos of Pittsburgh at the nadir from the cupola, an ISS program that will continue through the city's streetlight replacement.

We expected to see a bimodal distribution. During our data collection, the neighborhoods without a strong collective voice in local government appeared either darker due to neglect or brighter, assumedly from a concern for citizen safety as has been discussed in other city studies (Alvarez, 2020, Nadybal, 2020, Xiao, 2023). When hundreds of ground-based data points were set in census tract boundaries on an ArcGis feature layer and compared against a host of socioeconomic factors, the only factor that stood out in this feasibility study was age. Young people, predominantly at universities in the "Eds & Meds" corridor of the city called Oakland, had a significantly higher level of brightness (Kevin Ren, 2023).

The next phase of the research program is to refine the resolution and further diversify the location choices for the ground-based measurements and to complete a helicopter flyover documenting the whole city at night with the following constraints: no moon, snow, or wet ground, with the leaves off the trees, and when holiday lights are not in evidence. The plan is to repeat the map when the LED switch has been completed. Quantitively, this will document how many residents have benefited from the improved urban lighting.

Acknowledgement

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Abstracts of submitted talks and posters

The effects of ALAN on habitat use by nightjars in Western Canada vary across behavioral and landscape contexts

Theme: Biology and Ecology

Carrie Ann Adams[1,2*] Elly Knight[2], Colleen Cassady St. Clair[2], Erin Bayne[2]

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** presenting author*

Introduction

The effects of ALAN on habitat use can vary among species (Sanders et al., 2020) and within species across contexts (e.g. Barré et al., 2021). Bird species that eat flying insects (i.e. aerial insectivores) may be more abundant near artificial light if it attracts their prey. We call this idea the foraging benefit hypothesis. Birds may avoid nesting near ALAN if it affects their nest predation risk, especially for ground nesting species that rely on camouflage for nest protection (Troscianko et al., 2016). We call this idea the predation risk hypothesis. In addition to these spatial considerations, ALAN may alter temporal aspects of habitat use. Under the foraging benefit hypothesis, aerial insectivores may extend their activities into later twilight periods and true night if ALAN aggregates and illuminates their insect prey. Crepuscular species may shift or extend their daily activities later into the evening and earlier into the morning if ALAN shifts their perception of the photoperiod (Gilbert et al., 2022).

We explored species-specific effects of ALAN during two field studies in Western Canada that targeted species in the nightjar family (*Caprimulgidae*): Common Nighthawks (*Chordeiles minor*) and Common Poorwills (*Phalaenoptilus nuttallii*). These species are most active at dawn and dusk, hunt flying insects, and rely heavily on camouflage to protect their ground nests (Troscianko et al., 2016). Common Nighthawks can forage over ten kilometers from their nest sites, while Common Poorwill nest and forage within a small territory. We studied spatial habitat use by both species in British Columbia and both spatial and temporal habitat use by Common Nighthawks in Alberta.

ALAN affects spatial habitat use by nightjars in British Columbia differently across species and behavioral contexts

<u>Methods</u>: We tested the foraging benefits and predation risk hypotheses using survey data from the Canadian Nightjar Survey in British Columbia. We modeled the association between ALAN and the relative abundance of three group of nightjars (extra-territorial Common Nighthawks, territorial Common Nighthawks, Common Poorwills). We estimated ALAN using the annual composites from the Earth Observation Group's VIIRS Nighttime Light Products (Elvidge et al., 2017). We used a negative binomial generalized linear model to study the relationship between the relative abundance of each nightjar group and ALAN, as well as urban and other landcover types.

<u>Results/Conclusions:</u> The relative abundance of extra-territorial Common Nighthawks, which are likely to be foraging, showed a positive association with ALAN only at low levels of urban land cover. Relative abundance of Common Nighthawks and of Common Poorwills on their nesting territories were negatively associated with ALAN, regardless of urban landcover. These results suggest that Common Nighthawks may benefit from foraging on insects at artificial lights, but only in areas with very little urban development. Breeding nightjars may avoid ALAN, perhaps due to increased predation at their nests. For species like Common Poorwill that

nest and forage within the same area, the nest predation risks associated with ALAN may outweigh foraging benefits.

ALAN reduces spatial but not temporal habitat use by Common Nighthawks in Alberta

Methods: We assessed how ALAN affected both spatial and temporal patterns of habitat use by Common Nighthawks and compared these effects in a northern and southern region of Alberta. We collected acoustic recordings in the southern Grassland region and northern Boreal region and we measured spatial intensity of territorial and extra-territorial habitat use. At sites where we detected Common Nighthawks, we tested for differences in daily patterns of vocal activity between lit and unlit sites. To estimate ALAN, we developed an aurora correction for monthly composites based on Coesfeld et al. (2020)'s airglow correction procedure. We fit a binomial generalized linear model of the relationship between ALAN and spatial habitat use by territorial and extra-territorial Common Nighthawks. We fit a generalized additive model of the non-linear relationship between sun angle and vocal activity in sites occupied by Common Nighthawks, testing for an overall change in vocal activity and shifts in peak activity times relative to sun angle.

Results/Conclusions: We found a negative association with ALAN for intensity of both territorial and extra-territorial spatial habitat use in the Grassland region and no association in the Boreal region. We found no effect of ALAN on the relationship between sun angle and vocal activity. ALAN may be more likely to affect spatial habitat use by crepuscular birds at lower latitudes where natural illumination is lower during the breeding season. ALAN does not appear to affect circadian rhythms or extend foraging activity for Common Nighthawks in our study area, but further studies should focus on lower latitudes or regions where nightjars occur more frequently near light sources.

Conclusions

Together, these two studies show how the effects of ALAN can vary across species, context, and region. Nightjars may primarily forage under ALAN when they are not defending a nest site or if they can forage away from their nest sites, and species that perform this behavior may only do so in limited parts of their range. Furthermore, except at the highest latitudes of their range, nightjars may avoid ALAN for nesting. Together, this work highlights the importance of protecting nightjar nesting habitat from light pollution.

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Towards a First Spectro-Photometric Characterization of the Chilean Night Sky

Theme: Measurement and Modeling

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Light pollution is nowadays recognized as a global issue that, like any other form of anthropogenic pollution, heavily affects ecosystems and causes adverse health effects on living beings. Originally discussed by the astronomical community that was concerned that an inefficient, unnecessary and uncontrolled use of Artificial Light At Night (ALAN) could dazzle professional observatories, today it represents a fertile terrain for interdisciplinary scientific research, socioeconomic studies, and public cultural debates.

Chile is widely known for its rich and distinctive ecosystems, and the excellent quality of its northern skies has transformed it into one of the most important astronomical nodes in the world. Nonetheless, despite a long-standing effort from various public and private actors to keep the light pollution phenomenon under control, a coordinated scientific approach to characterize, quantify and monitor the effects of ALAN on the Chilean sky has started only recently.

Our interdisciplinary Research Group on ALAN (made of professional astronomers, MSc and PhD students, and experts in lighting technology) was born four years ago with the explicit purpose of filling this need, and aims at providing the international community with the first spectro-photometric characterization of one of the most pristine skies of planet Earth. Since 2019 we have been regularly monitoring about twenty distinctive sites across the Coquimbo Region -- also known as "Región Estrella" (*Region of the Stars*, in Spanish): the list includes professional astronomical observatories (e.g., the International Gemini Observatory, Cerro Tololo Inter-American Observatory, ESO La Silla Observatory, Las Campanas Observatory), astrotourism centers, natural parks, and urban centers.

In this contribution we would like to introduce our group by describing its raison d'être; stating its short, medium and long-term goals; and presenting the first results of its systematic Telescope and Encoder Sky Sensor (TESS-W) and Sky Quality Camera (SQC) surveying campaigns. We further describe how our scientific projects and outreach initiatives, through a constant synergy with public and private institutions, contribute to heighten public awareness about the subtle but devastating effects of light pollution, also by breaking down prejudices about proper lighting. Finally, we give an example where our scientific conclusions have supported different appointed committees (from municipalities to regional governments, up to the national one) in taking more enlightened decisions to preserve the darkness of the Chilean sky, a natural and cultural heritage that is our scientific, social and moral obligation to defend and preserve.

Attraction or avoidance? Shearwaters avoid -artificial light in Y-maze experiment

Theme: Biology and Ecology

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Light pollution affects seabird populations, especially of the burrow-nesting species, leading to massive mortality events during fledging. During their maiden flights to sea, fledglings of burrow-nesting seabirds become disoriented by urban lights, subsequently crashing into manmade structures or grounding after exhaustion (Rodríguez et al., 2017). Fallouts have been generally attributed to a light attraction hypothesis: fledglings are attracted to urban areas due to artificial light at night (ALAN) and become subsequently 'trapped'. However, the behavioural mechanisms driving these events have not been resolved (Atchoi et al., 2020; Brown et al., 2023). There is also an age component to fallout events. Fledglings make up most of rescued birds, after being affected during their first flights, while adults, which fly to and from the colonies across the breeding season, are seldom found grounded. Here we investigated the reaction towards contrasting light stimuli of Cory's shearwaters (*Calonectris borealis*) at two distinct life-stages.

We collected 131 grounded fledglings during the 2020 and 2021 fallout seasons, and 84 adults attending the colony during the breeding season of 2022. After placing a Y-maze facing the sea (a wooden structure with two separated arms at one end), we applied one of the three treatments: blue versus red light (spectra), and white light versus no-light (monochrome), with the different stimuli randomly interchanged between left and right arm, and a treatment with no-light on either arm (control). Each bird was tested only once, and we recorded the 'choice' and 'time taken to make a choice'. A choice was considered when the individual stepped into one of the arms of the Y-maze. Maximum treatment duration was 10 minutes, after that, if the bird did not choose an arm, it was registered as 'no-choice'.

Adults and fledglings displayed similar tendencies: both groups preferred red over blue light, and no-light over white-light (Fig.1). Fledglings made more choices, but took longer to choose, than adults. Both adults and fledglings were quicker to react during the control treatments than during either of the light treatment. There were no differences in the time of reaction between the spectra and monochrome treatments. Contrary to the apparent attraction observed during fallout events, Cory's shearwaters at two distinct life stages displayed avoidance of light stimuli. Our results indicate that fallouts may be a consequence of disorientation caused by light pollution, rather than mainly the result of an attraction to the light source. However, how fledglings are initially attracted to artificial light, the range (e.g. distance or intensity thresholds) of the attraction effect, and whether other mechanisms are at play, remain unknown. Regardless of the processes by which these naïve individuals arrive at urban areas, once there, the artificial light disorients them, causing the fledglings to become 'trapped' and unable to orient towards the ocean (Rodríguez et al., 2022). Supporting the disorientation effect, all fledglings made a choice when no light stimulus was applied (control treatment) but the rate of reactions decreased with the presence of light stimuli (79% of fledglings reacted in the spectra treatment; 57% reacted in the monochrome treatment).

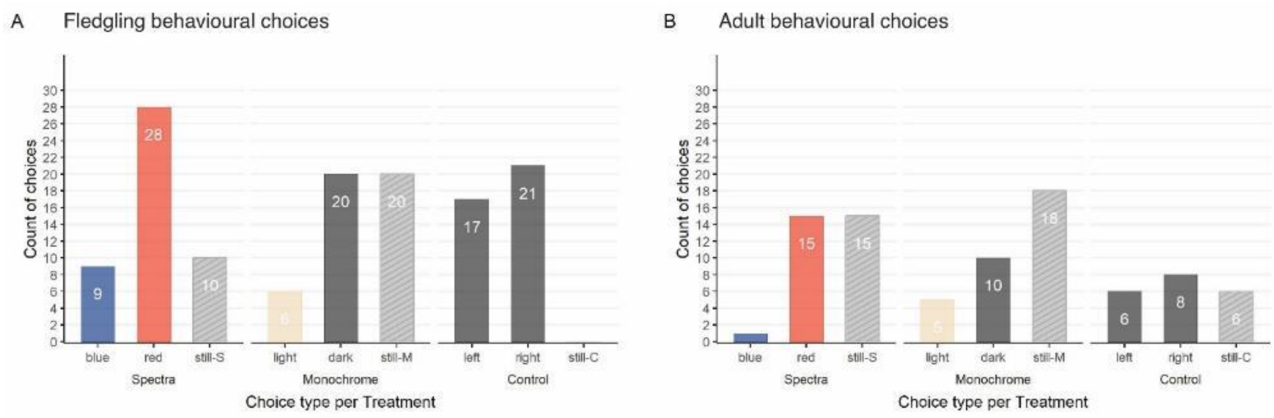

Fig. 1: Count of behavioural choices per treatment for (A) 131 fledglings and (B) 84 adults. Light grey striped columns represent no-choice.

Disorientation may be caused by an interference of artificial light with the seabirds' visual system, especially in the fledglings of burrow-nesting species, which most likely lack sufficient exposure to light during growth to properly stimulate development of the visual system (Atchoi et al., 2023). Our study provides further evidence for the disruptive effect that light stimuli, especially of shorter wavelengths, have on shearwaters and clarifies behavioural tendencies towards light stimuli for an ALAN-impacted seabird species.

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From the eyes to the sky: the distributed origin of the artificial skyglow

Theme: Measurement and Modeling

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The artificial night sky brightness arises from different physical processes. A complete description of this manifestation of light pollution shall include all relevant light emissions and all intervening media where the light is reflected or scattered, as long as human intervention leads to higher light levels than those expected in pristine conditions.

The largest share of studies in this field focused on the atmospheric scattering of artificial light along the line of sight from ground to the top of the atmosphere, typically with spatial pixel resolutions of a few hundred meters, as e.g. the iconic World Atlas of the Artificial Night Sky Brightness (Cinzano et al. 2001, Falchi et al. 2016). This is entirely appropriate since these studies provide key, world-wide information on the structural contribution of the artificial lights (typically estimated from satellite nighttime imagery with such spatial resolution) to the night sky brightness produced by atmospheric scattering, the most important component in many cases of interest. Studies are less numerous, however, on the night sky brightness generated and detected at the micro-scale, i.e., at very short distances from the sources, with sub-pixel resolution (see e.g. Bará et al. 2023, Zamorano et al 2023). The same can be said of the light scattered within the human eye (Bará and Bao-Varela 2022), and of its physical device counterpart, the stray light within optoelectronic detectors. Last but not least, an unexpected contribution to the overall brightness of the night sky has been recently modeled: the diffuse brightness caused by the reflection and scattering of sunlight in the cloud of artificial satellites and space debris objects, with sizes ranging from tens of meters to micrometers, moving in low Earth orbits (LEO), whose radiance could amount to a 10% of the natural reference level (Kocifaj et al 2021).

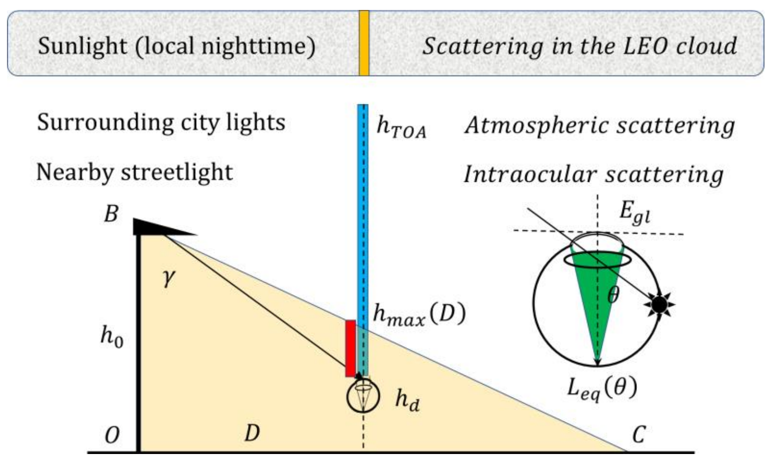

Fig. 1: Sources, media and physical processes involved in the build-up of the artificial sky brightness. Image credit: the Authors.

Active ground artificial light sources include streetlights, other outdoor functional and ambiental light sources, billboards and LED displays, indoor light from windows, vehicle headlights, and other. The light reflected on urban surfaces (façades, pavements, vegetal cover...) acts effectively as an secondary artificial source component. Fig 1 schematically represents the main sources and intervening material media involved in the generation of the overall zenith sky brightness. Whereas the surrounding city lights and other sources located up to hundreds of km away from the observing point contribute light scattered along the whole air colum, from the height of the observer to the top of the atmosphere (TOA), nearby streetlights produce a relevant amount of scattered light in the first few meters of this colum, especially relevant when the observer is located within their directly illuminated volume. Additionally, all sources external to the eye, whether active or secondary (including scattered components), give rise to intra-ocular scattered light. The retinal glare pattern, in many cases, is strongly dominated by the contribution of the nearest streetlights.

Whereas traditional detectors measure the night sky brightness generated outside the eye, i.e. the one originated in the air column and possibly in the satellite and space debris cloud, the human visual system also detects the additional light produced by intraocular scattering processes. The equivalent phenomenon to intraocular scattering is instrumental stray light, which for most modern devices is substantially smaller than that present in the eye. Usual radiometric sensors, then, may subestimate the actual loss of the night sky quality perceived by human observers.

The communication develops the scenario summarized in this abstract and provides some suggestions for future directions of research.

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The interplay between ALAN and brain plasticity - current knowledge and future goals

Theme: Biology and Ecology

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During the last few years we studied the effects of ALAN on brain plasticity in diurnal songbirds (zebra finches; *Taeniopygia guttata*). These birds are advantageous because of their long lifespan, high cognitive functions, and their ability to learn and acquire vocal patterns as humans (song and speech, respectively). This presentation will integrate our findings into an overall frame, suggest general conclusions and new insights, and will lay out a future road map for this still-unravelling topic.

Brain plasticity is a multi-stage process, and therefore we started our investigation by focusing on the first stage, which is cell proliferation (Moaraf et al., 2020a; 2021). We found that **ALAN increases cell proliferation** in brains of birds that are exposed to low and ecologically relevant intensities, compared to controls that were kept under dark nights. This increase is intensity-dependent, and we suggested that it might be caused by perturbation of the circadian rhythm under ALAN, and is mediated by melatonin. Indeed, we found that melatonin decreases under ALAN, also in an intensity-dependent manner. These findings occur in both sexes, but **males are more resilient to ALAN than females**, indicating the importance of studying both sexes. The second stage of brain plasticity is migration of the newborn neurons to their target destinations and eventually their recruitment into functional circuits there. Therefore, we sampled several brain regions that differ in their functions: Nidopallium caudale (NC), Medial striatum (MSt), and Hippocampus (HC), which process auditory, visual, and spatial information, respectively. In females, we found that **ALAN increases the recruitment of new neurons** in all these brain regions (Moaraf et al., 2020b). In males we found increased recruitment only in MSt, and to a lesser extent than in females (Moaraf et al., 2021), an additional indication that males are more resilient to ALAN. A possible interpretation of the increase in both cell proliferation and neuronal recruitment under ALAN conditions is that this could be a compensation for increased neuronal death that is caused by ALAN. To test this, we measured apoptosis (cell death) in the studied brain regions, and indeed found that **ALAN causes higher neuronal death** in MSt and NC.

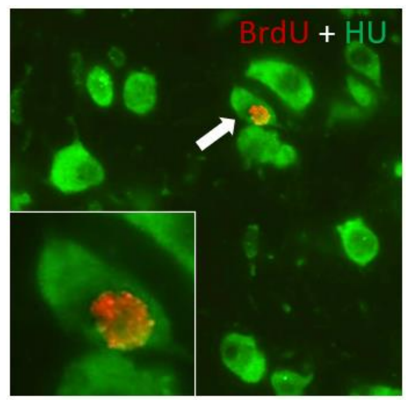

Fig. 1: An example of a new neuron in the brain of a zebra finch: All neurons are stained green (by Hu, a neuronal marker). The nucleus of one neuron (marked by an arrow) is stained red (by BrdU, a cell-birth marker), indicating a new neuron. Insert: A higher magnification of the new neuron.

These findings led us to the next question, whether the brain's homeostasis is retained, despite the effects of ALAN. Under normal conditions, neuronal densities in each region are kept constant by neuronal replacement, where new neurons replace older ones that die, which is the third stage of brain plasticity. To answer this, we compared neuronal densities in the studied brain regions under control and ALAN conditions. We found that **the effect of ALAN on neuronal densities is region- and sex-dependent**, and that also in this respect, males are more resilient to ALAN than females. More specifically, in males, ALAN did not affect neuronal densities, while in females we observed mixed effects, which also depended on ALAN duration (short- or long-term exposure). Taken together, these findings suggest that **ALAN causes differential apoptosis levels between regions and sexes** (Moaraf et al., 2021).

The differential responses of both sexes to ALAN, and the repeated indications that males are more resilient than females, led us to focus on the song system in the brain, because it is uniquely male-specific. This system is constructed of several nuclei, and we focused on two of them, HVC (that controls vocal behavior) and Area X (that is critical for song acquisition). We found that **although ALAN causes an increase in neuronal recruitment in both regions, it decreases neuronal densities only in Area X, an additional indication for the differential and region-dependent effects of ALAN** (Moaraf et al., 2021). In birds, only males sing, and this daily rhythmic behavior is important because it serves as an indicator of their quality. Therefore, the mixed effects of ALAN on the song-system might have significant ecological implications, because it could result in impaired or mistimed singing, which in turn might affect the fitness and survival of males, by decreasing their ability to attract females and defend territories.

We believe that our findings pave the road to novel directions regarding the interplay between ALAN and brain plasticity. For example, does melatonin mediate the effect of ALAN on brain plasticity, and is the effect of ALAN on brain plasticity related to behavior? New findings from our lab (see Moaraf et al. in this meeting), support these suggestions. In addition, I will present ongoing studies, in which we investigate whether the effects of ALAN on brain plasticity and behavior are reversible, and whether they are general across behaviors and species (including wild ones). Finally, I will discuss the very relevant, yet completely unknown, ecological aspects of life-long exposure to ALAN on brain plasticity.

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Classification of artificial light sources in urban areas – challenges and obstacles within the Nachtlicht-BüHNE citizen science project.

Theme: Measurement and Modeling

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Within the project "Nachtlicht-BüHNE" (Citizen-Helmholtz network for research on nighttime light phenomena), two teams of citizen scientists co-designed two data collection apps, together with researchers from the German Research Center for Geosciences (GFZ) and the German space agency (DLR). Here we present results obtained from the "Nachtlichter" (Night Lights) app[1], acquired during our main campaign in the fall of 2021 (Zschorn & Mattern, 2022). The Nachtlichter app was designed to allow participants to classify and count outdoor light sources over large spatial areas. More details about the two apps are available from the project website[2].

During the first Nachtlichter campaign, light sources were classified and counted in 33 cities and communities (mainly withing Germany) in the fall of 2021 using the app. Before the surveying began, self-contained urban areas ranging in size from 0.15 km^2 to over 1 km^2 were defined, and counting transects (typically street segments from one street corner to another) were assigned. These predefined counting areas were aligned with the Earth Observation Group's reprojected pixels for data from the NOAA Suomi NPP VIIRS DNB instrument (Fig. 1; Elvidge et al. 2021). One of our project's main aims was to examine the correlation between the number and type of light sources and the radiance observed by VIIRS DNB.

Our presentation will focus on three aspects of the project. First, we present the results of data consistency checks. For example, we compared official cadastral data (maps showing the positions of public street lights) to the number of street lights reported in the same areas by the night lights campaign for 5 major German cities. The numbers do not match exactly, both because some ostensibly street lights do not have a traditional street light form (Fig.2), and because some "street lights" are installed by private actors. Overall, we show that the data on artificial light sources in urban areas obtained through the Nachtlichter app have a consistently high level of quality.

Second, we present initial results of several analyses. For example, we compare total light counts to satellite data, examine trends in how different types of lights turn off over the course of the night, and study how the types of lights change with differing land use classification. Finally, we briefly outline our plans for an upcoming campaign as part of the German Ministry of Education and Research's Research Year 2023 – Our Universe.

[1] https://lichter.nachtlicht-buehne.de/

[2] https://nachtlicht-buehne.de/

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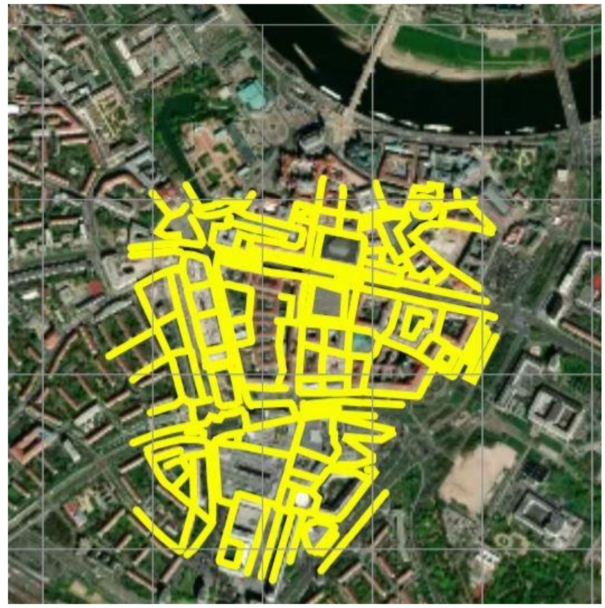

Fig. 1: The Nachtlichter transect locations in the Altstadt of Dresden, Germany. The region covers all publicly accessible areas in 5 DNB pixels in the Earth Observation Group's standard projection. Three other large areas in Dresden that were also sampled in 2021 are not shown.

Fig. 2: This light source is part of the public street lighting network (as can be seen by the number code shown below the light). However, it does not have the classical form of a street light, and was most likely counted by the Nachtlichter participant as a "light mounted on a building".

Response and recovery pattern of nocturnal insects and bats to alternating exposure to artificial light and darkness

Theme: Biology and Ecology

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Introduction

Artificial light at night (ALAN) has been identified as a major cause of environmental change in the 21st century, with critical consequences for both ecological systems and humans. ALAN has a wide range of negative ecological impacts, reducing the fitness of species and contributing significantly to insect decline (Hoelker et al., 2021; Owens and Lewis, 2018). To date, mostly long-term effects of ALAN exposure have been studied in both terrestrial (Altermatt and Ebert, 2016; Bolliger et al., 2022; Grubisic and Grunsven, 2021; Kalinkat et al., 2021) and aquatic systems (Schligler et al., 2021). However, to gain a better mechanistic understanding of ALAN as an anthropogenic disturbance, long-term response patterns should be complemented with studies of short-term impacts to determine the dynamics and resilience of ecological systems. Such an assessment allows us to identify which species groups may be able to cope with increasing ALAN exposure and which organisms are most strongly affected.

Fig. 1:. Amber (2000K) and neutral white (4000K) in forests. © Martin K. Obrist

Experiment

Our experiment was conducted during two field seasons (May-August 2021 and 2022) at three sites in the Swiss lowlands and pre-Alps. Each site contains 14 LED streetlights with different light treatments (three LED colors: 2000K, 3000K, 4000K), two luminaire shapes (focused, diffused) and two dimming levels (full light and dimmed to 50%), as well as two dark controls. We recorded abundance of flying insects and bat activity throughout the field season. During one week in the middle of thesampling period, in late June 2021 and 2022, the streetlights were turned off. The sites remained dark during this week, but the insect trapping and bat recording continued. Response patterns were assessed by comparing insect abundances and bat activity during the dark week with that during adjacent weeks with light. Thus, we analyzed the responses of flying insects and bats as a function of turning the lights on and off.

Research objective

The overall objective of this study is to gain a better understanding of the short-term responses to alternating one-week light-dark light exposures and recovery patterns of the abundance of seven taxonomic groups of nocturnal flying insects, as well as bat activity. We expect nocturnal flying insects to respond immediately to turning ALAN on and off, regardless of all light treatments considered in the experiment. In contrast, we expect that bats take longer to recover from ALAN exposure, especially rare, light-sensitive bat species.

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Shedding light on ALAN's impact on marine coastal organisms. Disruption of daily rhythm and physiological consequences in the cultivated oyster *Crassostrea gigas*.

Theme: Biology and Ecology

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Introduction

Natural light cycles are critical for biological timings since they are used by organisms to synchronize their biological rhythms with their environment(Bradshaw and Holzapfel, 2010), enabling them to be fully adapted to it and to anticipate its changes (Partch et al., 2014). However, Artificial Light At Night (ALAN) can disrupt the organisms' perception of natural light cycles, and affect their biological rhythms and their physiology (Gaston et al., 2017). ALAN is a growing threat for ecosystems since it affects the whole world and spreads fast with a 2.2 % increase of lit areas per year (Kyba et al., 2017). Coastlines are highly concerned by this phenomenon since 22 % of the world's coasts and 35 % of marine protected areas are exposed to ALAN. Despite the threat that ALAN represents towards coastal ecosystems, its effects on marine organisms remained poorly studied until recently (Marangoni et al., 2022). The oyster *Crassostrea gigas* is a key species of these coastal ecosystems and a species of commercial interest. all around the world (Herbert et al., 2016). Being a sessile organism living in benthic areas, oysters are inevitably exposed to ALAN, which could disrupt their biological rhythms. Oysters' daily rhythm has been described as a plastic endogenous circadian rhythm generated by a molecular clock (Mat et al., 2012; Tran et al., 2020). This plasticity enables oysters to easily adapt to new environments but could make them vulnerable to a disruption by ALAN. Thus, using *C. gigas* as model organism of coastal areas, we studied ALAN's effects on its behavioral daily rhythm, its circadian clock, light perception genes, and physiological consequences at the microbiota and growth levels. We characterized these ALAN's effects on oysters according to its intensity, its spectral composition, and its modality.

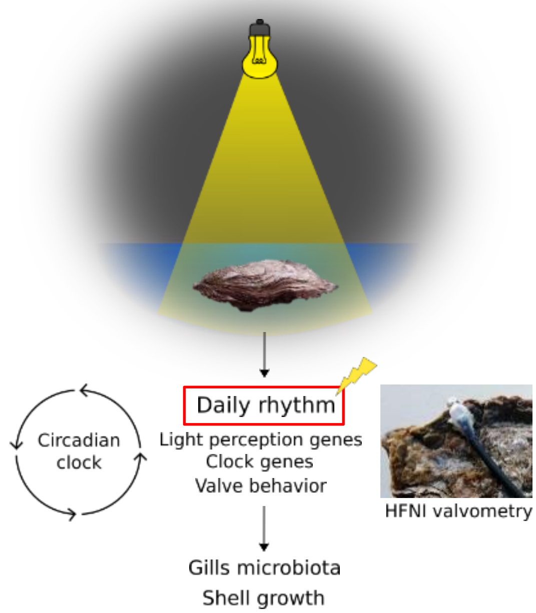

Fig. 1: Study of ALAN's effects on oysters.

Methods

Oysters were exposed in the lab to a nocturnal LED lighting at several realistic intensities (25, 10, 1, 0.1 lux), several wavelengths at 1 lux (blue, green, red, and white light), and several modalities (full night or part-night exposure). Impacts on oysters' daily rhythm were investigated at the molecular and behavioral levels, and resulting physiological consequences on the shell's growth and gills microbiota were observed. Molecular analyses have been conducted on oysters' gills using the quantitative real-time PCR technique to assess ALAN's effects on the expression of clock genes and genes involved in light perception. The impact on oysters' behavioral rhythm have been assessed using the HFNI valvometry (Tran et al., 2020). This biosensor uses two electromagnets glued on each oyster's valve between which an electromagnetic current is generated, allowing to continuously record oysters' valve behavior. Then, chronobiological and statistical analyses (Lomb and Scargle periodogram and Cosinor model) were performed on the valve activity data (Gouthiere et al., 2005). The HFNI valvometer biosensor is also used to evaluate the oysters' shell growth rate by monitoring the daily increase of the minimal distance between the electromagnets, since the bivalves' shell growth is occurring by calcification on the shell's internal surface. Moreover, ALAN's impact on the oysters' gills microbiota was analyzed by metabarcoding targeting the 16S rRNA gene (Liu et al., 2021).

Conclusions

Our results reveal that ALAN disrupts oysters' circadian clock and behavioral daily rhythm, with an impact on the shell growth and gills microbiota. ALAN's effects on the behavioral daily rhythm, the expression of oysters' clock genes, and genes involved in light perception, are starting from 0.1 lux, suggesting a disruption of the oysters' endogenous clock functioning. ALAN's disruption of oysters' behavior are the most important in the blue wavelength and also depends on its exposure modality with more important observed effects with a fully lit night compared to a part-night exposure. Furthermore, our study shows that the disruption of the oyster's daily rhythm by ALAN has physiological consequences since it induces a 32 % decrease in shell growth rate after a month of ALAN's exposure at 1 lux, as well as a disruption of the gills microbiota composition. Therefore, ALAN at realistic intensities has deleterious effects and physiological consequences on a key species of the coastal environment, which could lead to important damage in terms of ecosystem services, commercial shellfish production and biodiversity.

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Greenhouses: a growing threat of light pollution and practical solutions to mitigate it

Theme: Governance & Regulation

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For the last few decades, the means to reduce light pollution have mainly focused on applying good lighting practices on *outdoor* lighting, either from personal actions or through regulations. But what happens when the artificial light at night comes from *inside* a transparent building? How do you adapt the basics of good lighting to a very different source of light pollution.

With new technologies, policies for increasing food self-sufficiency, cannabis legalization, large subsidies and discounts on electricity rates, the number of greenhouses using photosynthetic lighting is rapidly increasing and the amount of light pollution they produce is staggering. Seen from orbit, they represent the brightest points of light on the surface of the Earth. Viewed from the ground, they can eliminate the night for people living nearby and look as if a new city was suddenly built.

Fig. 1: Light pollution escaping a large greenhouse facility viewed from almost 50km. The light dome from its neighboring city, St-Félicien, Qc, (pop. 10 000) is barely noticeable on the left.
Photo by Rémi Boucher / MMIDSR

Following the failed project for the construction of a large greenhouse inside the limits of the Mont-Megantic International Dark Sky Reserve (MMIDSR) in 2018, we looked into ways to prevent future threats. Regulations on light pollution have been in existence since 2007 for the Reserve's territory, but they were specifically made for outdoor lights. Without provisions adapted for greenhouses, the control of light pollution depended only on the goodwill of promoters and stakeholders.

Few studies looked into mitigating light pollution from greenhouses, and places enforcing regulations are sparse around the world. Luckily, enough information could be gathered and combined to find ways to meet the needs of protecting the nighttime environment while still allowing the use of photosynthetic lighting inside greenhouses. The provisions newly included in our regulations were specifically made to drastically reduce the amount of light pollution, while still allowing enough room to efficiently control the indoor climate of greenhouses. For example, blackout curtains, with an opacity of at least 99%, must be use during lighting operation at night, with a certain percentage of opening allowed to control heat and humidity. From our previous experiences, it was important to find provisions simple enough not only to be applied by greenhouses but also to be enforced by municipal officers. And most important of all, the provisions needed to be realistic, both economically and technically, so they don't get discredited by the industry.

Fig. 2: Comparison of using blackout curtain to limit artificial light from escaping a research greenhouse at Bishop's University in Sherbrooke, Qc. Same exposure settings were used for both images. Photo by Guillaume Poulin / MMISDR

We are now confident that these new additions to our regulations will help mitigate the negative impacts of light pollution from potential greenhouses in the region. No large facilities are currently existing inside the MMIDSR but a few smaller ones are already showing the good example and how properly used blackout curtains can greatly reduce the amount of light escaping in the environment.

We strongly encourage others to look into this growing threat because, just like every other light pollution problem, it is always easier to act upstream than when the damage has already been done.

Development of the Night Sky Scorecard

Theme: Measurement and Modelling

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Introduction

This paper presents the development of a Night Sky Scorecard rating system using available satellite data, mapping, data mining, and post processing tools. The work presented here outlines the methodology and results from development of the Ohio Night Sky Scorecard. The scorecard concept applied to the State of Ohio was developed based upon previous scorecard metrics (ASCE, 2021; UN CDF, 2021) and presents and ranks radiance per capita of light emitted annually from every county in Ohio between 2010 and 2019. The resulting scorecard provides a statewide overview of light pollution, identifies individual source applications that have significant effects on released light pollution, explores the role of population changes over time, and serves as a benchmark for future efforts to track, manage, and mitigate light pollution. The developed framework is currently being expanded to report on every county in the United States.

Methods

There are 88 counties in the State of Ohio, each with differing levels of emitted radiance as observed through yearly night time composites of VIIRS/NPP Lunar Bidirectional Reflectance Distribution Function data (NASA, 2012-2020). Using the VIRRS/NPP data and an area averaging tool available through lightpollutionmap.info (Stare, 2022), area boundaries are drawn around each county and the yearly mean radiance over the specified area is determined using backend processed statistics (POSTGIS, 2022) internal to the website. The resulting data is transcribed to a spreadsheet containing estimated population data for each county from the US Census Bureau (US Census Bureau, 2022). Radiance per capita and net change of radiance per capita is then calculated for each county for each year. Statistical analysis is then used to evaluate normality, outliers, and correlations in the dataset. A five-point ABCDF reference range, serving as the main reporting framework for the scorecard, is set based on standard scores (z-scores) equating to 20% quintile threshold cutoffs of the dataset. The higher the county radiance per capita measurement of a given county, the lower the county scored in the scorecard. A GIS based map is used to visually present the data using color codes.

Conclusions

Radiance per capita data observed for Ohio's 88 counties from 2012 through 2019 was found to be normally distributed. For the data presented here, the radiance per capita values are all provided in units of $x10^{-5}$ $Wcm^{-2}sr^{-1}capita^{-1}$. Within Ohio the mean, minimum, and maximum county radiance per capita values were determined to be 0.246, 0.088, and 0.740 respectively. The annual change in county radiance per capita from 2012 to 2019 observed within Ohio ranged from a minimum value of -6.53% to a maximum value of +46.39%, with observed mean and median yearly change of county radiance per capita of +2.43% and +1.89, respectively. Based upon the standard score ABCDF quintile approach, county radiance per capita measures above 0.320 were scored as an F; between 0.320 and 0.268 were scored as a D; between 0.268 to 0.224 were scored as a C; between 0.224 to 0.172 were scored as a B; while counties with a radiance per capita lower than 0.172 were scored as an A. As a result of the score rating for Ohio, 14 counties scored an F, 14 scored a D, 19 scored a C, 25 scored a B, and 16 scored an A.

Additional analysis of the Ohio dataset demonstrated a positive correlation (R^2 = 0.9437 through linear regression) between county population and observed radiance. However, three notable outlier counties with low populations that received an F were visible in the dataset. Closer examination of the outliers using satellite imagery indicated that high radiance producing locations within these three outlier counties occurred where greenhouses and a power station were observed.

The developed methodology used for the Ohio Night Sky Scorecard is currently being used as a framework for developing a Night Sky Scorecard for all of the 3143 counties in the United States. The effort will be achieved by the end of January 2023 through crowd sourcing the data mining within an Environmental Design course offered at Ohio Northern University. A complete report out on the US Night Sky Scorecard is anticipated for ALAN 2023 along with investigation of outliers, population dynamics, noted limitations to the approach, and regional observations. To the best of our awareness, this is the first and most comprehensive effort of its kind that seeks to score light pollution at this scale.

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Artificial light at night alters the distribution, behaviour and molecular clocks of a key sandy shore invertebrate

Theme: Biology & Biology and Ecology

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Introduction

The importance of seasonal and daily cycles of light to the functioning of natural ecosystems is well established (Gaston et al., 2013). However, the rapid expansion of artificial lighting has transformed the nighttime environment across a large percentage of the world's surface (Longcore & Rich, 2004). The rapid increase in use of artificial lighting is leading to a gap between evolutionary adaptations and current environmental conditions for many organisms. Despite the rapid rise in the spatial extent of ALAN and the growing interest in the ecological consequences of increased nighttime lighting, few studies have examined the effects of ALAN on populations and their ability to navigate. Even fewer studies have assessed how these impacts interact with natural light regimes, both predictable (lunar phase) and stochastic (cloud cover).

Talitrus saltator (Montagu, 1808) is a common European intertidal species which can be found inhabiting burrows on the upper shore of sandy beaches. This species has a well-defined circadian rhythm, undertaking nightly seaward migrations to forage on strand-line algae before returning to the refuge of their burrows to avoid predation, desiccation and immersion. These diel migrations are vital in maintaining the fitness and survival of *T. saltator*, and as with all species that undergo light driven migration patterns, any disruption to these patterns of movement is likely to have sever impacts on the viability of populations. Due to their abundance and well-defined activity pattern, *T. saltator* represent an ideal organism for the study of ALAN along sandy coastlines.

We know from previous studies that ALAN is capable of negatively influencing the growth rate, foraging activity, and navigational ability of Talitrid amphipods (Luarte et al., 2016; Torres et al., 2020). However, the extent to which ALAN is altering population dynamics, daily activity patterns and the underlying molecular clocks of *T. saltator* and other intertidal invertebrates remains unknown.

Methods

This study was conducted at Rhosneiger's Broad beach, located on the North Wales coastline, UK. Ground level illuminance (Lux) data was collected at night using a Skye® LUX sensor. These measures were GPS linked so that a prediction surface map of illuminance (Figure 1) could be interpolated from the data. Pitfall cross traps were used to collect *T. saltator.* The traps were designed to intercept animals travelling in four directions. Traps were placed in the same position each night along a transect located in the algal strandline of the eulittoral zone at GPS defined intervals. Each trap was filled 2 cm deep with 5% sea water-formalin solution to preserve caught organisms. Caught animals were counted, measured and divided into size categories. Over the course of the study period a total of 101,357 *T. saltator* were collected across 16 nights, spanning two lunar cycles. Cloud cover, temperature and lunar phase data was obtained from Valley and EGOV weather stations.

Under laboratory conditions, groups of *T. saltator* from the same population were acclimated under 4 light-at-night treatments (control = 0 lux; 1 lux; 5 lux; 30 lux). The locomotor activity of *T. saltator* was recorded over 5-day periods using automated behaviour loggers, at multiple points throughout simulated lunar cycles. For all light treatments, head tissue samples were collected every 4 hours over a 48 period to quantify expression of core molecular clock genes using qPCR.

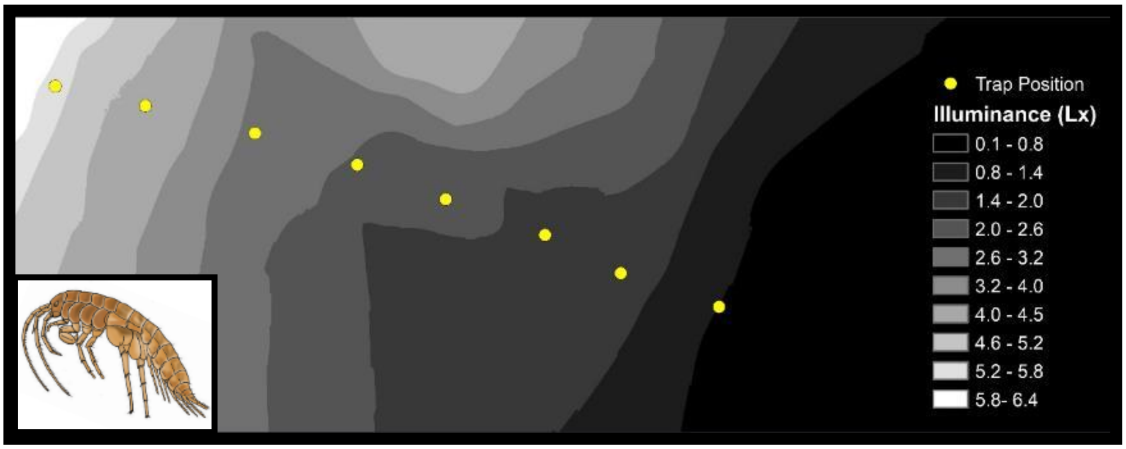

Fig. 1. The distribution of artificial light at night from High Pressure Sodium and LED street lighting across Rhosneiger's Broad Beach, Anglesey, North Wales.

Conclusions

The results from our study demonstrate that even modest levels of artificial light pollution (~3 lux) can have substantial effects on coastal invertebrate populations. Increasing illumination significantly reduced the overall abundance of *T. saltator*. This effect differed among size classes with larger individuals showing the greatest reduction in abundance. The negative effect of light pollution on *T. saltator* abundance increased as lunar irradiance increased, with the fewest individuals caught under full moon conditions. The presence of artificial light altered the migration direction of *T. saltator*. The number of *T. saltator* caught migrating along their normal sea/land axis decreased significantly with increasing illumination. In addition, we demonstrate ALAN has a substantial effect on daily patterns of activity in this species, likely driven by the altered expression rhythms of their molecular clocks.

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Comparison of activity and diversity of bats under LED public lighting with different spectral blue content (3000K and 1800K)

Theme: Biology & Biology and Ecology

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Introduction

Light emitting diode (LED) technology has been massively deployed in France for the last ten years. The firstly installed LED streetlights had a high correlated color temperature (*CCT*, 4000 to 5000K) emitting a high proportion of blue content, which assured high energy efficiency.

At the end of 2018, France adopted an ambitious national regulation (Cerema, 2019), applying to new lighting installations, including to street and parking lighting. A CCT maximal threshold of 3000K now applies to the latter, to limit blue content in the spectral power distribution (SPD) of the light source, hence less related impacts on biodiversity (Longcore et al., 2018).

In pre-existing public lighting technologies, low pressure sodium (LPS) lamps were considered less impactful on the perception of the nighttime environment on several taxa than other technologies (high pressure sodium, mercury vapor, metal halide, LED) (Davies et al., 2013). This lower impact is related to the narrowness of their SPD, with a peak around 590 nm (yellow/orange). However, LPS had several drawbacks, including their size, poor light directionality, and very poor color rendering for human vision.

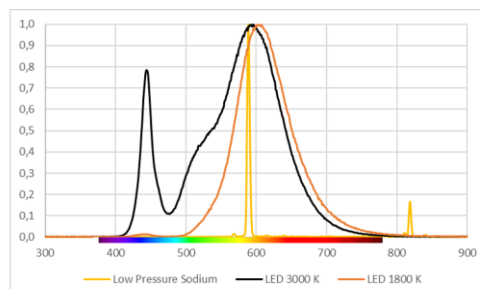

Fig. 1: comparison of the light spectra of three outdoor lighting technologies: 3000K Led (black) / amber 1800K Led (red) / Low Pressure Sodium (orange). @Matthieu Iodice, Cerema

Lighting manufacturers have thus developed so-called "amber" LEDs, whose SPD usually does not include blue content, at the cost of a lower energy efficiency than the current "standard" 3000K LED model.

We therefore planned to evaluate if these amber LEDs could be a relevant alternative for areas with biodiversity issues where light is still necessary for human needs. To achieve this purpose, we have carried out an experiment based on a BACI (Before After Control Impact) study design to compare the activity and the diversity of bats under these two types of LEDs (Amber VS standard 3000K).

We test the hypothesis that the behavior of insects and bats under “amber LED stimulus” would be closer to the behavior under “no light stimulus” than under “3000K LED stimulus”. In turn, we expect lower insect attractiveness under amber LED. Thus, we expect observed (1) less hunting activity of "light-tolerant" bats under amber LED because of this lower prey density (2) more contacts of lucifugous bats under amber LED.

Methods

To validate these hypotheses, we developed an experimental protocol (BACI) based on acoustics monitoring (Audiomoth recording devices), on in situ public lighting. Thus, the Energy Syndicate of Seine-et-Marne

Department has made available public lighting installations on which the LED modules could be replaced. Thirteen sectors were sampled, each consisting of three sites: One site was lit by a 3000K LED during “year 1” then a 1800K LED during “year 2”; one site was lit by a 3000K LED during both years; one site with no public lighting. A site corresponded to a 100m diameter area with an Audiomoth recorder at its center. The sites were selected to be as homogeneous as possible according to environmental and technical criteria (distance to the nearest forest edge, distance to the nearest water point, percentage of urban and forest coverage, height and light flux of the lighting source, etc.). The recordings took place during at least same three identified nights on the three sites of each sector, for six or seven sectors simultaneously, at the same periods for “year 1” and “year 2”.

The gathered acoustic data is analyzed in the current year with the help of the software “Tadarida” via an online deposit on a server of the French National Museum of Natural History. Hence early results will be available for the conference.

Conclusions

The deployment of LEDs is a global phenomenon. This switch in lighting technology can amplify some effects of ALAN on biodiversity compared to the former types of lamps, for example concerning SPD. In this context, amber LEDs are presented as an "ideal" alternative by combining the advantages of LEDs (lighting management, energy saving) while maintaining the lower impact of low-pressure sodium. However, we found that very few studies exist comparing amber LEDs and conventional LEDs, with robust in-situ experimental design. Our study therefore reveals strategic issues that are eagerly awaited, both by manufacturers and by managers (communities, Energy Syndicates). It also may bring arguments in favor of public aids dedicated to lighting solutions that have less impact on biodiversity (which do not currently exist in France, unlike energy savings aids).

Our final objective is to propose a standardized experimental design, which could be completed and implemented by lighting manufacturers themselves before the marketing of their lighting solution. This would allow to avoid the deployment of light solution that have too much impact. This approach has been taken up in a plan for biodiversity supported by the French Ministry of Ecology (2022), and we hope that our experiment will encourage political decisions in this direction, at the French or even European level.

Finally, if we succeed in demonstrating with this multiple set-ups experiment a significant benefit effect of amber LEDs on the activity and/or diversity of bats compared to 3000K LEDs, it will allow to offer lighting managers a less impactful alternative in sectors where bats are at stake, and where artificial light is nevertheless needed. It will however be necessary to adapt this protocol to other taxa (moths, small mammals, lampyrids, etc.) to evaluate which other species could benefit from these amber LEDs.

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A French review of lighting strategies to reduce the environmental impact of ALAN

Themes: Governance & Regulation
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Introduction

In 2018, France adopted ambitious regulations to reduce the impact of outdoor lighting installations on the environment (CEREMA, 2020). These regulations, which apply to new installations, focus on the luminaries' output flux, color temperature and distribution in space, and on the timeline of illumination. Since then, the geopolitical context resulted in a strong increase of energy prices, putting pressure on the finances of local and national public authorities, pushing a number of actors to implement strategies for lighting sobriety without being detrimental to the level of service delivered to citizens (AFE, 2022).

In this context, the LUNNE project (in French, "*La Lumière la Nuit Nuit à l'Environnement*") is a transdisciplinary research project (2023-2026) funded by the French *Agence Nationale de la Recherche*, aiming at understanding how to reduce artificial light at night (ALAN) and providing cues to implement strategies to lower the ALAN impacts on the environment, without loss for humans. It brings together researchers with various backgrounds (engineering science, social and cognitive psychology, urban planning), technicians from local authorities and public institutions. It aims to confront the points of view of (1) lighting decision-makers, for a better understanding of their constraints, and (2) urban citizens, to better understand their perception, behavior and feelings about modified ALAN strategies, while (3) designing relevant indexes of ALAN exposition among ecosystems at different scales, in order to achieve acceptable operational solutions with minimal impact.

We focus here on the first part of this project, which will review current practices of French cities to lower the impact of ALAN on the environment.

Method

An overview of the main realistic scenarios for limiting ALAN used by public lighting managers will be conducted, based on in-deep interviews with lighting managers involved in the project (Rennes Métropole, Montpellier Métropole, Syndicat d'Electrification du Tarn). In addition, a state of the art of best practices will also be carried out based on the international scientific and technical literature (Jagerbrandt, 2001) and via a census of French lighting managers (interviews, online census) about their practice, pressure for energy saving and environmental care. The expected scenarios include full extinction of lighting, reduction of light levels, modification of the lamps' spectrum and luminous intensity diagram, modulation of lighting during the night or according to pedestrian/car traffic, and dark infrastructure (Sordello, 2022).

Discussions with the partner lighting managers mentioned above will allow evaluating the technical, organizational and financial feasibility and constraints associated with the various options proposed in the literature and emerging from the census and interviews. A better knowledge will emerge about which ALAN reduction options are likely to be tested and which ones are not, and why. The *Association Française de l'Eclairage* (AFE), a French non-profit organization dedicated to lighting, will contribute to these discussions and is about to publish a guideline on the subject (AFE, 2023). Altogether, this comprehensive review should allow drawing a raw sketch of the consensus and dissensus on the available strategies for ALAN reduction, leading to the selection of several realistic scenarios to be used in experimental studies in other parts of the LUNNE project.

The main practices of French cities reviewed in this project will be presented at the conference.

Conclusions

The strategies implemented by urban communities to reduce the ALAN depend on a number of territorial specificities and constraints. These constraints can be:

- Organizational: having the know-how, the opportunity to experiment with new and ambitious solutions;
- Technical: having the equipment and knowing how to use it: adjusting the equipment, accessing the light sources, being able to modify them (e.g., adding a cover);
- Financial: investment, public consultation, experimentation and maintenance costs;
- Social: co-constructing lighting strategies with citizens may improve their acceptability;
- Regulatory: new lighting installations must comply to the normative context; alternatively, empirical data may help changing the standards;
- Ecological: the territory may host animal and plant species particularly affected by certain aspects of the ALAN (e.g., spectral, directional, spatial, etc.);
- Transversal: integrating non-financial parameters in the decisions regarding lighting, taking the multi-functionality of lighting into account (improving safety, mobility, and the attractiveness of the city), as well as its negative impacts (on environment, health, night sky quality, etc.).

The review of available strategies for ALAN reduction will allow to quantify and prioritize these constraints, and in the context of the LUNNE project, to design experiments and simulations allowing an assessment of relevant lighting strategies. The LUNNE project aims thus at providing empirical solutions to some of these constraints, including lighting and environmental indicators that can be measured or simulated based on available information, and decision support methods on how to achieve light sobriety.

The results of the project will be disseminated through academic publications, as well as information of lighting actors and policy makers, in order to contribute to the improvement of the regulation by limiting its contradictions, and by promoting more sustainable and acceptable lighting designs.

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Investigating effects of ALAN on native plant ecology

Theme: Biology and Ecology

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Introduction

It is established that artificial light at night (ALAN) can disrupt plant-animal interactions, such as herbivory and pollination (Bennie et al., 2018; Boom et al., 2020; Cieraad et al., 2022). However, the impact of ALAN on specific plant ecology and physiology is relatively under studied.

Plants rely on light cues for information and energy, and form the basis of the food web, providing habitat and food for other organisms. Increasing levels of ALAN could disrupt the dark recovery phase of plants, which leads to physiological changes that potentially disrupt native plant communities with effects in higher trophic levels (Liu et al., n.d.). Since ALAN is a rapidly increasing environmental issue with significant consequences at both the individual and community level, this study aims to investigate how ALAN affects plant ecology and physiology.

Therefore, we measured photosynthetic activity and allocation of carbohydrates and proteins in both controlled laboratory environments as well as a full-scale field setup. We specifically address the potential effects of different colors since the response of plant photoreceptors are sensitive to specific wavelengths.

Methods

In this study, we used a two-fold approach with controlled climate chamber experiments and in-situ field experiments under four different color regimes and a dark control. To replicate the effects of ALAN, we used LED lights to create blue, green, red, and white light treatments in both experiments. To accurately assess the impact of these treatments on plants, we measured the light intensity and spectral composition of the LED lights. This allowed us to explore effects of different light intensities and spectra and understand how these influence plant responses to ALAN. We exposed different plant species to these color treatments to investigate if the effect is different between plant groups.

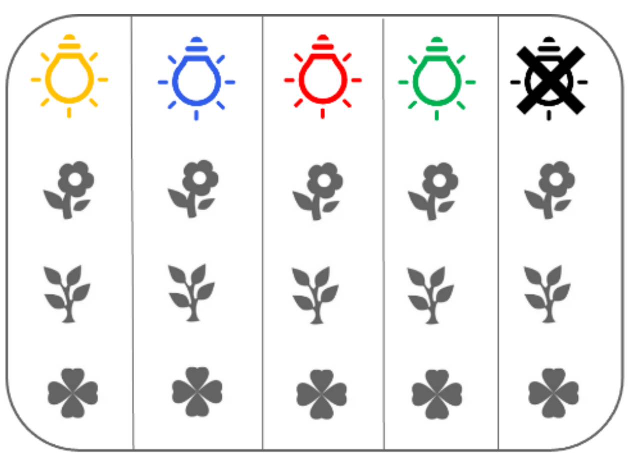

Figure 1. Schematic setup of the ALAN treatments in the climate room experiment. The three plants are used: *Trifolium pratense*, *Hypochaeris radicat*a and *Festuca rubra*.

Expected results

The study presents the results of these experiments on the impact of ALAN on plant physiology currently in progress. Specifically, we address the effects of ALAN on resource allocation and the changes to the photosynthetic system. We studied if ALAN can lead to modifications of primary metabolism in the levels of carbohydrates and proteins. Based on current understanding, we expect to find an increase in non-structural carbohydrates in the shoots, and a shift in the carbon-to-nitrogen ratio in leaves. These changes may have implications for the overall health and fitness of the plants. This research is particularly relevant considering the current transition towards the use of LED lights, which emit a broad wavelength spectrum that partly overlaps with the photosynthetic active radiation spectrum (PAR) of plants. The research findings from this study help to understand the extent of ALAN's impact on plant ecology and native communities.

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National Light Pollution Guidelines for Wildlife –ALAN Monitoring and Modelling

Theme: Governance and Regulation

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Artificial light is widely known to influence the behaviour and ecology of wildlife. However, a formal process for assessing the potential impact of lighting, and subsequently developing management tools to minimize and mitigate its effect, was lacking until recently. In 2020, the Commonwealth of Australia published the 'National Light Pollution Guidelines for Wildlife (NLPGW) for Marine Turtles, Seabirds, and Migratory Shorebirds' (Commonwealth 2020), which provides a framework for how to describe, assess and manage light pollution impacts, both at a broad- and species-specific level. These guidelines have been adopted by both state and federal regulatory agencies within Australia and have also been endorsed by the Convention on the Conservation of Migratory Species of Wild Animals, which consists of 133 signatory countries globally.

Regulatory bodies in Australia are now using the framework provided in the NLPGW to ensure that proposed industrial developments (mining, oil, and gas), resort developments, and local councils are assessing and managing impacts from artificial light on sensitive wildlife. The framework outlines the following key steps:

1. A description of the predicted project lighting (quantities, types, layouts, purpose).
2. A description of the wildlife likely to be impacted by the project (desktop study or field surveys where required).
3. A risk assessment conducted using this information.
4. Development of an Artificial Light Management Plan (ALMP), that includes steps 1-3 and describes lighting mitigation management measures to be put in place.
5. Requirements for ongoing biological and artificial light monitoring and auditing to ensure compliance with the ALMP and verify wildlife is not being impacted.

Monitoring and modelling Artificial Light At Night (ALAN) plays a critical role in the implementation of the NLPGW, which has driven the need for effective techniques to determine and predict the impacts of light pollution on sensitive receptors. Monitoring on a landscape scale is well established and a digital camera and fisheye lens technique is recommended (Hanel et al. 2018; Barentine. 2019). While the science of light modelling is well understood, there exists no commercial landscape-scale models for light emissions that can quantify light as viewed by a biological receptor. However, utilizing existing research models (i.e., *Illumina* - Aubé et al 2020) it is possible to model biologically meaningful artificial light for use in impact assessment.

Currently, artificial light impact assessments have focused on coastal developments due to their proximity to biologically important areas for marine turtles, seabirds, and migratory shorebirds. With appendices for Terrestrial Mammals and Ecological Communities currently in the final stages of drafting, these guidelines will soon apply to inland developments, where the understanding ALAN impacts on terrestrial fauna are now emerging. As the NLPGW continue to evolve with the addition of new species this will further drive the need for effective artificial light monitoring and modelling tools for sensitive receptors.

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Lights, camera, attraction? Artificial light at night and predator-prey interactions

Theme: Biology & Ecology

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Introduction

To protect biodiversity, we urgently need to better understand the effects of artificial light at night (ALAN) on ecosystems[1,2]. Despite copious evidence linking ALAN to negative biological impacts on individual species, little is known about its role in disrupting ecological communities; meanwhile, ALAN continues to intensify and spread[2]. Critically, the severe declines observed in insect biodiversity may, in part, be driven by ALAN[3,4]. Insects are vital to ecosystem functioning and represent a key component of the world's biodiversity. Insects drawn into orbit around lights are left vulnerable to predators and exhaustion: some studies estimate a third die before the end of a night[4]. As the most important predators of nocturnal flying insects, bats can thrive in the short term, but may face long-term prey scarcity[5,6]. ALAN may also disrupt circadian rhythms, potentially affecting survival and reproduction of both insects and bats[7,8]. While some evidence suggests that brighter, whiter LED lights are more harmful to insects than older, less-efficient yellow lights, most past work has examined one to two species in isolation, as manual insect collection and identification are prohibitively time-consuming[7,9,10]. Furthermore, to complement correlative studies, light treatments must be introduced to areas without histories of ALAN[11]. These so-called "naïve" areas often lack infrastructure, hindering the longitudinal, multi-trophic biomonitoring needed to understand the role of ALAN in insect declines. Remote sensing has a critical role in filling this knowledge gap, especially combined with advances in artificial intelligence (AI) that greatly accelerate analysis. Correspondingly, we have developed ALANizer, a programmable battery-powered system for introducing ALAN to experimental sites while monitoring light intensity and quality. ALANizer also monitors the ecosystem with open-source automated tools: smart traps to identify captured insects and map their activity across 24-hour cycles and smart microphones that detect and record bat calls[9,12]. Together, these tools provide unprecedented and taxonomically specific insight into activity levels, ideal for studying ALAN effects in biodiverse species communities. This system is novel, usable, and applicable to other ALAN-related questions.

Objektives

To determine the potential effects of ALAN on important species interactions, we aim to (1) compare circadian activity of flying insects under white light, yellow light, and darkness with ALANizer and (2) find which species exhibit the greatest changes in capture rates under these conditions. Concurrently, we are using ALANizer with pitfall traps to examine (3) whether insect predators are more active under white or yellow light and (4) whether hypothetical shifts in bat and insect activity patterns correlate.

Methods

We are deploying ALANizers and pitfall traps for a full year at 12 stations we are building at the University of British Columbia Farm. At these stations, battery-powered simulated streetlights switch between white LED light, yellow LED light, and control (off) periods every 10 days. Concurrently, sensors measure light intensity and spectral character. These experiments will run continuously over multiple seasons, generating a large volume of data from different yet comparable sources that can be used to validate computational tools. AI will be instrumental in both collecting and analysing these data to identify and compare the activity patterns of all identifiable species under these light conditions.

Significance

Inexorably, the converging forces of anthropogenic intensification, global industrialisation, and affordable LED technology are eradicating dark nights. Maintaining biodiversity in these environments alongside accelerating climate change, pesticide use, and habitat loss is as challenging as it is essential. This project addresses a leading threat to insect biodiversity by examining ALAN's impacts across trophic levels at an unprecedented spatiotemporal frequency, while validating an open-source, open-hardware lighting system generalisable to a wide range of field experiments. Studies like this one are crucial for providing private and public actors with novel insight into the effects of lighting infrastructure on a wide range of important species. This will enable guidelines and policy rooted in high-quality evidence, on which the future of biodiverse insect populations may depend.

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Artificial light at night affects plant–herbivore interactions

Theme: Biology and Ecology

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Introduction

Artificial light at night (ALAN) affects species' physiology and behaviour, and the interactions between species. Despite the importance of plants as primary producers, it remains poorly understood whether and how effects of ALAN on plants cascade through the food web. We assessed the extent to which ALAN of different spectra results in plant-mediated insect herbivory damage.

Methods

In a 6-month field experiment, we exposed plants of differing palatability to three colours of ALAN (green, red, white, at environmentally relevant -streetlight- brightness levels) and a dark control, and assessed plant traits (growth rate, leaf size, foliar density and thickness) and insect herbivory (represented by insect damage as loss of foliage to leaf-chewing insects).

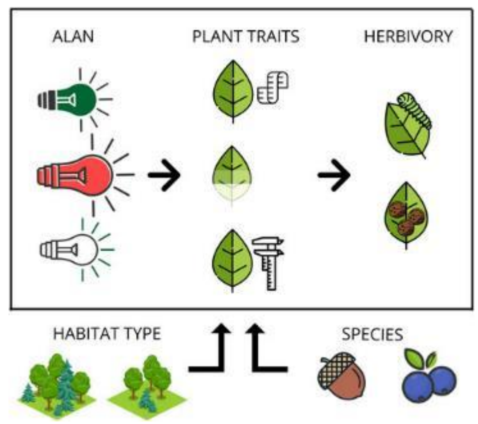

Fig. 1: Graphical abstract

Results

We found evidence for plant-trait mediated ALAN effects on herbivory for oak, but not for blueberry. In oak, ALAN of different colours changed the direction of relationships of insect damage with relative growth rate and with leaf thickness. Moreover, we found that the effects of ALAN on herbivory damage differed markedly between forest types within the same locale.

Conclusions

Our results show that continuous night-time light, as provided by street lighting around the world, affects food web interactions. The nature of these effects differed by species and appeared to depend on forest type and the light spectrum employed. These findings highlight the complexity of using spectral manipulation as a mitigation measure, as well as the need to consider ALAN in environmental management and planning, to limit the exposure and impact of cascading effects of artificial light at night on food webs and communities.

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What comes after the adoption of a lighting regulation?
Experience sharing of our 16 years as an International Dark Sky Reserve

Theme: Governance & Regulation

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Sixteen years ago, a region of 5300 km2 around Mont-Megantic National Park became the first International Dark Sky Reserve, combining the territory of the national park with 34 surrounding municipalities. To preserve the integrity of the night where 225 000 people live, Mont-Megantic International Dark Sky Reserve (MMIDSR) adopted regulations for external lighting at night. As regulation could appear like a magic wand to decrease light pollution, we want to share our regulatory enforcement challenges, as well as what we have experimented and learned over the years.

The adoption of lighting regulation is a key point to protect the night where communities live: it acknowledges their commitment to dark sky, it sets clear limits on permitted lighting practices, and it offers essential leverage in the event of non-compliance. To become an International Dark Sky Reserve, lighting regulation comes along with sensitization and good examples of light conversion. To sustain and increase the benefits of these efforts and to support the evolution of communities living under the certified Dark Sky over the years, we strongly recommend apprehending the challenges of regulatory enforcement.

Here are the main ones we have identified at MMIDSR:

(1) vested right (lights installed before the regulation don’t need to comply unless a change occurs)
(2) knowledge of the regulation (citizens often don’t know its existence or might find it too technical)
(3) availability of compliant product
(4) field surveillance (under the responsibility of municipal officers)
(5) evolution of lighting needs, technology, and terminology (LED, greenhouses development, etc.)
(6) good lighting practices among electricians and salespeople.

To tackle these challenges, we have been using different and personalized approaches depending on the communities or stakeholders we are addressing to. These approaches are also evolving based on our learnings. Here are some examples of positive changes we made happened:

-While streetlight conversions for dark sky friendly options often required our help, there is now more ways for them to happen without our input.

To achieve this, we convinced the Quebec Federation of Municipalities (FQM) to offer 2200K LED as an option, which previously only offered 4000K and 3000K. The FQM offers turnkey solutions which greatly simplify the conversion of streetlights for municipalities.

To speed up the streetlight conversion in the outer part of the MMIDSR, where old HPS lamps proved more resilient than anticipated, we took an approach similar to industry vendors. By conducting energy and maintenance costs savings studies ourselves, we showed municipalities the cost and return on investment of converting to PC-Amber LED, along the benefits in the reduction of light pollution. Not only did this helped to greatly increase the number of fully compliant streetlights in communities farther from the

Reserve's core, but it also showed us that small municipalities often lack the technical knowledge and need to rely on outside help.

Fig. 1: Fully compliant PC-amber LED streetlights on Mont-Megantic International Dark Sky Reserve municipalities (photo by Guillaume Poulin).

-Private landowners are converting lighting to protect the dark sky.

To support the work of the municipal officers in charge of regulatory enforcement we started a new campaign a year ago. We identify properties with bad lighting practices and offer their owners a personalized diagnosis of compliance with the regulations and specific recommendations for compliant lighting products. Without any coercive power and often dealing with vested right, this campaign is already showing encouraging results to improve the preservation of the night integrity and will keep going in 2023.

-Children in the Dark Sky Reserve can recognize good and bad lighting from their neighborhood and identify solutions to preserve the night environment.

To raise awareness among citizens and promote good lighting practices we have used many different ways, such as social media, awe and outreach activities inside and outside Mont-Megantic National Park, the creation of a lighting guide, a website full of information… but to make sure we are diversifying our audience, we created a school outreach program that we offer to all the schools across the MMIDSR. Today we are reaching hundreds of households through this sensitization.

Despite the existence of outdoor lighting regulations, bad lighting practices can still occur in the Mont-Megantic International Dark Sky Reserve. While old High Pressure Sodium streetlights on our territory have mostly been changed for dark-sky friendly solutions, non-public lighting is sometimes trickier to improve. Main challenges have been identified and are being tackled with creative and agile solutions. Besides the need to continue to raise awareness about good lighting practices and the impacts of light pollution among MMIDSR citizens, there is also a need for more collaboration and consultation with electricians, lighting designers, engineers, manufacturers, hardware stores to develop and offer more dark sky friendly solutions.

Study of the Spectral Response of Sky Quality Measurers

Theme: Measurement and Modeling

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Introduction

This study was presented as an end of degree project of Physics Batchelor at the University of Barcelona. The aim of the project is to study the spectral response of two sky quality measurers, SQM and TESS-W, and compare the instrumental sky brightness obtained by these two photometers with the sky brightness obtained synthetically using its spectral response and night sky spectra from Montsec, measured by SAND-4B spectrometer. We are going to analyze the difference between the magnitude measured by SQM and TESS-W to study if the atmospheric emission (airglow) at red wavelengths triggers the difference between the sky brightness measured by the previously mentioned instruments at the Montsec.

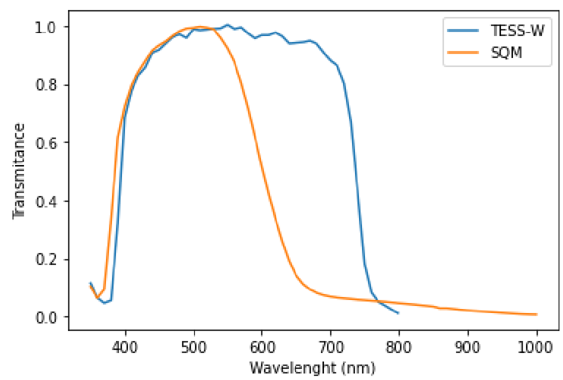
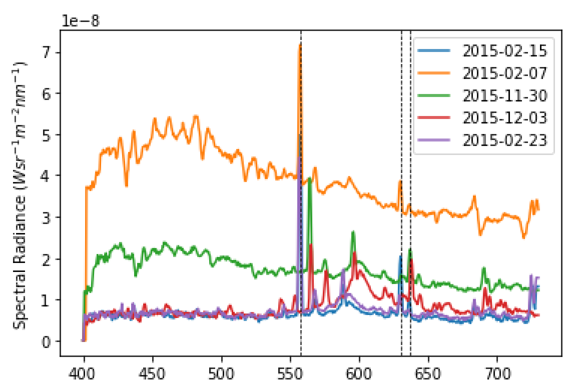


Fig. 1: Spectral response (Transmittance) in function of wavelength of TESS-W and SQM.

Methodology

The results obtained from measuring the sky brightness with SQM and TESS-W photometers are popular to be similar, to the point of being comparable. These two instruments have been used mainly in light-polluted areas but performing measurements at the Parc Astronomic del Montsec in Montsec (Lleida, Spain) where the night sky quality is excellent noticed a difference between the data obtained by the instruments.



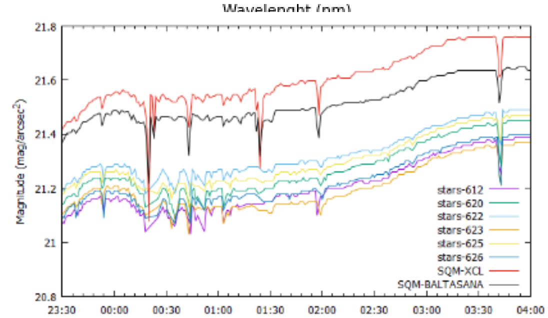


Fig. 2: Spectra of Montsec night sky from 2015 measured by SAND-4B. The dashed lines correspond to wavelengths of airglow emission.

To perform the analysis, we coded a python program to calculate the synthetic magnitude that the photometers would measure using as input their spectral response (fig. 1) and night sky spectrum measured by SAND-4B (fig. 2). To compare the synthetic magnitude with the instrumental magnitude we selected a night where we had measurements of six different TESS-W and two SQM, we can see the data collected at fig. 3. The results of the synthetic photometry show that the magnitude obtained for each spectrum is between 0.1 and 0.3 brighter for all

TESS-W, as we can appreciate in fig. 3, the instrumental magnitude measured at PAM's roof is also between 0.2 and 0.3 brighter for TESS-W.

We can appreciate in fig. 1 that the spectral response of SQM at red wavelength is $\approx 0.2 - 0.3$ meanwhile the TESS-W is ≈ 1at that wavelength. The results previously mentioned indicate that the root of the difference between the night sky magnitude measured by the two photometers must be the red line of the Montsec spectrum produced by the airglow inasmuch as performing synthetic photometry directly from the spectral response of the instruments factors like the ageing of the lens or their correct functioning and calibration are discarded.

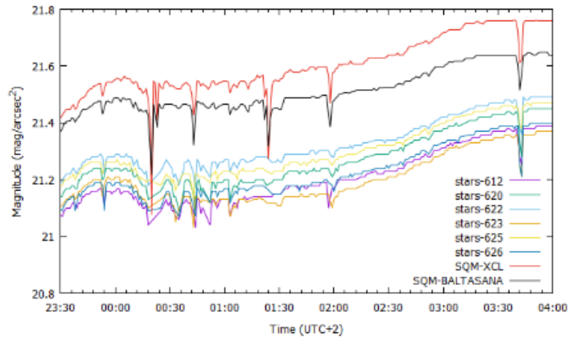


Fig. 3: Sky brightness magnitude of six TESS-W, labeled as"stars" and two SQM from night of 2021-08-13.

Conclusions

The analysis of the comparison of the instrumental and synthetic response of the photometers TESS-W and SQM using night sky spectra of a region with a characteristically dark night sky is not done in any previous project. With the results obtained performing synthetic photometry using SAND-4B spectra, we can conclude that the difference in the instrumental magnitude measured at Montsec by TESS-W and SQM has its source at the red line emission of the spectrum from airglow and the different spectral response at that wavelength.

In Montsec night sky conditions these two instruments are not comparable, and they must not be used indistinctly. In general, we must not compare the results of instruments with a different spectral response. However, this particular case is especially relevant as in dark night sky regions we can detect atmospheric phenomena, such as airglow, that contribute to the sky brightness.

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Disruptions of daily and seasonal rhythms in migrating fish

Theme: Biology & Biology and Ecology

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Virtually all organisms on earth have adapted to light-dark cycles of ~24 hours, which is achieveable due to the evolution of endogenous rhythms that regulate most biological processes such as circadian rythms.Thereby, light plays a key role in the functioning of an array of behavioural and physiological patterns in fish, such as orientation, breeding, hormone expression and migration. However, light is heterogenous, following daily and seasonal rhythms in which the duration and intensity changes, meaning fish must rely on the biological clock's "connection" to the external environment in order to interpret and respond to said changes.

Such dependency on daily and seasonal rhythms raises concerns for the impact of anthroprogenic light on the biological clock as light pollution (artificial light at night, ALAN) may disrupt these rhythms, negatively impacting the behaviour and physiology of fish as day-night differences become less discernible. This is especially concerning for migratory fish as light pollution may mask the natural cues used for the triggering of and navigation during migration, which can influence energy expenditure and migration success.

Using a combination of field and laboratory studies, we investigate the long- and short-term consequences of light pollution on swimming physiology and behaviour of three-spined sticklebacks and European eels under varying levels of light pollution. In the field, we use swimming respirometers to test swimming patterns and energy consumption during their seasonal migrations (Spring and Autumn) and, in the lab, we test if rhythmicity patterns correlate with personality types in migratory sticklebacks. Currently, we have completed our first field season and have preliminary results with more data to be collected over the coming year.

We further aim to test the differing migratory types of three-spined sticklebacks to understand if they vary fundamentally in swimming physiology and possibly clock rhythmicity, which could be used as indicators for how they will cope in light polluted environments.

With our results, we hope to provide an in-depth overview of the impact of light pollution on freshwater ecosystems, allowing for the establishment of policies in order to mitigate negative impacts on the biological clock.

The underestimated impact of streetlights on the orientation of moths revealed by harmonic radar

Theme: Biology & Biology and Ecology

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Introduction

One of the most dramatic changes occurring on our planet in recent decades is the ever-increasing extensive use of artificial light at night, which drastically altered the environment nocturnal animals are adapted to (Gaston et al., 2015; Kyba et al., 2017; Kyba et al., 2023). One nocturnal species group experiencing marked declines are moths, which are not only of great importance for species conservation, but also for their key role in food webs and in ecosystem services such as nocturnal plant pollination (Biesmeijer et al., 2006; Potts et al., 2016). Light pollution has been identified as a driver in the dramatic insect decline of the past years (Owens et al., 2020; van Grunsven et al., 2020), yet little is known about its impact on natural insect orientation behaviour.

Methods

Using harmonic radar, we recorded trajectories of free-flying moths and linked these to the light environment quantified via all-sky photometry (Jechow et al., 2020). Six typical streetlights (high pressure sodium street-lights) were arranged uniformly in a circle around the release site with each light at a distance of 85 m to the release site and to its nearest neighbours (Fig. 1). The animals were prepared with the transponder, the necessary antenna for radar tracking, shortly before their release and we ensured with specially designed control experiments that neither the attachment of the transponder nor the handling procedure itself had a significant impact on flight behaviour. The lights were either switched off to record the flight trajectories under conditions without near-by artificial lights, or switched on to test their influence on flight behaviour. In total, we recorded 95 flights of 94 individuals of various species, nearly all of them either belonging to the family of lappet moths or hawk moths.

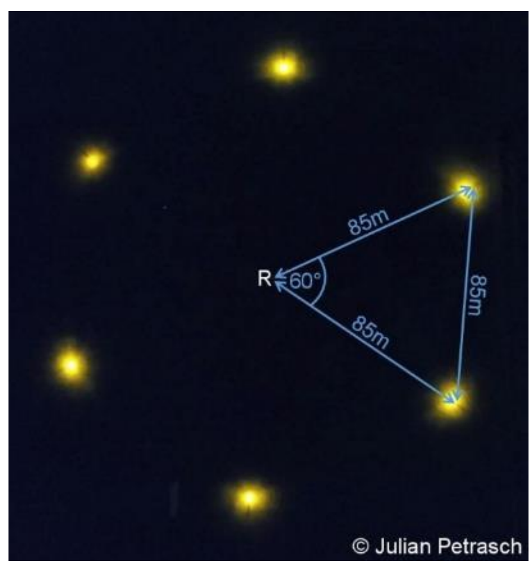

Fig. 1*: Arrangement of streetlights imaged by a drone.*

Results

Surprisingly, we found that only 4% of individuals ended their flight at one of the streetlights, which was an unexpectedly low fraction of ani-mals. To characterize flight beha-viour, the tortuosity of an animal’s path is a key parameter in orienta-tion, including search behaviours, and is inversely related to the efficiency of the orientation mecha-nism involved for oriented flights while it reflects searching intensity for local search flights (Benhamou, 2004). We found, in interaction with the moon, an increased tortuosity of flights for lappet moths (Lasiocam-pidae) and hawk moths (Sphingidae) when streetlights were turned on (Fig. 2). Furthermore, we observed a barrier effect of streetlights on lappet moths when the moon was not available as a natural celestial cue.

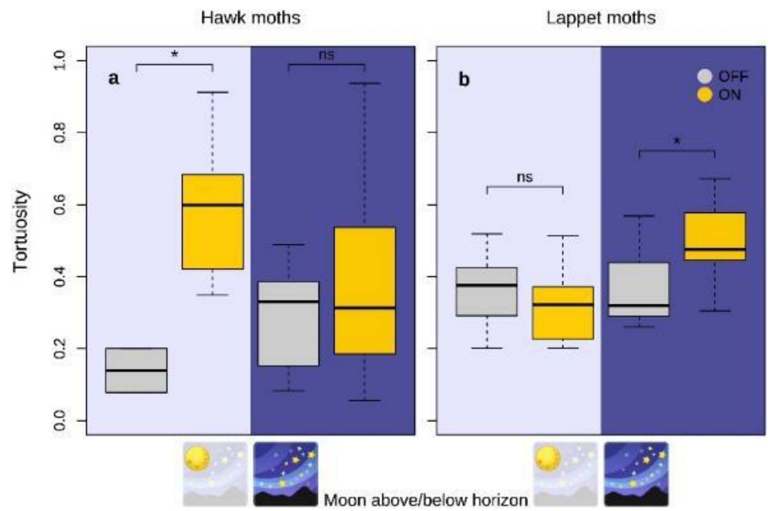

Fig. 2*: Tortuosity of flights when streetlights were turned off or on in the presence or absence of the moon.*

Conclusions

We revealed a species-specific barrier effect of streetlights on lappet moths whenever the moon was not available as a natural celestial cue. Furthermore, streetlights increased the tortuosity of flight trajectories for both hawk moths and lappet moths. Our results provide the first spatially resolved experimental evidence for the fragmentation of landscapes by streetlights and demonstrate that light pollution affects movement patterns of moths beyond previously assumed extent, potentially affecting their reproductive success and hampering a vital ecosystem service.

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Light only where it is needed: A tailored shielding for street lighting reduces attraction of nocturnal flying insects

Theme: Biology/Ecology

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Introduction

Light sources can attract nocturnal insects and dislocate them from their native ecosystems, which interferes with many physiological and behavioral processes, ultimately affecting many facets of ecosystem functioning. Recently, many streetlights are replaced by energy-efficient LEDs, which is often accompanied by a modified light distribution on the ground. This may influence the attraction effect on flying insects from nearby habitats and should therefore be considered for sustainable lighting management (van Grunsven et al., 2019). Although there is already evidence for mitigation strategies that work (e.g. light orientation, upward shielding or spectral tuning), uncertainty remains which approaches are best for reducing the ecological impacts of ALAN (Hölker et al., 2021). Unfortunately, in most cases the head of the luminaire, often with high luminance, is visible far beyond the lit area. Here we show that a tailored light distribution, that only emits light onto the target area in combination with a novel shielding that renders the luminaire head nearly invisible beyond the lit area, significantly reduces insect attraction.

Methods

The project "NaturLicht" aimed at identifying insect friendly street lighting in a before-after approach from 2021-2022. We carried out an insect monitoring with 28 flight interception traps mounted at three sites with different illumination context (urban, peri-urban, rural), all close to nature reserves in Baden-Württemberg, Southern Germany. This included HPS- and LED-lights of different color spectra and light distributions. The conversion of half of all lights per site in "NaturLicht" involved LED-lighting with an individually tailored shielding, developed with Selux GmbH (Berlin, Germany) in context of the project "Tatort Straßenbeleuchtung - AuBe". Here, the shielding refers to a shutter box, which confines the light emission at the luminaire head. In the result, the light emission beyond the lit area (spill light) and the visibility of the luminaire head from a distance are significantly reduced (Figure 1, bottom panels), while keeping the illuminance at the street nearly identical to the previously installed streetlights. Depending on geometry und lighting structure, these shielded streetlights were specifically adapted to local conditions site (street width, hight/distance of luminaires) and represent an optimized solution for each site. In "AuBe", similar experiments with the same approach were conducted in an undisturbed and highly standardized experimental setup with a completely unlit dark control site.

Results

Comparing different treatments in the NaturLicht project (Figure 1), analysis showed that shielded luminaires attracted significantly less insects per night at three study sites in 2022, independent of light regime (urban, peri-urban, rural), previous lighting (controls), and associated habitats. This effect was similar for the most abundant taxonomic insect groups at each site. Finally, the reduction of insect attraction through shielding in NaturLicht in 2022 under realistic all-day scenarios fit to the results from AuBe over two years (2021-2022).

Conclusion

To reduce ecological impacts, LED luminaires with suitable shielding can be recommended for a future municipal conversion of street lights in proximity to nature reserves.

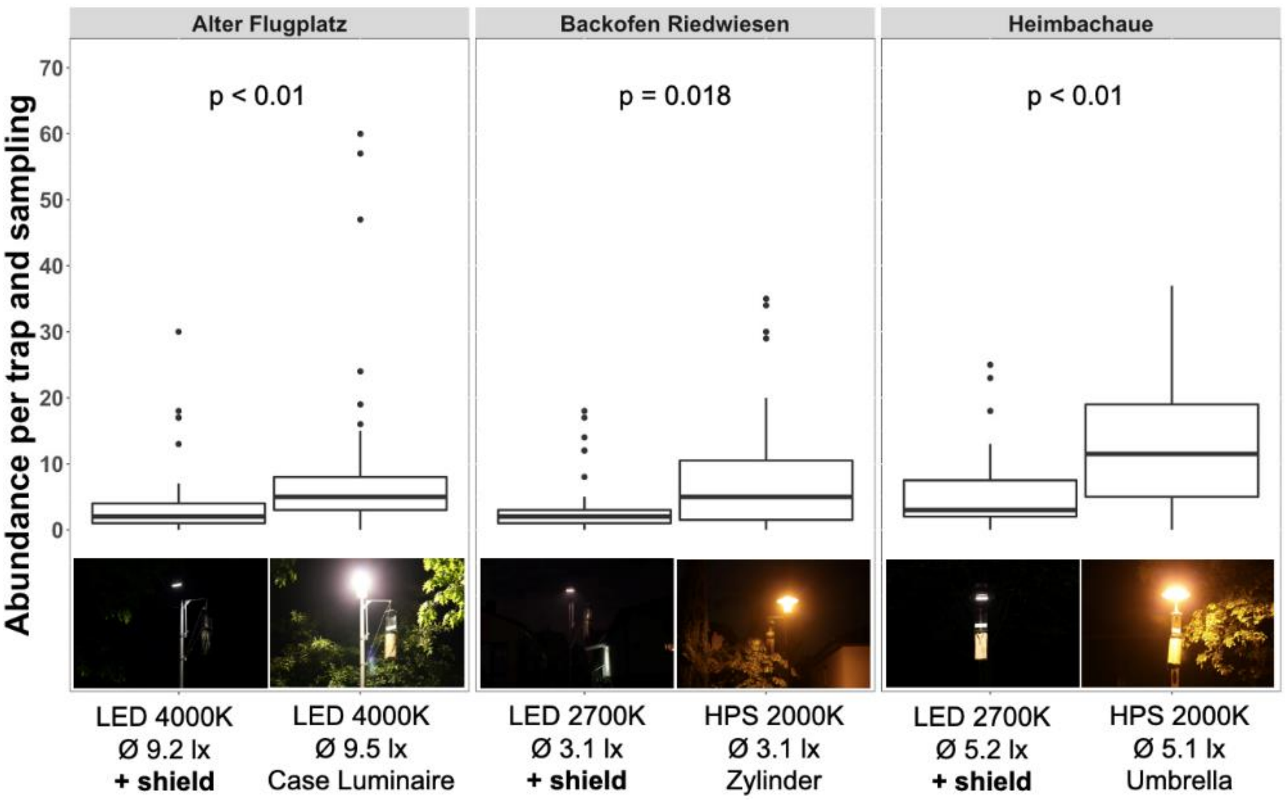

Fig. 2: Abundance (number of Individuals) per night and trap/light for two different treatments at each of three study sites in 2022 represented as boxplot. Alter Flugplatz Karlsruhe (urban: n = 5 street lights per treatment in 9 sampling events, Kruskal-Wallis Test: p=0.0005707), Backofen Riedwiesen Mannheim (peri-urban: n = 5 street lights per treatment in 7 sampling events, Kruskal-Wallis Test: p=0.01788), Heimbachaue Freudenstadt (rural: n = 4 street lights per treatment in 7 sampling events, Kruskal-Wallis Test: p=0.005491). Photos of the luminaires (bottom panel) were taken at the same distance and with the same camera settings from beyond the area to be illuminated.

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Artificial light at night induces spatiotemporal shifts in movement and predation of insect communities

Theme: Biology & Ecology

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Artificial light at night (ALAN) is predicted to have far-reaching consequences for natural ecosystems due to its influence on organismal physiology and behaviour, species interactions, and community composition. Movement and predation are fundamental ecological processes that are of critical importance to ecosystem functioning. The natural movements and foraging behaviours of nocturnal invertebrates may be particularly sensitive to the presence of ALAN. However, we still lack quantitative evidence of how these fundamental processes respond to ALAN within a community context. Here, we assembled insect communities (eight species across two taxonomic groups) and quantified their movement activity and predation rates across a gradient of skyglow intensities during simulated moon cycles. Using an RFID sensor array, we continuously tracked the movements of individual animals within a mesocosm experiment of fragmented grassland landscapes. We additionally quantified predation rates by using sentinel prey. Our results reveal that already low skyglow light levels cause a temporal shift in movement activity from day to night, and a spatial shift towards open habitats at night. The change in movement activity is strongly linked to predation rates, implying an associated indirect shift in predation rates in response to ALAN. Spatiotemporal shifts in movement and predation can have important implications for ecological networks and ecosystem functioning, highlighting the disruptive potential of ALAN for global biodiversity and the provision of ecosystem services.

Time of day of vaccine administration influences the magnitude of SARS-CoV-2 anti-spike IgG antibody levels

Theme: Health

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Introduction

Data from human and animal studies are highly suggestive of the importance of circadian rhythms and sleep hygiene – typically disrupted by artificial light at night - in the regulation of host immune responses to infections and vaccinations, which might be relevant for COVID-19 vaccines (1,2). Here we evaluated the impact of time of day of vaccine administration on vaccine induced antibody responses in medical university employees (study 1) and in a cohort of immunosuppressed patients (study 2).

Methods

In a population-based study (study 1), we aimed to investigate the effect of time of day of administration of a COVID-19 vector vaccine, ChAdOx1 nCoV-19 (AstraZeneca), on SARS-CoV-2 anti-spike S1 immunoglobulin (IgG) levels. Participants were 803 university employees who received their first vaccine dose in March 2021, had serology data at baseline and at 3 weeks and were seronegative at baseline. Antibody levels were determined in binding antibody units (BAU/ml) using ELISA. We used generalized additive models (GAM) and linear regression to evaluate the association of time of day of vaccination continuously and in hourly bins with antibody levels at 3 weeks. Study 2 was a cohort of 365 immunocompromised patients (144 cancer patients with solid tumors, 75 multiple myeloma patients, 146 patients with inflammatory bowel disease) and 74 healthy controls vaccinated with two doses of an mRNA COVID-vaccine (75% Moderna and 26.3% Pfizer). Blood was drawn and serology (SARS-CoV-2 anti-spike S1 immunoglobulin IgG levels) was available at baseline, 1 month after the first dose and at 1 and 6 months after the second vaccine dose.

Results

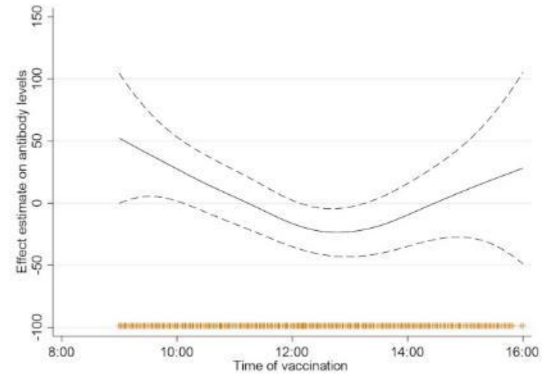

Fig. 1: Multivariable adjusted Generalized Additive Model splines for the association of time of day of vaccination with anti-S1 IgG antibody levels at 3 weeks after vaccination with a COVID-19 vector vaccine (N=803).

Participants in Study 1 had a mean age of 42 years (SD: 12; range: 21-74) and 60% were female. Time of day of vaccination was associated non-linearly (‘reverse J-shape’) with antibody levels (Figure 1, p for gain=0.045). Morning vaccination was associated with the highest (9:00-10:00: mean 292.1 BAU/ml; SD 262.1), early afternoon vaccination with the lowest (12:00-13:00: mean 217.3 BAU/ml; SD 153.6), and late afternoon vaccination with intermediate (14:00-15:00: mean 280.7 BAU/ml; SD 262.4) antibody levels at 3 weeks after vaccination. Antibody levels induced by 12:00-13:00 vaccination (but not other time intervals) were significantly lower compared to 9:00-10:00 vaccination after adjusting for potential confounders (beta coefficient -75.8, 95% CI -131.3, -20.4). Differences were greater among men and younger participants.

Participants in study 2 were 54% female and had a mean age of 54 years (range 19-83 yrs). Preliminary results showed an influence of time of day of vaccination on antibody levels elicited at several time points after vaccination among immunosuppressed individuals and healthy controls. Study 2 final results of the effect of time of day of vaccination on antibody levels will be presented at the conference.

Conclusions

Overall, our data indicate that circadian parameters (e.g., time of day of vaccination) play a role in human COVID-19 vaccination immune responses. When feasible circadian rhythms could be harnessed to help elicit a stronger immune response and optimize vaccination strategies against SARS-CoV-2. In study 1 we included healthy participants, but a “timed” vaccination approach might be in particular useful among people showing weaker vaccine induced antibody responses such as the population included in study 2. Future studies need to evaluate if time of day of vaccination has an impact on the responsiveness to the full vaccination schedule against SARS-CoV-2 and whether this might lead to a higher protection rate.

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High-Resolution Modelling of Light Sources & Obstructions using LiDAR Data

Theme: Measurement and Modelling

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Introduction

Light pollution is increasingly recognized as a disturber of the night-time environment, with an impact on biodiversity as least as large as that of climate change and has been implicated in a range of other impacts, including as a contributory factor to the striking collapse in insect populations as well as to human health.

As a result of the recognition of these impacts across the wider research community there has been a surge of interest in light pollution work, supported by the increased availability of higher resolution quantitative satellite, aerial, and ground measurements together with the development of increasingly sophisticated models incorporating realistic atmospheric conditions so that light scattering can be better modelled. It has become recognized, however, that there are difficulties in the interpretation of night-time data due to non-uniformities in emission, obstruction, and scattering of light from the many diverse sources present in the urban environment such as street lighting, commercial and architectural lighting, and LED billboards, amongst others. In order to determine the effects of these heterogeneous contributing sources on the environment we need to improve measurement through the use of a range of high-resolution multi-spectral and multi-angle views and also develop more sophisticated and high resolution models that can efficiently handle large city areas. We thus need realistic and efficient models incorporating the range of light sources and also obstructions at a local level, prior to the escape of photons to the wider environment in order to estimate the city emission function (CEF).

Methods

The approach that we describe here was first presented in Espey (2021) and involves the use of high resolution (1-2 metre/pixel) wide-area light detection and ranging (LiDAR) data for a range of urban areas from small villages to whole cities. These data have been made freely available by the Irish government at https://data.gov.ie/ and include all digital height data for an area with a vertical accuracy of approximately 20 cm, including buildings, trees etc. For areas with multiple observations data can be obtained for different seasons, thus enabling seasonal foliage effects to be determined.

To efficiently model the light output we make use of a geographical information system (GIS) based approach which can efficiently handle the large raster datasets and for which a wide range of software tools is already available. We have chosen to use a combination of the R and quantum GIS (QGIS) software packages which have the advantage of being freely available, are supported by a wide on-line community, and which enable the scripting of tools to produce more complicated models. In our initial work we have also made use of public lighting datasets which contain the location, type and wattage of lanterns used. As well as bring an important source of light in the urban environment, public lighting also has the advantage that manufacturer photometric data is available containing values of radiance vs. azimuth and elevation angle. Both direct (i.e., straight to the observer) and diffuse (i.e., reflected from ground and obstacles) emission is included in our model and hence the effects of different ground albedos – e.g. concrete or tarred surfaces – can be readily implemented.

Some Results

Our work to date has focused on streetlighting in Irish towns consisting of low- to mid-rise buildings. For these models we find the following results:

1) Our model efficiently calculates the angular emission function (also called the city emission function or CEF) and we have modelled the angularly-resolved diffuse component for 50,000 streetlights in the Dublin City Council area of 117 km^2 in a matter of an hour;
2) The typical azimuthally-averaged emission function is similar to that derived through inversion of skyglow observations by Falchi et al. (1996), although the *absolute* emission depends on the individual area;
3) Our normalized azimuthally-averaged emission functions are consistent with the emission behaviour inferred from SUOMI VIIRS/DNB data from global urban areas with similar building height (e.g., Li et al. 2019);
4) The major difference between azimuth-averaged angular emission for similar residential areas is due to differences in the emissive distributions between low- and high-pressure sodium lighting;
5) Comparison of LiDAR data taken in summer and winter shows that foliage obscuration where lighting and mature trees are collocated can decrease the radiance observed by over 30% relative to the winter value;
6) For single observations of small areas, e.g. single observations taken from the International Space Station, account needs to be taken of the azimuthal as well as the elevation dependence of lighting emission due to the interplay of emissive and obstructive effects;
7) Angular-resolved emission from the model can be deduced for arbitrarily small areas, permitting comparison with balloon or satellite data down to the individual pixel level.

On-going Work

We are pursuing a number of directions at present, particularly the inclusion of façade lighting and determination of the relative proportion of artificial light components to the total urban output. We also plan to use a drone to obtain in situ data for representative environments and hence provide ground truth for our modelled results as angular emission functions for representative urban light sources. In our presentation we will include an overview of the results outlined above and include a sample of new results.

Acknowledgements

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What happened to the dark at night: a birds' perspective

Theme: Biology & Biology and Ecology

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Introduction

The introduction of electric-powered light sources has abruptly and significantly changed the physical and temporal structure of twilight- and nocturnal semidarkness [1]. How this affects diurnal and nocturnal organisms has been primarily investigated for direct light emissions chronically or temporarily infiltrating local nocturnal habitats. These studies demonstrate that isolated or aggregated point sources of light can alter individuals' physiology, daily activity patterns and life-history treats in various ways [2,3]. By contrast, our understanding of the biological impact of skyglow remains extremely limited [4]. Behavioural responses of animals to skyglow are expected to differ from those inflicted by point sources of light, which have a local impact that individuals can avoid or be attracted to [5]. Skyglow extends far into natural habitats tens of kilometres away from urbanized areas, is amplified ten-to hundred-fold during overcast nights and lights up larger surfaces of the nocturnal sky [6]. Performed under controlled (laboratory) environments, so far, a few studies have demonstrated that skyglow interrupts orientation behaviour [7], triggers nocturnal vocalisations in some diurnal bird species [8] and that even low levels of skyglow (e.g. 0.01 lux) affect sleep patterns and the physiology of diurnal animals [9] . To document the impact of skyglow on activity patterns of free-living animals, we equipped Eurasian Nightjars (Caprimulgus europaeus, hereafter nightjar) with multi-sensor data loggers to measure individual flight activity.

Methods

Nightjars are medium-sized (~70g), visually-orienting aerial insectivores sensitive to small changes in light conditions, utilizing daylight during twilights and nocturnal moonlight for the timing of daily activity, orientation, navigation and the identification of traits and resources (29). We deployed multi-sensor loggers in sites differing dramatically in skyglow-exposure, ranging from a night-time sky brightness approximately six times brighter than starlight (Belgian breeding sites) to sites with a pristine night-time sky brightness (Mongolian breeding site). The loggers continuously recorded flight activity of the same individuals during the wintering season (November-February) in Sub-Saharan Africa [10,11] under presumed natural night-time sky conditions. Each data logger contains sensors that, among things, record ambient light intensity for geolocation and flight activity in 5-min intervals. We recorded daily activity of 15 individuals during a total of

Fig. 1: European Nightjar during dusk in a Belgian breeding site. Image by Ruben Evens.

16 breeding seasons in Belgium, three breeding seasons in Mongolia a total of 19 wintering seasons in Sub-Saharan Africa.

Conclusions

Our analysis demonstrates that activity patterns of nightjars in Belgium deviate from natural activity patterns. Nightjars in Belgium display higher flight probabilities during moonless periods of the night than in Sub-Saharan Africa. Furthermore, during cloudy, moonless parts of the night, flight probability of nightjars in Belgium increases whereas cloud cover reduces flight probability in Mongolia and Sub-Saharan Africa. We observe that in the absence of direct light pollution, approximately 5-10km from urbanized areas, anthropogenic changes in the sky brightness relieve Belgian nightjars from visual constraints. When this occurs, behavioural plasticity likely allows individuals to quickly respond to this anthropogenic night-sky brightness by becoming more active. At this point, it is unclear how the chronic loss of a naturally dark environment effects individual physiology, trade-offs in daily behaviour, life-history treads or inter-specific interactions and eventually ecosystem functioning. To close this knowledge gap, ecologists and physicists should design collaborative studies to quantify variation in natural and artificial sky brightness and subsequently assess its biological impact.

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LISAC (Lights In Streets And Cities)

Content Curation of Street/Public Lighting and Night Life

Theme: Social Sciences and Humanities

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Introduction

On the world wide web, street and public lighting, a niche topic has been the focus of a scientific and technical watch on the evolution of technical developments of lighting devices. Such monitoring of information available on the web also now reveal more and more societal and environmental concerns related to night life. It involved not only lighting professionals but also lay people interested in this theme. This content curation approach initiated in 2011 allowed to collect and archive information related to subjects related to lighting in streets and cities which are more and more on the frontline at a global level.

Methods

The curation tool used Scoop.it enables to find, select, gather, tag, comment and share information on subjects of interest. A crawling engine (keywords « public lighting » and « street lighting ») complemented by a human selection and through social networks browsing made it possible to compile and preserve relevant open information and knowledge links to original resources.

More than 11000 scoops are now available at this topic address https://www.scoop.it/topic/lighting-innovation-design and their number is incremented almost daily.

Subsidiary topics cover « lighting in art » https://www.scoop.it/topic/lighting-in-art and « lighting in history » https://www.scoop.it/topic/lighting-in-history .

Results

This « content curation » research action focused initially on technical and industrial aspects of street and public lighting. LED technologies, solar lighting, smart cities… which represents more than half of the posts. Competitive intelligence with information from international established lighting companies as well as industries from developing countries (China, India and Africa) is included.

Nowadays, the content hubs gather also links to information, websites and scientific publications allowing to follow relationships between night lighting and living species, human and non-humans, in relation with increasing ecological concerns. The economical aspects of lighting have been nourishing policy making discussions in many cities and countries, for some years now. Those societal aspects of night life are increasing regularly on the web.

Information covers most countries of the world with original approaches, for instance a focus on Africa and its energy access peculiarities. Indeed, in many countries, topics addressed are rapidly changing : not only security, individual and collective, but also night life up to night economy. Light pollution was considered thanks to environmental consciousness, costs, financing shortage and technical progress modifying comportments and attitudes of decision makers.

Health and well-being of humans, animals, insects, and plants during the night becomes a true society concern and can be documented. Inequalities between countries, social groups regarding electrical networks, technical solutions, work and education at night can also be analyzed and evaluated.

Web resources on historical developments of artificial lighting since antiquity, but mainly from more recent times with implementation of gas and electricity are collected in one of the subsidiary topics. In the other, night painting and photography fascinate artists with or without artificial lighting in cities and countryside.

Conclusions

We report on the development and maintenance of a content hub of relevant information on the topic of public lighting at night in public spaces of cities, streets, but also countryside and still wild spaces.

Content curation allows finding, selecting, collecting, commenting, archiving and sharing relevant knowledge dispersed on the web, scientific, technical and societal information, building a watch adding human flair to automatic search and artificial intelligence. Content curation can help identify and follow trends in public and street lighting.

This tool offers its active curators/producers and passive readers/users a control of evolution and regular actualization of a global topic of interest to laypeople, researchers, students and policy makers sometimes overwhelmed by information overload and diversity.

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Instagramable Cities: a report on light pollution in urban centers

Theme: Social Sciences & Humanities

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Introduction

This article intends to raise the issue of cities that have tourist spots whose spaces are excessively illuminated and which are widely publicized on social networks. The aim is to present the major changes that have occurred recently in public lighting in these cities, understand and highlight the possible harm that this too bright light can cause to users of the place and its surroundings.

Night lighting in instagrammable cities

The choice of the 3 instagrammable cities was made according to the relevance that has been given to them at the time this article is written.

1. The city of Rio de Janeiro, Brazil, because it is going through a transition in its public lighting, with the Luz Maravilha program, and because it has a large green coverage and beach areas. Unfortunately, we did not find any study that relates any of the aforementioned harms with the new lighting in the city.
2. The city of Doha, Qatar, in evidence for hosting the recent Football World Cup event, organized by FIFA, in November and December 2022. Qatar is proud to be a modern country and very connected to technology. Its streets and buildings are famous for their bold designs and lights that color the skies at night.
3. The city of New York, USA, for being known as the city that never sleeps and famous for its illuminated streets throughout the night. It is also well known for its photos of Times Square, one of its main tourist attractions, with street crossings where overlapping signs create an atmosphere of light and color and make anyone passing by lose track of time.

Although the governments of the aforementioned cities have shown interest in sustainable guidelines, very little is said about the fight against light pollution, making the subject even unknown among important environmentalists.

Is there an alternative?

Urban lighting projects must be designed taking into account user comfort and visual acuity. Currently, artificial lighting is considered indispensable and is part of human life. The Founding Partners of Responsible Outdoor Light At Night published, on December 14, 2022, a 10-point Manifesto that sets out a series of fundamental principles for the development and execution of outdoor lighting projects and an action plan to implement positive changes in the lighting community.

As the UN Sustainable Development Goals do not explicitly refer to external lighting and its multiple impacts, the intention is to sensitize the organization so that the fight against light pollution is considered one of the objectives.

Conclusions

Although we are witnessing a great concern in making cities more sustainable, little is said about light pollution. This lack of knowledge and interest regarding this agenda has been making cities increasingly enlightened, which makes them vulnerable to various harms, both in human beings and in the local fauna and flora.

We know that this is due to the fact that the night free of light pollution is something increasingly rare and increasingly unknown by the population. In this brief epistemological analysis, we can observe the challenge imposed to change the perception of light and darkness, as the act of lighting is loaded with meanings.

Even though studies are presented proving the harm that excess lighting can cause, we are faced with a very strong barrier to be overcome with public opinion, and even within the most technical areas, in view of the consolidated positive meanings associated with lighting, in force in our society.

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A facility for measuring and assessing the spectral responsivity of SQM radiometers

Theme: Measurement and Modeling

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An uninterrupted growth of outdoor artificial lighting at night (ALAN) is observed at present [1]. A cheap radiance meter is commonly used to measure a physical parameter describing the effect of ALAN, the Night Sky Brightness (NSB) at zenith. It is the Sky Quality Meter (SQM) [2]. It is used alone or in network in particular to track changes in NSB and associated changing in outdoor lighting systems. With that issue the instrument stability is of fundamental importance. Only knowing the changing of the instrument allows to estimate how much of the detected variation on NSB can be correctly attributed to variation on upward light. It can be done supposing that no significant changing in effect of atmospheric conditions and in natural causes of sky brightness are present. Long-term trends of the SQM measures were observed in different sites and the tendencies are toward darker sky, examples are in [3, 4]. Those trends seem to move the opposite way of results based on satellite data. The latter show an increase of 2.2% per year of the lit outdoor area over the Earth from 2012 to 2016 and a growth of 2.2% per year of the brightness of the outdoor lit areas [1]. A method to analyse possible variations of the instrument sensitivity is described in [5]. It is based on the evaluation of changes of the response of SQMs to the Sun light at twilight. The method was applied to analyse ageing of SQMs of the network covering the Veneto Region in Italy and an SQM at La Silla in Chile [6]. In particular the analysis considers measurement of sky brightness at zenith both at sunset and at dawn. The results showed clear trends in the direction of the decay of the instrument performances. The measures at twilight showed also that the effect of changing in the atmospheric conditions is different for in air polluted and unpolluted site. The possible decay of the performance was found between about 30 to less than 90 mmagSQM arcsec^{-2} year^{-1} for the different instruments. The variation is comparable with the growth of outdoor artificial lighting, therefore SQMs can still be used to track variations of outdoor lighting only if their outputs are corrected for their ageing.

Obviously, it is of interest to understand the causes of the ageing and what instrument components are more affected. The easy way should be removing the instrument from the network, and analysing the SQM as a whole, then, in case, studying some components separately. That approach could not assure a complete continuity of operation of the instruments, therefore, for the SQMs of the Veneto network, up to now only on-site checks are seldom performed with portable SQMs used as references. Only when an instrument is definitely removed from the network, it is completely analysed. Recently some components of an SQM were replaced for maintenance reasons. They were a weatherproof housing window, which did not show significant ageing even after 9-year exposition, and an internal infrared blocking filter, which showed a variation of its spectral transmittance at short wavelengths of about 80%. The latter causes a clear decay in SQM performance, even if it does not completely justify the detected trend of the SQM output.

About ten-years operation is considered an appropriate time to renew the instruments at Ekar and Pennar, two sites on the Asiago plateau facing the Padana plain in Italy. Therefore, new SQMs were placed in parallel with the old ones. It allows a first comparison, in fact in the same site old and new SQMs analyse the same NSB. The acquired data could allow to highlight differences due to the ageing of the old instruments, already shown by the twilight method. Before their outdoor use, the new SQMs were tested in terms of spectral responsivity and directional response to know their “zero” state. Their spectral responsivity was evaluated considering the response of the SQM to a source ad hoc made for that assessment. The source is composed by an integrating sphere with an output port of 38 mm. At the entrance port, 9 coloured LEDs are present by turns, they have a spectral width (FWHM) of about 40 nm. Their peak wavelengths are evenly spaced in the range of 360 nm to 720 nm. Outside that wavelength range the SQM response is expected to be less than 10% of its maximum. Figure 1 shows an SQM placed at the output port of the source. Figure 2 present a first estimate of the spectral response of the two new SQMs and of an SQM often used as reference in outdoor comparison. The presented quantity is the ratio of the linear output of each SQM normalised to the total radiance at the output port. The latter quantity was measured by a calibrated spectrometer available in the laboratory. Even it is not the spectral response of the SQM to spectral lines, the approximation is acceptable, however it is a sign of the analysed instrument. The maximum dispersion is ±4.5%, which is considered a low value for instrument bought ten years later. The repeatability in the response measurement is much lower, about 0.2%. At the end of the comparison under the sky, both the spectral and the directional responses of the old SQMs will be measured and an estimate of their ageing will be done. It will be compared with its evaluation based on the twilight method.

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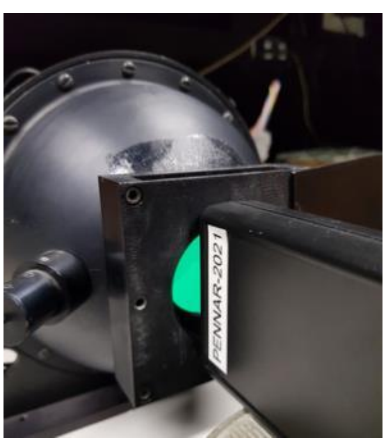

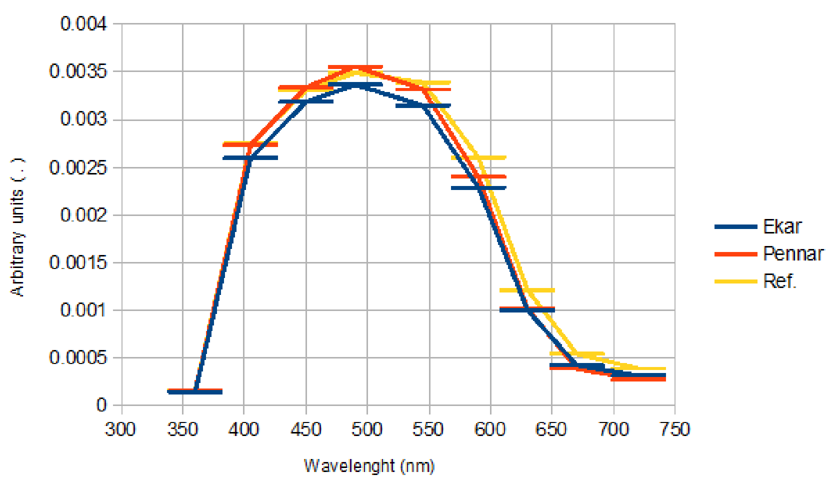

Fig. 1: Left: SQM at the output of the test source.. Right: Spectral responses of the analysed SQMs

Correlations between the CCT, the % of blue and the Spectral Impact Indices for a variety of lamp technologies

Theme: Technology and Design or Society

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With the constant increase in artificial light masking natural cycles, people and light are more closely linked today than at any other time in history. It is therefore important to understand the impact of artificial light on human health and the environment. The information provided by the suppliers (e.g. CCT) is not sufficient to understand the impact of human produced light on biological processes and the starry sky. In 2013, Aube et al, introduced spectral impact indices (MSI: Melatonin Suppression Index: IPI: Induced Photosynthesis Index, SLI: Star Light index) that allow a quick estimate of the potential spectral impact of a lighting device on human health, photosynthesis, and starry sky visibility by considering the spectral response of the biological process and the lamp spectrum.

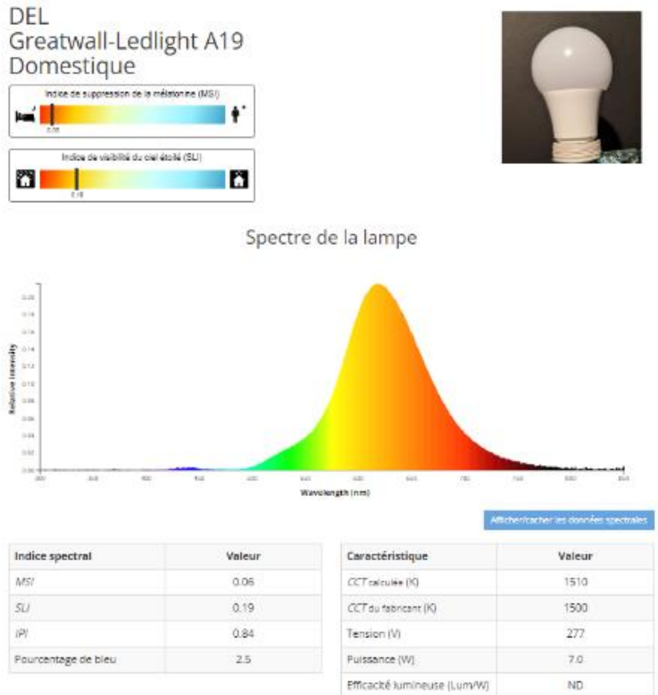

Fig. 1: Screen capture of the data sheet from LSPDD (LED, 1500K)., This image by Johanne Roby is in the public domain.

On the other hand, to provide independent information about the spectral characteristics of commercial light bulbs or luminaries products, our research group is building an extensive spectral database of domestic and commercial lamps of different lighting technologies that were initiated about ten years ago. This database also contains Biological Sensitivity Curves (e.g. Photopic and Scotopic, Melatonin Suppression), CIE Standards Illuminant curves and mid-latitude ambient spectral power distribution (SPD) from civil twilight to noon during a typical sunny day. It is available online (www.lspdd.org) under a Creative Commons BY-NC-ND license. It is intended to provide information to both the scientific community and the public in order to better understand the impact of artificial light on wildlife, flora and human health. A data sheet is associated with each lamp containing the SPD (including raw file), the manufacturer's CCT, the calculated CCT, the % of blue, the power in watt as well as the spectral impact indices (MSI, IPI, SLI). Figure 1 shows one example of the technical sheet including SPD extracted from the LSPDD database (LED, 1500K).

Using this database, we made the correlation between CCT, % blue and the Spectral Impact Indices of the different lighting technologies. The results will be discussed during this presentation.

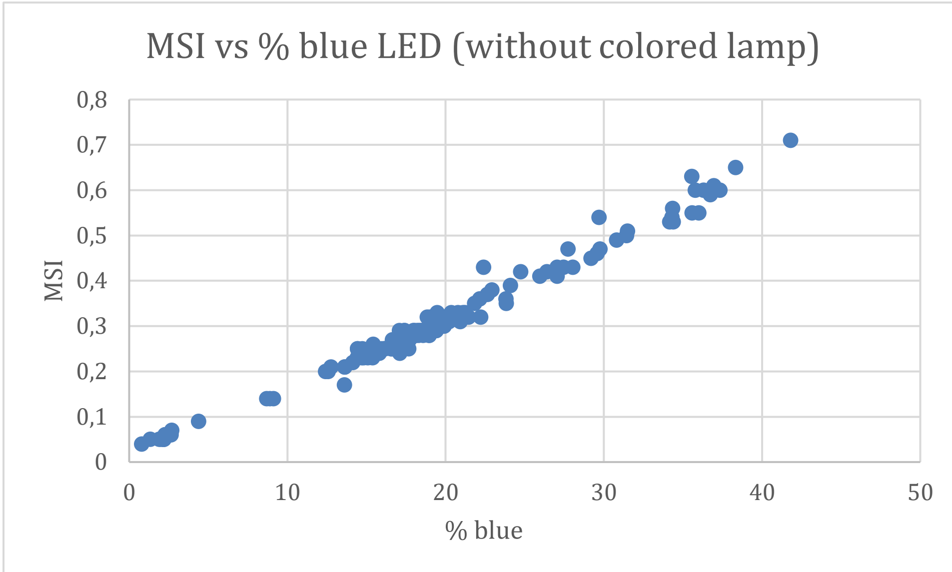

Fig. 2: Comparison of the MSI and the % blue of each LED without colored lamp in the LSPDD database as of 30 September 2023.

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IDSReserve Rhön as a success for reducing light pollution in municipalities

Theme: Governance and Regulations

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The recognition of the UNESCO Biosphere Reserve Rhön as an International Dark Sky Reserve in 2014 was very successful. Many municipalities appreciated to receive guidelines based on the IDA criteria for their International Dark Sky Places on how to reduce excessive lighting and light pollution. In the consequence the city of Fulda with about 65 000 inhabitants applied provisionally as IDSCommunity, which was acknowledged in 2019.

More and more municipalities became interested in the lighting guidelines to reduce light emission and light pollution in their own municipalities. Therefore more information material was created in close cooperation with nature protection organizations and lawyers.

These are

- master lighting guidelines,
- guidelines for insect friendly lighting
- master guidelines for development plans,
- master guidelines for construction permissions,
- award for sustainable lighting (#lichtbewusstsein) chamber of commerce and industry

and many more, which are available (in German) at https://www.biosphaerenreservat-rhoen.de/natur/sternenpark-rhoen/ruecksichtsvolle-beleuchtung/#&gid=lightbox-group-8007&pid=0

Many municipalities reduce mainly the public lighting or even switch-off during late night.

A cooperation on the level of the county (Land) Hessen was created to cooperate more coordinated on a larger area: https://www.lichtverschmutzung-hessen.de/

We'll report about these activities.

Fig. 1: Switch-off at 0:30 in the village Tann in the Rhön (photo: A. Hänel)

Illuminating the impact of artificial light at night on vocalization patterns in avian cavity nesters

Theme: Biology & Ecology

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Abstract

The predictability of natural light and dark cycles has had a paramount effect on the organization of Earth's biota. A growing body of literature has demonstrated that artificial light at night (ALAN) has elicited a diverse response to the alteration of natural temporal light regimes with a complex network of ecological consequences. The full extent of ALAN's impact is unknown; in birds, there is evidence that ALAN impacts or disrupts several physiological processes and life history events. Field studies of wild populations are lacking, and many avian studies remain limited to diurnal activity during the breeding season.

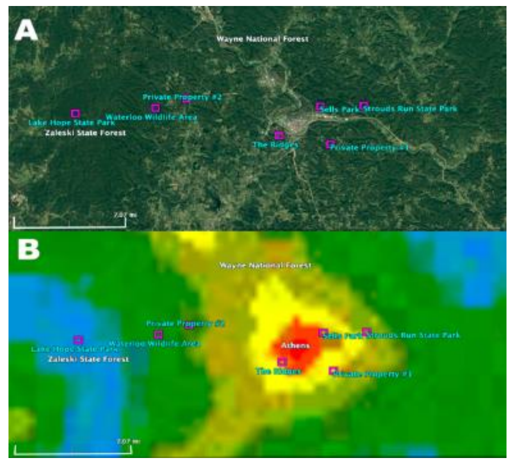

Fig. 1: Locations of study sites in relation to the rural university town of Athens, OH, approximately 70 miles south of Columbus (a). Study map overlayed with night sky light data from CIRES' New World Atlas of Artificial Sky Brightness (Falchi et al. 2016) to illustrate the local light gradient (b). Satellite imagery courtesy of Google Earth Pro (2023).

ALAN's impact on the cavity-nesting guild has received limited attention. Woodpeckers are considered to be predictors of avian diversity in forests, being ecological engineers that provide critical nesting habitat to other avian species as well as small mammals. This study aims to evaluate the seasonal impact of ALAN at the community level, and to investigate vocalization patterns in wild woodpecker and songbird populations subjected to altered light regimes. ALAN-induced behavioral shifts may impact woodpecker population dynamics that could have a cascading effect on secondary cavity nesters. This study employs bioacoustic methods and site-specific light data to evaluate differences in vocal phenology of eight cavity-nesting avian species (five woodpeckers and three songbirds) in southeastern Ohio. The impact of ALAN on woodpeckers is functionally unexplored, despite their pivotal ecological role in forest ecosystems. Preliminary results have demonstrated potential shifts in species' activity patterns at ALAN-impacted sites, providing grounds for further investigation within this guild.

To obtain data on vocalization behavior in our eight focal species, we deployed autonomous recording units (ARUs) at seven local sites near Ohio University in rural southeastern Ohio. The local artificial light gradient (Figure 1) results from most local infrastructure in the city of Athens being in close proximity to the university, and the surrounding rural area having little or no lighting infrastructure. This light landscape provides an excellent study area for observing the effect of human factors on wild populations. ARUs were deployed from May until December of 2022 to collect vocal data over the course of three meteorological seasons, and these data are being analyzed using the Wildlife Acoustics Kaleidoscope Pro software. Site-specific light data were also recorded at each site during the study period during the new and full moons to characterize the ground-level light conditions that local populations are exposed to.

Despite the characteristically rural landscape and the small town of Athens being the sole locally concentrated source of ALAN, the results of our study warrant further investigation of the effects of artificial light in rural areas and provide additional context for future ALAN and bioacoustics-related research on wild avian populations.

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Investigating the combined effect of ALAN and noise on sleep by simultaneous real-time monitoring using low-cost smartphone devices

Theme: Health

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Introduction

The association between artificial light at night (ALAN) and noise, on the one hand, and sleep, on the other, has been investigated to date mainly in laboratory conditions (e.g., Cho et al., 2013). However, laboratory studies often lack generality due to small study cohorts (Lick & Unger, 2016) and inability to reflect real-world conditions (Shiffman & Stone, 1998). In this respect, modern technologies can help, as modern wearable devices, such as smart- phones (SPs) and watches (SWs), integrate a wide range of built-in sensors that enable real-time collection of data and seamless data transfer to the cloud for subsequent analysis (Kim et al., 2017). Albeit several studies looked at the accuracy and reliability of SP/SW devices for sleep research (see, inter alia, Asgari Mehrabadi et al., 2020; Partridge et al 2021), none of such studies have used SW/SP devices for simultaneous real-time monitoring of multiple physical variables, such as noise and ALAN, and their sleep effects. In the present study, we demonstrate that this task is feasible while attempting to answer the following three main questions: 1) Do ALAN and noise exposures significantly reduce sleep duration and quality? 2) Do the impact of ALAN and noise on sleep differ by the time of exposure, that is, before sleep or during the sleep phase? and 3) Whether ALAN and noise affect sleep duration and quality independently of each other, or interactively, with the impact of ALAN exposure on sleep depending on the level of surrounding noise and *vice versa*?

Methods

72 volunteers, evenly divided by gender, with the mean age of 44±12.43 yo were drawn from different urban localities in Israel. The survey participants were asked to use their personal SPs and SWs to monitor sleep for 30 consecutive days, with ALAN and noise exposures monitored in parallel, with the inputs reported each second. The experiment helped to accumulate ~70.5M individual observations of ALAN, noise, and sleep variables. The volunteers were also asked to fill in an online questionnaire about their individual attributes, daily habits, room settings, and personal health, to serve as individual-level controls. Upon cointegration, the assembled data were co-analyzed using bivariate and multivariate statistical tools.

Results

As the study revealed, the effect of ALAN and noise on total sleep time (TST) and sleep efficiency (SE) largely depends on when the exposure occurred. In particular, the effect of ALAN was found to be most pronounced, if occurred before sleep, while exposure to noise mattered most if it occurred during sleep. As the study also revealed, the effects of ALAN and noise are found to amplify each other, shortening sleep duration by up to 14-15.3% and reducing sleep efficiency by about 8-9%. The study also unfolded, apparently for the first time, the ALAN-noise-sleep gradient (Figure 1) that enables to assess changes in TST and SE that occur in response to different combinations of ALAN and noise exposures.

Conclusions

ALAN and noise exposures, both before and during sleep, need to be restricted by enforcing stricter environmental standards and implementing different technological solutions. Regarding noise, such solutions might include using acoustic materials to achieve a noise-free living environment and eliminate noise at its source by using electric vehicles, improved tires, and quiet pavement of roads. Concurrently, ALAN pollution can be reduced by adjusting the illumination levels indoors and outdoors in response to natural radiance and space occupancy. People should also be educated about light and noise pollution and their adverse effects on human health and natural ecosystems, so they behave responsibly.

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Method for modelling obtrusive light at night on ISS images

Theme: Obtrusive light modelling

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The recent infatuation of lighting technologies, especially high intensity white light-emitting diodes is accelerating light pollution in cities all over Canada. The prolonged exposure to artificial light at night (ALAN) presents risks for human health [1]. In fact, there are increased risks of developing a hormone-related cancer after being exposed to ALAN for a long period of time [1]. In this work we assess those risks, space-borne imagery is used with a light pollution model to evaluate the spectral irradiance falling on house facades in a city. The images are acquired from the International Space Station (ISS) by astronauts using a DSLR camera for colour information and a 400 mm lens. Furthermore, data acquired on the ground with sensors are compared to the results of modelling to evaluate the errors of the modelling method.

This research project aims to develop a new method to model ALAN and use it on health research. The Illumina model was used in the past in modelling ISS images to evaluate the zones most exposed to ALAN [2]. The images in this project are treated for the noise, background light and passed through a deconvolution algorithm in order to retrieve the artificial light sources. The algorithm used is based on the Richardson-Lucy deconvolution [3]. In parallel, the evaluation of lighting characteristics is key in the modelling process and is achieved by creating a lighting devices inventory of the study area. To create this inventory, the study area is divided into polygons of homogenous spatial distribution. Characteristics such as lighting fixtures and obstacle heights are extracted using open-source tools. The inventory and images are used as inputs with other parameters in the Illumina model. The result of the modelling is a spectral irradiance image from which zones of concentrated MSI [4] can be calculated. Results will be validated against data acquired on the ground with the LANcube sensor [5]. The LANcube is attached to the top of a car and then collects the surrounding light's information. Then, the car is driven in as many streets as possible in the study area and information about the RGB and clear channels are extracted as well as the coordinates.

The version of the Illumina model that will be used is one being developed exclusively for human health applications. The treatments on the ISS images will increase the precision of the modelling result. The deconvolution algorithm will help to retrieve point-like streetlights instead of light patterns spreaded on the ground. This research is conducted on five Canadian cities: Calgary, Edmonton, Montreal, Vancouver and Victoria. The results of the modelling will be used by epidemiologists to try to find statistical connections between light pollution and cancer development.

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Let there be darkness

Theme: Governance & Regulation

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Forward

Urban and rural areas in UK and elsewhere for past several years are changing over roadway and residential street lighting from high pressure sodium [HPS] to blue-rich LED's often simply on the basis of saving energy but without health and environmental impact assessments.

Research has shown that making choices simply on the basis of energy consumption is shortsighted. Research has shown that blue-rich LED's affect human health and wellbeing in having an impact on people's ability to get a good night's sleep, circadian rhythms, road safety and view of the night sky.

It is crucial for policy makers to link LED installation to heath, ecology considerations and involve local communities in deciding how streetscapes including trees and lighting are planned, managed and maintained.

Street lighting and human health & well-being

Studies recognized by World Heath Organization [WHO] show blue-rich LED's emit a form of blue light that suppresses the production of melatonin, responsible for regulation of the body's biological clock - which can disrupt people's circadian rhythms and is associated with health problems including sleep disruption, depression, diabetes, obesity and cancer.

The effect of artificial light on trees is not a newly discovered problem. Botanists were aware of deleterious affects of incandescent street lighting on trees 81 years ago by Matske in 1936, while horticulturalists became aware as result of research 42 years ago by Cathey and Campbell in 1975 with harmful affects on both wild and domesticated plants.

CCT (correlated color temperature) LED'S of 2700K (Kelvin)

It is wildly now accepted that in lighting of streets, roads and other outdoor public places should ideally have a CCT of 2700K - but must not exceed a CCT of 3000K. A study published in 2010 found that LED's contain lead, arsenic and a dozen other potentially dangerous substances and we must be vigilant about any toxicity in supply chain of these products.

The environmental threats of artificial light

Pollinators are declining worldwide. The rapid global increase in artificial light at night is a new threat to terrestrial ecosystems as artificial light at night disrupts nocturnal pollination networks. In artificially illuminated plant–pollinator communities, nocturnal visits to plants were reduced by 62% compared to dark areas. Sensory biologists fear we are polluting the world with too much light.

Excessive outdoor lighting disrupts many species that need a dark environment. Poorly designed LED lighting disorients some bird, insect, turtle and fish species. Knowing this U.S. national parks has adopted optimal lighting designs and practices that minimize the effects of light pollution on the environment.

The Cardiff City Council opted for blue-rich LED's 3000K after public trials and consultations. It has estimated the City can reduce electricity consumption and save more than £750,000 per year and contribute to reducing CO2 emissions.

Yet, in contrast, the Sheffield City Council (SCC) installed 5000K LED's and against the advice of AMA (American Medical Association), IDA (International Dark Sky Association), CPRE (Campaign for Rural England) and PHE (Public Health England); they were all recommending 2700K lights to minimize glare and discomfort.

Research has shown that making choices simply on the basis of energy consumption is shortsighted. It is crucial for policy makers to link LED installation to heath, ecology considerations and involve local communities in deciding how streetscapes including trees and lighting are planned, managed and maintained.

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Identifying thresholds of effects of artificial light at night for biodiversity protection

Theme: Biology and Ecology

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Introduction

Mounting evidence shows that artificial light at night affects biodiversity (Hölker et al. 2021). Legal frameworks to mitigate its adverse effects on flora and fauna are however lacking, partly because there is no clear insight in threshold levels for different protected organisms and thus definitions of biodiversity-friendly lighting. The project sLIGHT aims to develop recommendations and guidelines for biodiversity-friendly lighting solutions, based on existing literature, which would help the German federal government in preparing legal ordinances to limit light pollution and mitigate its adverse effects on biodiversity.

Methods

We conducted a comprehensive systematic literature review to summarize reported effects of artificial light at night on physiology, behavior, life history traits etc. of various groups of organisms as well as on ecological interactions, populations, communities, and ecosystems, in terrestrial and aquatic habitats. For each organism group we identified minimum light levels that were reported to have an ecological impact and compared the impacts of different light types studied.

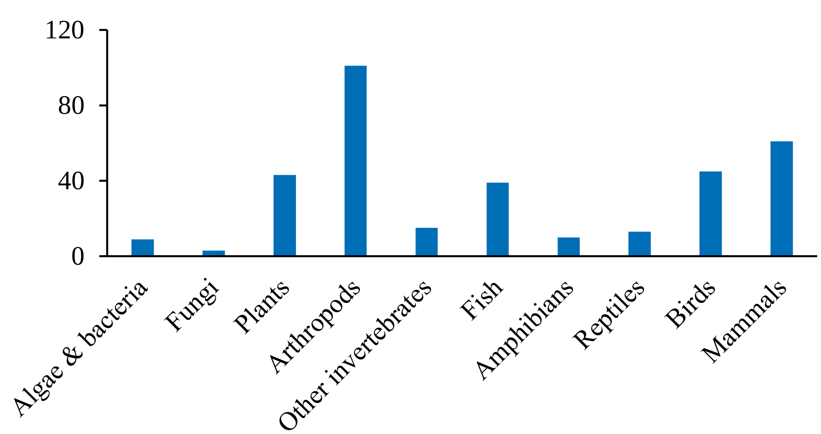

Figure 1. Distribution of studies across different study organisms (n = 339)

Results and Conclusions

There is a bias in the taxonomic groups tested (Fig. 1), with some groups of arthropods being relatively well studied, and a lack of studies on microorganisms, invertebrates other than arthropods, amphibians and reptiles (Fig. 1). In many cases, the lowest light levels that were reported to have a significant effect were the lowest light levels tested. Large gaps in knowledge were identified concerning the studied light intensities, as low light levels, such as those comparable to skyglow, have hardly been studied. Furthermore, a relatively small number of studies have examined the impact of different light types and regimes on biota, especially in the context of light colors, or lighting practices such as part-time lighting. For example, in plants, which are one of well-examined groups, only 5% of papers investigated the effects of light levels comparable to skyglow, 15% the effects of light colors other than white and 4% studied the effects of part-time night lighting. The lowest light intensities of artificial light at night at which significant morphological effects on plants have been documented were 0.3 lx (Crump et al. 2021), whereas significant effects on plant physiology have been reported lowest at 3 lx (Segrestin et al. 2021). Low light levels have been shown to have various ecological effects on biota, but since very low light levels are rarely assessed, there is insufficient data to draw conclusions on minimum light thresholds for most organism groups.

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Perception and mitigation potential of light pollution in Switzerland

Theme: Goverance and Regulation

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The extent of artificial light at night (ALAN) is growing worldwide. Yet the negative ecological and public health impact of light pollution is increasingly recognized (Longcore & Rich, 2004; Navara & Nelson, 2007). There is thus scientific consensus of the need to reduce light pollution, yet little is known about public awareness of the issue and support for measures.

Public awareness of an environmental issues is essential for protection measures against it to be accepted. Yet there are suggestions that constant exposition to high level of artificial light led to a shifting baseline symptom, whereas the degraded light conditions are considered the normal situation (Lyytimäki, 2013; Pauly, 1995). This suggestion might be supported by recognized differences in perception of light pollution by rural and urban residents (Coogan et al., 2020). However, awareness of light pollution as an environmental and/or public health issue has be found across several contexts (Lyytimäki & Rinne, 2013), including in people highly exposed to strong lights (Nguyen & Peña-García, 2019). Evidence is however still too limited to draw general conclusions on whether awareness is high enough for support to light pollution reduction measures across all levels of light pollution.

Studies on acceptability of different measures to reduce public light pollution showed higher support for measures motivated by improved energy efficiency and ecological sustainability than for sky visibility or general darkness/brightness (Besecke & Hänsch, 2014). People also tend to prefer technological improvements over than fiscal measures (Lyytimäki & Rinne, 2013). As for individual measures, there tend to be an externalization of the responsibility for light pollution reduction (Lyytimäki & Rinne, 2013). Social norms were found to moderately explain the uptake of light reduction measures targeted for nesting turtles (Kamrowski et al., 2014). There are however still no studies investigating which beliefs would need to be changed to decrease general light pollution, without a focus on a specific organism and timespan.

With this study, we aim to describe the Swiss populations' awareness of light pollution as an environmental and public health issue, linking it to the level of artificial light around their residence ; to identify the sources of light most rated as disturbing; to rank the support for different measures against light pollution from public sources; and to establish which beliefs are the most important in explaining behaviors to reduce light pollution.

We will carry out a cross-sectional survey of the Swiss resident population, with oversampling in the darker regions. The questionnaire will include evaluations of (1) how respondents' perceive the night light levels around their place of residence; (2) respondents' understanding of light pollution as an environmental and public health issue; (3) potential sources of light pollution in different settings; and (4) support for measures to mitigate public lights. The questionnaire will also include a section based on the theory of planned behavior (Ajzen, 1991) to assess which beliefs influence three individual behaviors to reduce light pollution, namely turning off external lights, closing curtains or blinds when internal lights are on and replacing lightbulbs with orange/yellowish ones. The questionnaire will be distributed in February 2023, with the help of a panel agency. We aim to collect a total of 1200 answers.

We will compare the respondents' perception of the light level around their place of residence and levels of awareness of the environmental and public health impact of light pollution to the New World Atlas of Artificial Night Sky Brightness (Falchi et al., 2016) in order to ascertain whether or not there is a shifting baseline symptom in term of light pollution. We will highlight which sources of light pollution are rated as the most disturbing and should be targeted for by public measures to reduce light pollution, as well as which of those measures would receive the most support. Finally, we will describe how best to target a campaign to reduce individual light pollution by identifying the relative importance of personal attitudes, social norms or perceived behavioral controls on the intention to reduce light pollution.

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Measuring Reference Dark Sky in Namibia

Theme: Measurement and Modeling

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Introduction

Nocturnal landscapes that are not influenced by ALAN are getting rare on Earth. Even professional astronomical observatories experience more loss of natural darkness (Falchi et al., 2023). Namibia is a country with good observing conditions, where the first large observatory was installed in 2002, the H.E.S.S. observatory for the detection of cosmic radiation. In addition several farms have installed astronomical observatories and facilities under the dark sky that can be rented by amateur astronomers. As Falchi et al. (2023) have shown, some of these observatories offer still nearly natural dark skies.

How dark is a dark sky?

A natural dark sky is essential as reference for polluted skies. Therefore measurements of the sky brightness with different methods were taken in May/June 2022 at several farms in the south of Namibia, that offer a very dark sky. The measurements were taken with different Sky Quality Meters and fisheye lenses with digital cameras which were evaluated with different methods, especially with the Sky Quality Camera (SQC) software. As the observing places were only marginally influenced by artificial light, characteristics for a dark sky are derived and compared with values proposed by Falchi et al. (2023) and the values derived with the model GAMBONS for a natural dark sky (Masana u.a. 2022, https://gambons.fqa.ub.edu/about.html). Other than point measurements (like with SQM or TESS, Deverchère et al., 2022, Grauer et al., 2019) all sky images reveal influences from the Milky Way, zodiacal light or airglow immediately.

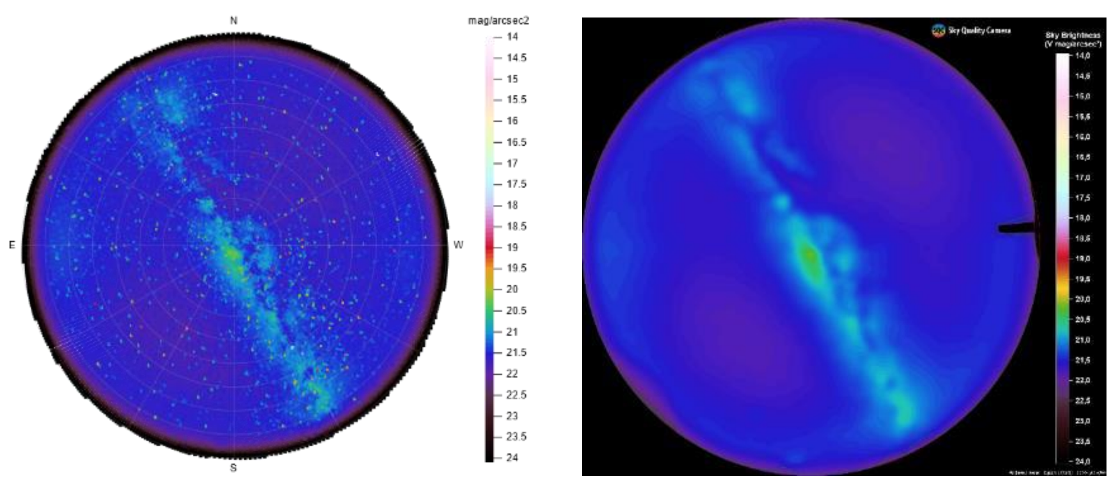

Fig. 1: From GABONS derived (left) and observed map of sky brightness as derived with SQC software at one of the observing places in southern Namibia without artificial light sources.

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The impact of artificial light at night on the behaviour and physiology of freshwater fish

Theme: Biology and Ecology

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Introduction

With rapid and widespread urbanisation, the world has experienced unprecedented population growth over the last century, with urban areas predicted to house up to 68% of the global population by 2050 (United Nations, 2018). Throughout the course of history, humans have preferentially settled along rivers and coastlines for the associated security of food, water supply, transport, and trade (Ceola et al., 2015). These urbanisations demand large-scale modification of the natural environment, from land clearance and habitat loss, to air, water, noise, and light pollution. Nowadays, artificial light is introduced from numerous sources: street lighting; domestic lighting; advertisement, architectural, and security lighting; and vehicle, ship, and underwater vessel lighting (Gaston et al., 2014, 2015). Whilst providing modern society with the means to be active during the night-time, artificial light at night (ALAN) has become a fast-growing, serious, and ongoing pollution event.

Considering the dependence of numerous biological phenomena on natural light regimes, it is unsurprising that ALAN constitutes substantial anthropogenic pressure on natural biological systems (Bradshaw & Holzapfel, 2010; Gaston et al., 2015). Recent decades have seen a considerable growth of interest into light pollution, and an associated increase in the number of publications that report findings into the effects of light pollution on a wide range of organisms and responses (for example, see Longcore & Rich, 2004; Fonken et al., 2009; van Langevelde et al., 2011; Dominoni et al., 2013; Cravens & Boyle, 2019; Manríquez et al., 2019; Vowles & Kemp, 2021). However, most research focusses on terrestrial organisms, and in comparison, aquatic organisms and environments have been substantially understudied (Sanders et al., 2020). Therefore, this study investigated the influence of low intensity ALAN on the physiology and activity behaviour of two co-occurring and contrasting freshwater fish, brown trout (*Salmo trutta*) and European eel (*Anguilla anguilla*).

Methodology

The experiment was conducted using large husbandry tanks at the International Centre for Ecohydraulics Research facility (University of Southampton). After a 2-week acclimation period, individual fish were weighed and measured, and personality traits were established using triplicate scototaxis assays, after which fish were randomly distributed between two large tanks for the light treatment phase. Each tank experienced 12-hr day-night cycles, with a sunrise and sunset period between 06:00-07:00 and 18:00-19:00 respectively. In each tank, daytime light intensity reached 2000 lux at the water's surface, similar to the intensity of an overcast day. At night, the control tank experienced an intensity of 0 lux, or complete darkness, and the ALAN treatment tank was exposed to a constant intensity of 10 lux at the water's surface throughout the night. The light treatment phase lasted for 20 days.

After the light treatment phase, growth measurements were recorded, and blood samples were taken from individuals and analysed for cortisol (a stress hormone) and melatonin using enzyme-linked immunosorbent assay (ELISA) kits. Furthermore, population-level activity was monitored continuously throughout the experiment using underwater cameras. Activity was quantified by the number of passes made across a vertical marker in each tank during set time periods each day.

Conclusions

Initial results indicate impacts of ALAN on population-level activity for both species. For brown trout, daytime activity following exposure to ALAN was approximately 50% lower compared to those in the control tank. For eel, a species generally considered active at night, early indications suggest increased activity across the entire 24-hour period after exposure to ALAN, but data analyses are ongoing. Although behavioural impacts were observed, effects on fish physiology appear less obvious. This talk will present these results and discuss their implications within the context of experimental studies aimed at identifying ecological impacts of ALAN and the need to better understand and mitigate this major form of environmental change.

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Cultural and Societal Impacts of Increasing Satellites in the Night Sky

Theme: Social Sciences & Humanities

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The emerging phenomenon of satellite mega-constellations is rapidly changing both low-Earth orbit (LEO) and the night sky. In early 2019, prior to the launch of the first Starlink satellites, there were only a little over 2000 operational satellites in orbit around the Earth; as of late January 2023, this figure had more than tripled to 7,300, and it is projected to reach 100,000 or more by the end of the decade (Space-track.org; Long, 2021). The deployment of thousands of satellites in the coming years stands to irrevocably alter the appearance of the night sky worldwide, and unlike in the case of conventional "ground based" light pollution, the changes to the sky will be visible even in locations far from urban centers (Lawler et al, 2021). Such changes include both the visibility of satellites as moving points of light and an increase in diffuse sky brightness brought about by light reflected off of satellites and orbital debris (Walker et al, 2020a; Kocifaj et al., 2021).

While efforts have been made by some operators, such as SpaceX, to reduce the brightness of their satellites, to date, the goals of reducing brightness to at least 7th magnitude (the approximate limiting magnitude of visibility to the naked eye) have been challenging and not yet achieved (Mallama and Respler, 2022a). Additionally, there are also projects in planning or early deployment stages utilizing even larger solar panels, which result in significantly brighter satellites. To give a recent example, the first satellite launched by AST SpaceMobile has been observed at approximately 1st magnitude (Mallama et al., 2022b). Currently, there are no laws limiting the brightness of satellites (Lawler et al., 2021).

This marked increase in highly visible human made objects in orbit will have significant impacts on professional astronomy, and increasing research is being conducted to better understand these impacts, find ways to mitigate adverse effects, and reduce science losses (Hall et al, 2021; Walker et al, 2020a; Walker et al, 2020b; Walker and Benvenuti, 2022). However, while software and other mitigation techniques may reduce the severity of satellite impacts on professional astronomy, such tools will not erase the changes to the night sky that will remain visible to the naked eye in real time. This is problematic for a variety of users of the night sky, such as amateur astronomers, astrophotographers, recreational stargazers, and indigenous peoples.

A few of the concerns raised by some members of these communities include the following: undesired impacts on cultural teachings and practices related to the night sky; lack of consultation and ability to participate in decision-making processes about changes to LEO and the night sky; disruption to recreational and/or scientific astronomical activities; and a sense that rising commercial exploitation of LEO and the night sky may be "a new form of colonization" (Venkatesan et al., 2021). Issues such as these have been mentioned in recent papers (eg. Venketesan et al., 2020) and increasingly, have been discussed in media articles about satellite constellations. However, there has been comparatively little rigorous research focused on exploring the cultural and societal impacts of satellites' effects on the night sky. Such research is necessary to better understand these impacts, raise awareness of their existence, and to indicate where issues pertaining to equity and inclusion may need to be addressed.

This presentation will discuss preliminary results from research conducted with selected communities impacted by these changes. This research employs the use of online surveys, semi-structured interviews, and focus group discussions in order to better understand the experiences and perspectives of community members affected by changes to the night sky from satellites and related human activity in LEO.

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Visual Diversity and Artificial Lighting at Night in Public Spaces

Theme: Society

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Introduction

If cities claim to be inclusive, the night has to be accessible for everyone and artificial lighting at night (ALAN) in public spaces must be appropriately designed and planned. Given the growing number of people with visual impairment of different kinds especially due to the aging of populations these groups have to be accounted for. However, the topic of inclusive ALAN in public spaces is rather understudied in literature, as emerged from the literature (Radicchi & Henckel 2023).

Against this backdrop, we present the results of an exploratory study where we made the case for inclusive ALAN planning in public spaces, by 1) introducing the concept of pedestrian visual diversity defined as the condition, capabilities and needs of visually impaired pedestrians, 2) providing a systematization of overlooked issues in planning ALAN for visual diverse pedestrians in public spaces and 3) proposing a participatory framework for the application of lightwalks as an experiential method for involving visual diverse pedestrians in data collection and analysis of ALAN in public spaces (Radicchi & Henckel 2023).

Methods

A literature review of ALAN in public spaces with a focus on visually impaired pedestrians was conducted across several scientific fields, e.g., urban and mobility planning, light planning and design, health and disability studies and universal design. This review showed that artificial light for visually impaired people is addressed to some extent for indoor lighting especially in the workplace and at home, and for the design of outdoor traffic signs and signposts' lettering, potential barriers, and points of danger. Little evidence could be found concerning ALAN in public spaces that accounts for the needs and abilities of visually impaired people.

Based on these limited results, twenty-one open-ended interviews were conducted with experts in the fields of health, urban and mobility planning and light planning and with organizations for blind and visually impaired people for further exploration.

Drawing upon the findings from the interviews, five overlooked issues about planning ALAN for visual diverse pedestrians in public spaces were systematised and discussed, i.e., 1) reasons why there are few studies and projects focusing on planning outdoor ALAN for visually impaired pedestrians; 2) standards, norms, and recommendations; 3) lighting features; 4) new digital technologies for designing and planning ALAN in public spaces; 5) best practices that take into account visually impaired pedestrians when planning outdoor ALAN.

Finally, a participatory framework for the application of lightwalks as an experiential method for involving visual diverse pedestrians in assessing and planning ALAN in public spaces is provided, based on experiences gained via previous projects developed in Berlin, Florence and Rome (Radicchi & Henckel 2018, Radicchi 2021).

Conclusions

The contribution of this paper is threefold:

- Proposing the concept of pedestrian visual diversity and making the case for taking visual diversity systematically into account for inclusive planning of ALAN in public spaces.
- Providing a systematization of issues to be tackled to acknowledge and address ALAN for pedestrian visual diversity.
- Outlining a participatory framework for the application of lightwalks as an experiential method for involving visualdiverse pedestrians in assessing and planning ALAN in public spaces.

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Bouncing bats: spatial interaction of artificial light and vegetation on foraging behaviour of synanthropic bat species

Theme: Biology & Ecology

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Artificial light at night has a negative impact our natural environment. Nocturnal species are especially affected by Artificial Light At Night (ALAN), and among these, bats are strongly represented. For bats, the presence of light is a hazard in the form of predation risk: it negates the safety of darkness, the essence of their temporal niche in the ecosystem. As a result light deprives many bat species of suitable habitat, and this especially holds true for slow-flying bat species that need to be extra prudent as they need more time to skedaddle. However, some fast-flying and agile bat species opportunistically utilize accumulated insects around light sources for foraging. At such locations, in order to catch these insects, bats have to venture into brightly illuminated space, which entails a trade-off between elevated predation risk and food reward. Bats are therefore expected to find an optimum between light exposure and foraging efficiency, which may show by bats keeping out of the brightly illuminated zone directly underneath light sources, and catching insects in the darker area just around it.

Fig. 1: we studied the distance relationship between bats and light sources at experimentally illuminated sites.
Image: Kamiel Spoelstra / NIOO-KNAW

In order to study the impact of light intensity on foraging bats, we recorded bats flying around light posts experimentally placed in natural habitat at seven unique sites in the Netherlands. We used microphone arrays to acoustically track bats using differences in arrival times of bat echolocation pulses, triangulating back the precise position of the bat when it emitted the pulse. This fine-scale tracking allows for the quantification of bat activity around, and flight patterns towards light sources, and hence provides knowledge on the effect of light intensity on bat foraging activity.

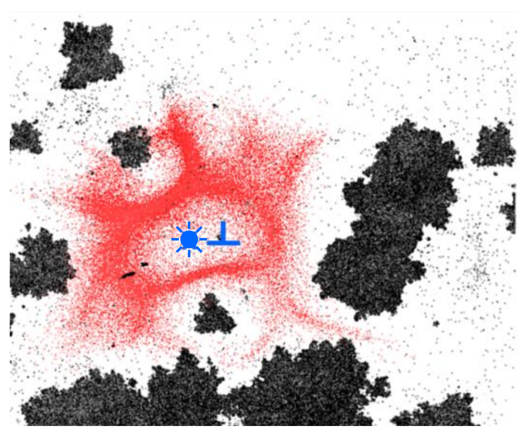

Fig. 2: areal plot of bat activity (fine red dots). The blue star indicates the light source, the blue T indicates the position of the microphone array frame.
Image: Claire Hermans / NIOO-KNAW

As bats may use surrounding vegetation structures to avoid visual exposure when foraging close to light sources, the presence of vegetation close to streetlights can interact with the distance relationship between bat activity and light intensity. The vegetation itself however deprives bats from foraging space, as the bat's ability to detect insects close to objects may be hampered by limitations of echolocation. In order to quantify a possible interaction effect between light, prey availability and vegetation on bat activity, we used precisely 3D-mapped vegetation scans of the direct surroundings of the light posts using LiDAR.

Our work provides novel information on the impact of light on bat activity, more specifically on the relation between light intensity (thresholds) and bat foraging activity, which is of importance for street lighting design. We further show how bat activity around light sources is spatially affected by vegetation structure, which may provide additional possibilities for mitigation of impact of light in our natural environment.

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Atmos, a professional tool for real-time atmospheres simulation

Theme: Technology and Design

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Atmos is a digital tool for decision support in the field of artificial lighting developed by the French consultancy L'Observatoire de la nuit, as an extension of a PhD project entitled *Pédagogie de la sobriété lumineuse* (Houel N. 2020). It is an immersive interface that simulates outdoor lighting environments in real time, based on real geographical, environmental and material data. It allows to reconstitute specific geographical environments and to simulate, analyze and improve artificial lighting practices.

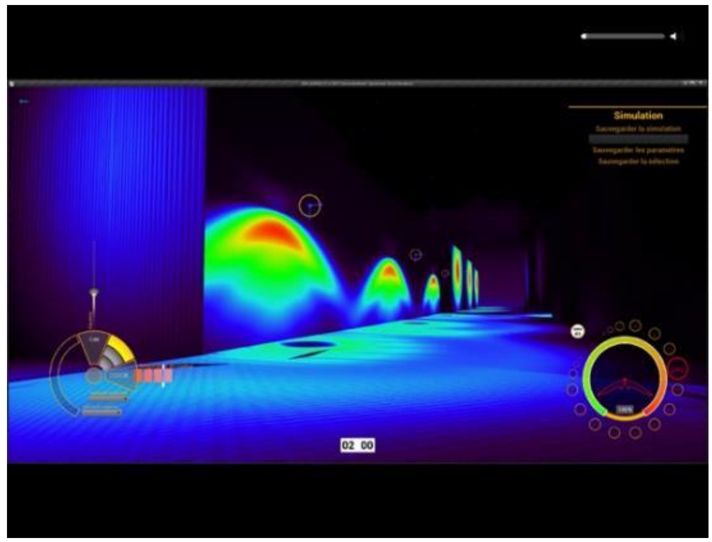

Fig. 1: Atmos interface. The displayed functionality shows the distribution of the luminous flux on the vertical and horizontal surfaces of a street (Brest, France). The tools on both sides of the display allow to vary in real time the characteristics o the light source (height, power, color temperature) to obtain immediately a spatial representation of the impacts of the artificial lighting on the study site.

Atmos tries to answer to a simple question: in view of the changes in practices linked to energy, environmental and social issues (Kyba C. & al, 2023), how can we design, share and decide on tomorrow's lighting ambiences ? It addresses the fundamental characteristic that links human beings, light and night: perception. It is entirely dedicated to the qualification of artificial lighting (Zielinska-Dabkowska K. & al, 2020), and offers a unique representation of how luminous ambiences can affects nocturnal landscapes.

It is a solution for the actors of the environmental and astronomical preservation of the night, as well as for architects, lighting designers, landscapes architects, urban planners and engineers who want to access with ease and professionalism the lighting studies of their projects and their impacts on the natural nocturnal environments. It provides real-time simulations of domestic, professional, landscape or urban environments, form volume modeling to the measurement of lighting levels on surfaces.

Atmos is dedicated to the democratization of moderate and high-quality lighting, to the search for an opening to the restitution of natural night atmospheres and the benefits of darkness for all living beings. It accompanies the evolution of practices towards a reasoned and adapted integration of digital tools, and encourages the rise in requirements of lighting projects through interactive and collaborative simulations. The interface, with its unique ergonomics, allows to simulate, calculate and realize quality night-time atmospheres, where the use of lighting is primarily designed to protect the natural environment.

During the presentation, participants will attend a real-time demonstration of Atmos. The will discover how easy it is to use and the quality of its simulation. Three types of case studies will be presented : urban lighting, architectural enhancement and rural environments.

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Nighttime Visual Impacts from Offshore Wind Farms

Theme: Governance & Regulation

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Summary

Thousands of wind turbines will be built along the east coast of North America on the Atlantic Ocean Outer Continental Shelf by 2030. Blinking red lights will be attached to the tops of the turbines to provide warning signals to approaching aircraft. Hundreds of synchronized blinking lights will alter the visual environment of the nighttime ocean surface and sky. The US National Park Service is providing strategies to the lead federal agency to help evaluate and minimize the environmental impact of these installations. Specifically, video simulations during daylight, dusk and nighttime hours are particularly useful in assessing potential impacts. Additionally, the use of Aircraft Detection Lighting Systems (ADLS) can effectively keep the lights off most of the time. We will present the scale and the size of these offshore wind projects and include video simulations and modeling reports.

Introduction

The United States is entering a new era with developing renewable offshore wind energy. According to a statement from the White House: "President Biden issued an Executive Order that calls on our nation to build a new American infrastructure and clean energy economy that will create millions of new jobs. In particular, the President's Order committed to expand opportunities for the offshore wind industry." [1] The Atlantic Coast is the epicenter of offshore wind development in the country (Figure 1). The region's Outer Continental Shelf (OCS) is wide and shallow, making it perfect for offshore wind development. Thousands of wind turbines will be built by 2030. These wind turbine generators are much taller and larger than ever before. The largest turbines can reach 1000 ft (300 m) in height, close to the height of the Eiffel Tower. Each blade can be 400 ft (120 m) long, which is greater than the height of the Statue of Liberty.

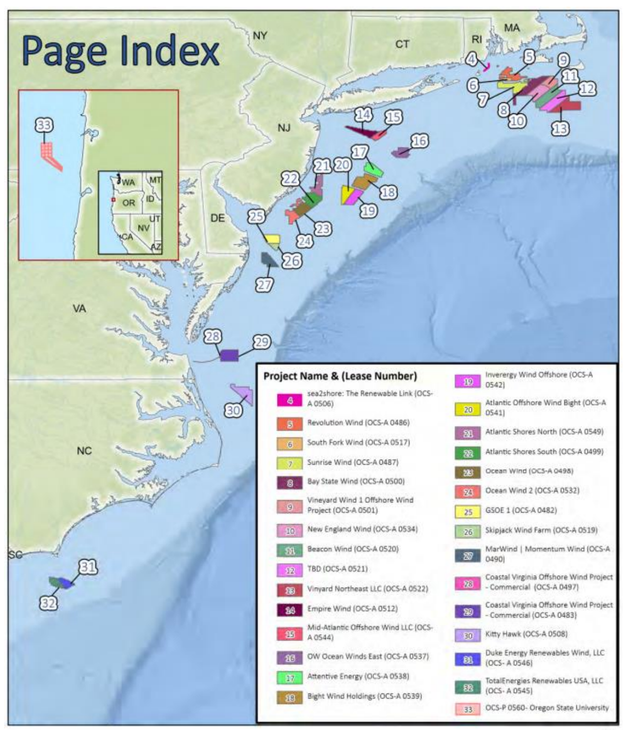

Fig. 1: Outer Continental Shelf Renewable Energy Leases Map. Source: The Bureau of Ocean Energy Management, US Department of the Interior.

Blinking red lights from these wind turbines will alter the natural dark sky above the ocean. Tens of National Park Service Units are within the 40-mile (65-km) zone of visual influence of the wind farms. The wind turbine generators and offshore substation platforms are to be lit and marked in accordance with Federal Aviation Administration and U.S. Coast Guard lighting standards. The lighting is needed for safty in aviation and navigation. This requirement means each turbine will have a red light mounted on top of the turbine tower. Lights will be set to blink about every two seconds, and hundreds of lights from nearby wind farms will be set to blink in synchrony. Many of the wind turbines can be seen from shore. Some turbines, for example, are only 15 miles (24 km) from the shore. Not only will the nighttime lighting have visual impacts to the natural sky and cultural settings, these artificial lights can also have negative impacts on wildlife.

Strategies to Understand and Minimize Impacts

The National Park Service (NPS) provides comments and serves as a Cooperating Agency in the review of many of these projects. The Bureau of Ocean Energy Management (BOEM) is the lead federal agency in approving the leasing and development of the OCS. NPS has made two requests to BOEM to mitigate or minimize lighting impacts of offshore wind projects: (1) evaluation via visual simulation and (2) inclusion of ADLS controls.

(1) Visual Simulation
NPS has recommended that as lease areas are developed, visual simulations are created, including static photos, videos, nighttime simulations and time lapse simulations from coastal national parks and national historic register listed properties. Visual impact assessments should include projections of turbines under different lighting and atmospheric conditions, their movement, and include other related project equipment such as transmission substations that may be located near or along the shore. Video simulations of operating turbines during daylight, dusk and nighttime hours are particularly useful in assessing potential impacts.

(2) Aircraft Detection Lighting System (ADLS)
NPS encourages use of ADLS to control aviation obstruction lights in response to detection of nearby aircraft. If ADLS are installed, the red blinking lights will only be turned on when a nearby aircraft is detected. A modeling report can show how effective ADLS will be for a specific project area based on the historical flight paths and data. With ADLS installed, lights often can be off more than 95% of the time at night.

Conclusions

The authors will present the scale of the upcoming US offshore wind energy development as planned by the current US administration. Blinking red lights on top of the turbine towers will impact visual scenery and wildlife, and mitigation has been proposed. The authors will present video simulations and modeling results to showcase the strategies we can use to effectively understand and minimize impacts at this early planning stage.

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Sky Brightness in Texas: A Comparative Study Between International Dark Sky Places and Control Communities

Theme: Measurement and Modeling

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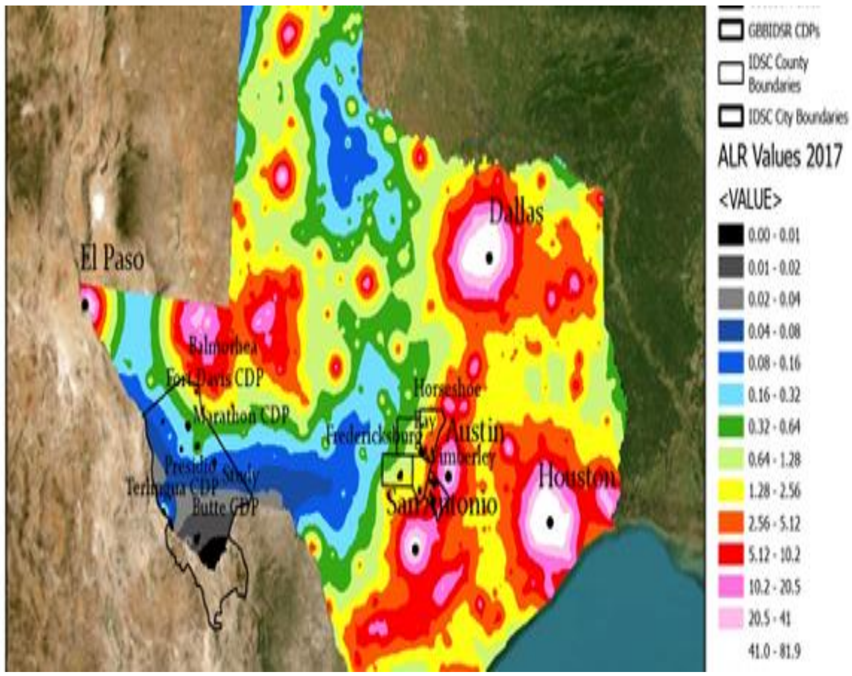
Introduction



As the work of the IDA has been gaining in popularity and an increasing number of parks and communities as well as natural resource conservation areas in Texas have started to become IDA certified places, it is interesting to ask if IDA certified places show a decrease in sky brightness compared to other places that are not IDA certified. This project compared the mean, annual sky brightness between Texas IDSCs and communities inside the Greater Big Bend International Dark Sky Reserve (GBBIDSR) boundaries with control communities using the National Park Service's All Sky Light Pollution Ratio (ALR) sky brightness model and fieldmeasurements of sky brightness in all locations in this study.

Hyde et al. (2019) conducted a comparative study of 98 total control communities to 98 total designated IDSCs or communities located in an IDSR. Overall, they did not find evidence of a difference in trends in upward radiance between IDSCs and control communities (Hyde et al. 2019). A follow up study by Kyba and Coesfeld 2021 duplicated the previous study using VIIRS DNB upward radiance data corrected for radiance of atmospheric airglow which had caused an increase in upward radiance for regions without any artificial lighting for years that overlapped their study, 2017-2018 (Kyba and Coesfeld 2021). According to Hyde et al. 2019, "... we wish to stress one final time that satellite datasets measure upward emission, not sky brightness. Understanding changes in night sky radiance in the IDSP will require ground based observations". Kyba and Coesfeld, 2021 agreed with Hyde et al, 2019 that "Satellite datasets measure upward emission, not sky brightness. Understanding changes in night sky radiance in the IDSP therefore requires ground based observations."

For mapping sky brightness of larger regions, two sky brightness models have been created that use remotely sensed upward radiance data from the Visible Infrared Imaging Radiometer Suite Day Night Band (VIIRS DNB) of the NASA Suomi-NPP satellite. The New World Atlas of Sky Brightness model (Cinzano et al, 2014) shows filtered VIIRS DNB data and was used to create a world map showing zenith, overhead, sky brightness. The

National Park Service created the All Sky Average Light Pollution Ratio (ALR) sky brightness model showing sky brightness taking into consideration sky brightness from horizon to horizon instead of strictly from zenith. VIIRS DNB monthly composites were used as input for the model and along with ground based methods. Their horizon to horizon sky brightness model is important to the visitor experience of a natural night sky at US National Parks as well as wildlife, plants and pollinators that inhabit the US National Parks (Duriscoe et al. 2018). The ALR model also allows for ease of night sky quality interpretation as well as the ability to support landscape assessment and management decisions, both of which are important to the geographic regions in this study.

Methods

This research utilizes upward radiance VIIRS DNB data yet is different in that it uses sky brightness as the metric as predicted by National Park Service's ALR horizon to horizon sky brightness model to compare IDSCs and IDSR communities to control communities between 2012-2022. This project also includes current ground-based sky brightness measurements in each location. The study area of this research encompasses 10 communities within the boundaries of the Greater Big Bend International Dark Sky Reserve (GBBIDSR) in Texas and 5 International Dark Sky Communities in Central Texas and compares sky brightness from 2012-2022 to 15 control communities outside of the reserve boundaries. Results of this sky brightness change study will be concluded in May and available to be presented by the time of the conference.

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Studying change of behavior of greater mouse-eared bats when changing the lighting around roosts with drones, thermal imaging and counting devices

Theme: Biology and Ecology

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Introduction

Light pollution can have diverse negative impacts on flora and fauna. These include also mammals and especially bats, which are highly protected species. Mouse-eared bats (Myotis) are known to be particularly susceptible to artificial light (Voigt et al. 2019), which is a problem because their roosts are usually located within human settlements. There, bats can suffer from façade lighting e.g. of churches (Rydell et al. 2017) or from street lighting, which spills unnecessarily into the aerial space. To better understand those impacts it is crucial to thoroughly quantify the nocturnal light field around bat roosts on the one hand, but also to improve the lighting situation and study changes in behavior when the light has been changed. Here we show results from a two-year multi-site study on greater mouse-eared bats (*Myotis myotis*) using a comprehensive array of monitoring tools to study bat behavior and light measurement tools to measure light from the bats perspective at their roosts and from the aerial space.

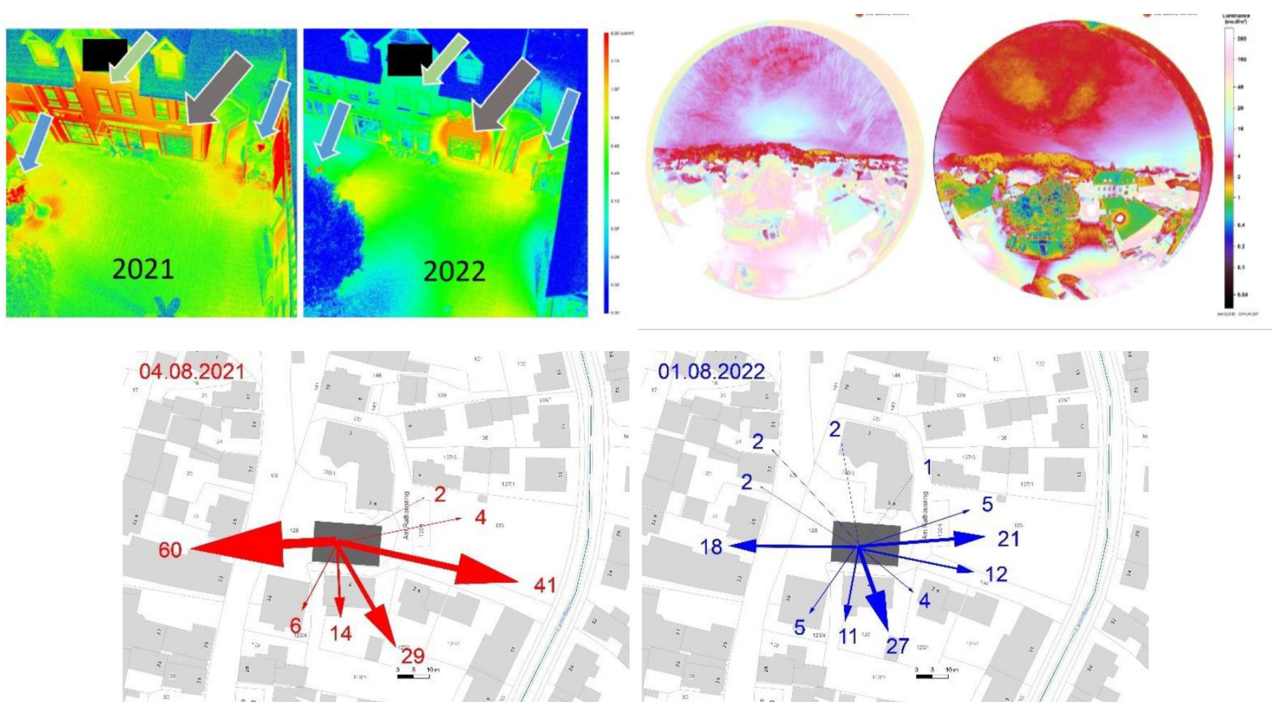

Fig. 1: Summary of results from one of the brightly lit bat roosts. Upper left: Aerial luminance map obtained from a drone before (2021) and after change of lighting (2022). Upper right: Hemispherical luminance map obtained from near the exit point of the bats, left image before and right image after change of lighting. Lower panel: Flight path observation directions before (left panel 2021) and after (2022) lighting change.

Methods

We studied bat behavior at six roosting sites of greater mouse-eared bats over a course of two years with an BACI (before-after control-impact) approach. In the first year the lighting was analyzed and the ”before” behavior was monitored. Afterwards, the lighting was changed at three brightly lit sites and the lighting remained unchanged at three less illuminated sites. Then, the “after” behavior was monitored, with the dark sites serving as controls. We used optical or acoustic counting devices to permanently track the timing of the nocturnal flights, and a thermal camera and personal observations three times per year at each site. We also thoroughly characterized the light field at the bat roosts using a drone with a camera calibrated for luminance to measure in the aerial space (Fig. 1 upper left) and digital cameras with fisheye lenses to measure from the ground and at the exit point of the bat roosts (Fig. 1 upper right). The data from the light measurements was used to identify disturbing light sources, which were then replaced. This included foot path lighting at a two-story building, road and path lighting at a historical town hall and façade lighting with flood lights at a church. At the two-story building path illuminance remained constant, at the town hall the lighting was adjusted to meet a lighting class following road lighting standards and at the church the flood lights were switched off in the second year.

Results

We have characterized the lighting situation around bat roosts from the ground, but also from the aerial space, important for the bats using digital cameras and a drone (Fig. 1 shows one site as example). We identified light sources that impose a disturbance and improved these at three locations. Parallel monitoring with optical or acoustic counting devices, thermal imaging and personal flight observation unraveled a change of behavior. While the analysis of the counting devices is ongoing, a change of behavior was observed with the other two methods. Bats changed their departure direction and flight altitude at all three sites where the lighting was changed. Bats flew in previously lit directions and used lower flight altitudes. At all three sites a diversification of flight direction was observed (see Fig. 1 lower panel for an example).

Conclusions

In this study we showed that the impact of ALAN on evening emergence and commuting behavior of greater mouse-eared bats could be reduced by implementing shielding and other measures to mitigate lighting impacts on commuting behavior. This underlines the importance of taking the aerial space into account when designing lighting to avoid unnecessary spill light. At bat roost exits, light trespass should be generally prevented. This is not in contrast with road safety regulations and recommendations, which were not hampered in the study.

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The BELLVUE project: measurement tools and procedures to quantify ecological light pollution in German nature conservation areas

Theme: Measurement and Modeling

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The BELLVUE project aims to test tools and to develop procedures how to quantify ecological light pollution in and near nature conservation areas. The plan is to on the one hand evaluate the precision and applicability of different light measurement methods (mainly imaging systems) and on the other hand provide guidelines to communities that plan lighting near conservation areas and help conservation agencies and NGOs with adequate tools to assess light imissions into protected areas.

The imaging methods range from state-of-the-art luminance imaging devices with additional multi-spectral capabilities to standard consumer cameras. These imaging methods include hemispherical and 4-Pi approaches (Jechow et al. 2019) and free and commercial software options. Other devices include spectro-radiometers, luxmeters and cheap sensors for smart phones.

Multiple nature conservation areas and also towns with change of lighting in Germany serve as test sites and it is aimed to cover different ecosystems as well as seasonal situations across the project timeline. Also, methods will be tested and evaluated in participative workshops with stakeholders from nature conservation and communities that are non-experts in light measurements but might need these methods to mitigate future lighting conflicts.

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Towards a new reference for ecologically dark skies: pan-continental all-sky measurements of overcast skies at places (almost) free of ALAN

Theme: Measurement and Modeling

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Introduction

The night sky brightness of clear skies without ALAN is relatively well understood. Furthermore, many studies address the problem of clear skies with ALAN and several studies for cloudy skies with ALAN. The amplification of ALAN by clouds is important for ecology and has seen some empirical and theoretical research in the last years (e.g. Kyba et al. 2012; Jechow & Hölker 2019), but measurement and modeling approaches of overcast skies nearly free of ALAN are very scarce (Ribas et al. 2016). However, these natural conditions are important from the point of view of ecology and evolution because nocturnal animals have evolved under the change between clear and cloudy skies without light pollution. To fill this gap, we have measured at very dark places across three continents over the last years. Sites include the Kalahari in Namibia, Sölktal in Austria, Aral desert in Kazakhstan and Kolka Peninsula in Latvia. Additionally, we performed spectral measurements and modeling of overcast skies using the spectral data at the site in Austria.

Methods

At all sites, all-sky measurements with a Canon EOS 6D calibrated with “Sky Quality Camera” (SQC, Euromix, Slovenia) as well as DiCaLum software were obtained. At the dark site in Austria multiple other measurement instruments were used including a spectroradiometer (Konica-Minolta CS-2000A, Japan). Measurements were obtained at different time scales. While at the site in Latvia only a single overcast night was studied, in Kazakhstan and Namibia multiple consecutive nights were studied. The site in Austria was studied over a course of two years.

Results

The darkest values for overcast skies were observed in Namibia (Fig. 1), with zenith brightness as low as 24.2 mags/arcsec² (approximately 0.023 mcd/m²) and illuminances as low as 95 µlx. During a clear night, the zenith brightness was about 21.6 mags/arcsec² (approximately 0.240 mcd/m²) and illuminance was 920 µlx in Namibia. At the Aral desert near Aral Sea in Kazakhstan and at Kolka Peninsula in Latvia, we measured a zenith brightnesses of about 22.9 mags/arcsec² (ca. 0.074 mcd/m²) and illuminances between 210 – 220 µlx. In Sölktal, Austria we measured a zenith brightness of about 23.0 mags/arcsec² (ca. 0.070 mcd/m²) and illuminances as low as 190 µlx. The spectral measurement is shown in Fig. 1c for clear and overcast skies at Sölktal and further Monte-Carlo modeling using the spectral attenuation are in good agreement with the empirical measurements. For comparison: At Berlin Alexanderplatz we measured 430 mcd/m² (13.5 mag/arcesec²) zenith brightness and an illuminance of 1.1 lx. This means Berlin center is more than 18,000 times brighter at zenith and has an illuminance more than 11,000 times higher during an overcast night than the site in Namibia.

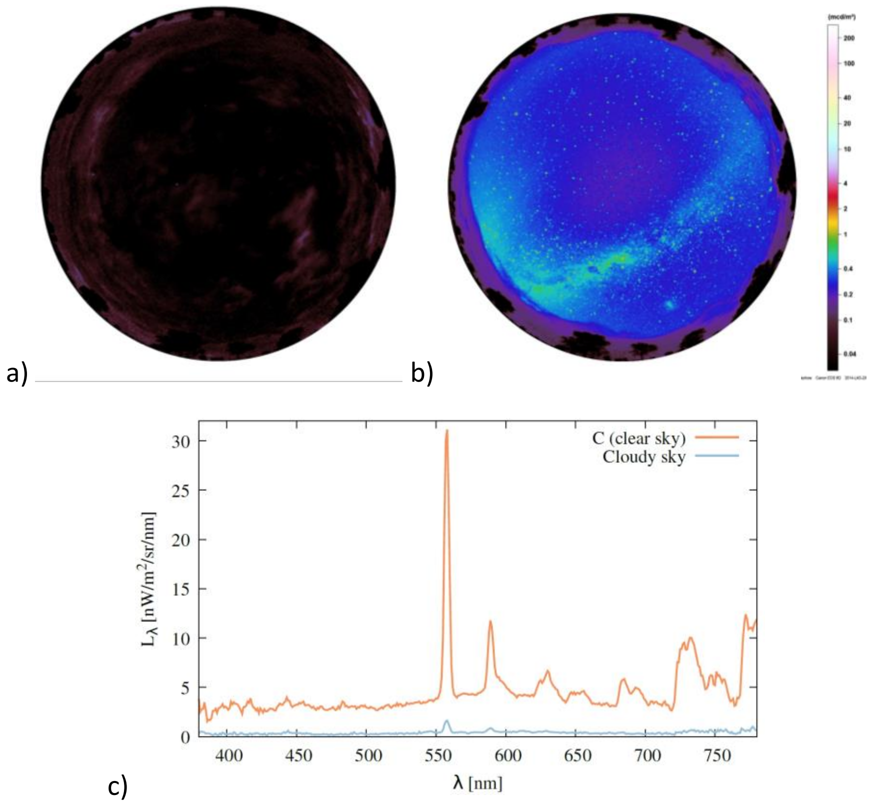

Fig. 1: a) overcast and b) clear sky in Namibia, c) spectral measurements clear overcast in Sölktal.

Conclusions

In conclusion, we have reported the darkest values for overcast sky to date, with zenith brightness as low as 24.2 mags/arcsec² measured during summer in Namibia, where the overall brightness decreased by about a factor of 10. Additional spectral measurements and modeling showed results in good agreement. This is an important step towards a reference for ecologically dark skies using overcast nights free of ALAN.

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Exploring the Interdisciplinary Impact of Light Pollution on Biodiversity through Interactive Live Art

Theme: Social Sciences & Humanities Society

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Introduction

In this study, we present the methodology of an art performance titled "Sentient of Lights" which aims to raise awareness about the impacts of light pollution on various species in the natural environment. The performance explores the theme of contemporary phygital identities, specifically focusing on the powerful resistance and suffering of species affected by light pollution. Through the use of visual and audio elements, the performance aims to give voice and visibility to these creatures, highlighting the challenges that human-beings impose while interacting with light in our environment. The performance also hints towards the journey of light evolution and where we are heading next. The performance is intended to be used as a dark sky outreach tool to educate and engage the general public about the importance of responsible lighting practices. We examined the effects of light pollution on four species using scientific research and local observations, translated into an interactive live art performance featuring wearable art pieces mimicking the species' physiological changes. The performance aimed to communicate the impact of harmful light and bridge the gap between science and art.

The preservation of biodiversity is a crucial concern for the management of urban landscapes in mega-cities, particularly those in pre-industrialized nations. The city of Karachi, which serves as the economic hub of Pakistan, has seen significant population growth and inadequate planning, resulting in a number of ecological issues. To address this issue, a novel approach has been proposed, involving the integration of technology into the design and construction of costumes inspired by various species, referred to as "sentient" characters. This methodology incorporates both fictional and factual elements and challenges traditional techniques of textile and costume production.

Methodology for Creating an Interactive Live Performance: Incorporating Scientific Data on Light Pollution and Specific Species into the Design and Movement

The research methodology employed in this study utilizes a mixed-methods approach, incorporating a variety of intermixing processes such as manual 16mm or HD found footage, camera data with contemporary digital footage, traditional painting with digital collage, and textiles and recycled materials. These techniques were utilized to visualize and explore various distinct storylines and contemporary issues related to light pollution. Additionally, the realm of theatrical costumes and scientific archival data were incorporated into the study to bring attention to the issue of light pollution through the interaction of sentience with the audience. This approach was chosen due to the limited amount of research on the topic in our country, with only sporadic studies being conducted. Furthermore, the study draws on personal experience and observations of older individuals to highlight the changes in terms of species found in the city of Karachi as a result of light pollution.

In this study, we present the methodology of creating a new breed of masks, wearables, and multi-media props that aim to re-examine the relationship between nature and technology. This is achieved through the use of simulation and design techniques such as AI mapping (Chung et al., 2020), movement design (Ducheneaut et al., 2006), and physiological analysis (Jonsdottir et al., 2019) to reassemble marine and landforms. The purpose of these props is to reflect on how our lives have shifted due to subtle global environmental events of recent years and comment on the impact human beings have had on the environment. The larger narrative of co-existence and symbiosis that we disturb, rearrange, and redefine in our surroundings makes us rethink and imagine our collective future. The species become a conduit to communicate the essence of light pollution full circle across generations and time.

Conclusion

In conclusion, this study presents a novel approach to raise awareness about the impacts of light pollution on biodiversity by integrating technology into the design and construction of costumes inspired by various species. Through the use of visual and audio elements, the performance titled "Sentient of Lights" aims to give voice and visibility to these creatures and highlight the challenges that human-beings impose while interacting with light in our environment. The performance also hints towards the journey of light evolution and where we are heading next. The study was based on the analysis of available scientific data and research on specific species affected by light pollution, utilizing archival data, research, and local observations. The performance uses wearable art pieces that mimic the physiological changes of the species and communicate the effects of harmful light in an interactive live art performance. The performance is intended to be used as a dark sky outreach tool to educate and engage the general public about the importance of responsible lighting practices, thus bridging the gap between the public and the effects of light pollution on biodiversity.

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Public light planning: finding the right balance

Theme: Governance & Regulation

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Light planning in the public space has to consider several parties, whose needs and expectations are sometimes contradictionary and might not be balanced adequately. Currently, light planning considers primarily the following aspects:

(1) requirements for car drivers and, to a lesser degree, bike riders and pedestrians
(2) the perception of safety in (potential) pedestrians
(3) energy efficiency

To achieve (1), planers refer to lighting norms and regulations. However, these norms have been criticized for overly high light levels and for having a small empirical basis. Also, the underlying research has mostly been performed on young healthy adults, mostly men. People with visual impairments, elderly people and children are rarely included into these trials (Fotios & Gibbons, 2018; Radicchi & Henckel, 2023). The idea that brighter light levels result in less accidents has not been proven yet, data from Leeds, UK, suggest that it could even have opposite effects (Richard & Paul, 2022).

For (2), scientific data are even smaller. There is no clear evidence for an objective increase in safety with brighter lights (Steinbach et al., 2015). This leaves the argument of perceived safety. Though women's safety and fear of sexual assault are a common argument for more light, there is a lack of studies on light scenarios and their perception by women. A study by ARUP and Monash University suggests that for women, bright areas do not necessarily feel safer since contrasts are higher and dark spots are created by bright light (ARUP, 2022).

(3) has entered light planning as reaction to climate change and has led to a transformation of streetlights to LED technology. Since energy efficiency roughly increases with color temperature and blue content, this results in an increase of white light. Contrary to the goal of energy saving, there has additionally been a rebound effect of using more light and illuminating areas between settlements.

In the last years, there has been growing research on the ecological consequences of ALAN, showing that while all light is detrimental to nature, the negative impacts generally increase with the blue content. The positive long-term global effects of energy efficiency therefore need to be balanced against the immediate and mid-term local damage.

Another group usually overlooked are residents. Streetlights are planned for road users. In Germany and many other countries, residents have to accept light trespass by streetlights, even if the light enters their bedrooms. However, evidence that ALAN is detrimental for health is increasing, i. e. mental illness, obesity, cardiac diseases and breast cancer. Are these negative effects balanced against the safety from crime and accidents?

Health problems caused by ALAN are usually linked to melatonin suppression but it has not been proven if the average light trespass into bedrooms is enough for this. There are, however, other modes of action by which light can interfere with health. ALAN has been shown to raise blood pressure and alertness without melatonin suppression. Similar with noise, ALAN can directly cause a stress response, raise stress hormone levels, interfere with sleep onset, and weaken the immune system (Münzel et al., 2021). Light trespass is also regularly perceived as an intrusion into private space, gardens and rooms loose livability if illuminated by streetlights. This can result in chronic stress and anger in residents. While noise is generally accepted as stress factor, light at present is not.

Fig. 1: Light planning must consider different aspects and find the right balance between them.

To improve public light planning, the protection of residents and local nature needs to be considered and balanced against objective safety, perception of safety, and energy efficiency. Even more, the necessity of light on a local and temporal plane needs to be challenged. Light planning must step away from strict following of numbers towards the creation of complex, adaptive lighting situation. The amount and quality of light needed for safe traffic and against crime needs to be determined scientifically. In communities, the need of residents for healthy darkness must have at least equal weight as the subjective expectations for safety. We also need more education on the dark side of ALAN and good light planning for residents, communities, and lighting professionals.

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Long-term consequences of ALAN during early postnatal period

Theme: Biology and Ecology

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Introduction

The circadian system allows organisms to adapt and synchronize to a 24-hour period, ensuring an increase in efficiency of physiological and behavioural functions to the most appropriate time of day. The generation of the 24-hour period is made possible by the transcription-translation feedback loop of clock genes present in most cells and tissues. The entire system is synchronized by the central clock in the SCN in the hypothalamus, whose rhythmic activity is based on and controlled by changes in light intensities during the day and night (Hastings et al., 2018; Patke et al., 2020). If there is insufficient contrast in light intensities between day and night in the environment, or if the organism is in a 24-hour constant light, the rhythmic activity of the SCN is lost and its ability to synchronize oscillators in the rest of the body to a uniform time is impaired. In the presence of intense light at night or 24-hour constant light, a number of serious health complications can develop. These can range from reduced sleep quality or deterioration of cognitive abilities in the morning, to the development of metabolic syndrome and/or insulin resistance, and an increased likelihood of developing cancer or faster tumor growth if cancer is already present (Coomans et al., 2013; Guerrero-Vargas et al., 2017; Fonken, et al., 2010). Severe symptoms can be observed after only a few weeks of constant light. If no malignant disease has developed, the health status of the adult individual also returns to its original state when returning to the standard LD12:12 light regime. However, recent studies show that long-term health complications develop when an individual is exposed to constant light conditions during early postnatal development. These include a significant development in the occurrence of anxious behavior, changes in the rhythms of clock gene expression in many tissues or a decrease in the sensitivity of the circadian system to light pulses (Canal-Corretger et al., 2001; Cissé et al., 2016). We investigated the extent of these long-term changes in the circadian system and behaviour due to light at night during the critical phase of circadian clock development.

Methods

The experiment was conducted on Long-Evans rats, which were exposed to constant light (light intensity = 30 lx) for 20 days from birth. The animals were then placed on a standard LD12:12 light (30 lx) and from day P60 were tested in the Open Field Test and the Elevated Zero Maze to detect anxiety-like behavior. On day P90, all animals were sacrificed at 4 time points (CT2, CT8, CT14, CT20) and samples of brain regions and peripheral organs were collected for gene expression determination. After RNA isolation and reverse transcription into cDNA, gene expression was determined by the RT-qPCR method.

Conclusions

We could confirm that constant light during early postnatal development causes an increased occurrence of anxiety-like behaviour. We also found significant shifts in the acrophase of clock gene expression rhythms in the retina. Significant changes in the expression rhythm of the clock gene *Nr1d1* were found in the samples from the frontal cortex, the parietal cortex and the hippocampus. The hippocampus was the most affected structure we investigated. In addition to the changes in clock gene expression, we also detected a loss of the rhythmic expression of NMDA receptor subunits and a significant increase in the expression of the *Bdnf* gene. Our data show significant changes in the hippocampal gene expression pattern and increased anxiety-like behavior in animals exposed to constant light during the critical period of circadian clock development.

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Satellite imagery as a tool for identifying light pollution sources

Theme: Measurement and Modeling

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Introduction

With the onset of modern technologies, electric light is becoming more affordable commodity, contributing to the continuous growth of visible light pollution (Kyba et al., 2017) (Falchi, 2016). Public lighting and architectural lighting provide safety and visual comfort in urban places during the night but also represent a significant contributor to this growth. Recent research studies point to the negative effects of light in the nighttime environment when excessive levels are used (Gaston et al., 2015). By limiting inefficient lighting, we can help to maintain a healthy environment (Bennie et al., 2016) with respect to human and animal physiology (Robert et al., 2015), as well as the overall sustainability of lighting installations (Maierová, 2018).

Obtrusive light in public spaces is mainly caused by inadequate choice of the intensities of installed light sources, but also by incorrect set light flux direction and timing (Schroer et al., 2020). This paper discusses the use of satellite imagery for identifying locations with obtrusive light in the structure of urban settlements.

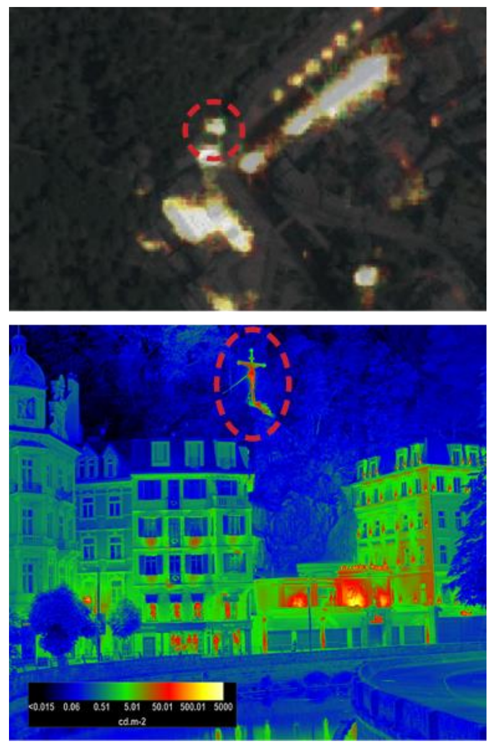

Fig. 1: Detail of a satellite image at a predefined critical spot with luminance map verification

Aims and Methods

The analysis directly focuses on the identification of critical spots with inappropriate lighting in the city of Karlovy Vary (CZ). Night satellite images of the city were used to identify po+tential critical spots and its relevance was further verified by field investigation and luminance mapping of the area, see Figure 1. All images were taken in the first half of 2022. The satellite data collection was carried out under favourable weather conditions, mainly cloud-free sky necessary for correct interpretation of the results. The imagery provided separate data in three basic electromagnetic spectra - red, green and blue, all with resolution 1 px/m^2. The images provide information on the intensities of the illumination in pixels, and thus the possibility of individual evaluation of light emission into the surroundings. To accurately identify the location, the data was entered into a geographic information system (GIS) that allows the images to be interlaced with the individual map bases.

The critical spots were evaluated on the aggregate image as well as separately in each spectral layer. By separating spectra, it is possible to determine the contribution of LED sources with a higher representation of short wavelengths (blue, partly green) compared to older sodium sources, in whose short wavelengths are almost absent. A particular attention has been paid to the interpretation of images displaying short wavelengths, due to the proven negative impact on the environment and the dire effect on the chronobiological rhythm of the human body (Wahl et al., 2019). A local investigation was subsequently carried out with the use of luminance and spectral analyses in each of the spots of interest in order to verify the accuracy of the interpretation of the satellite image results.

Conclusions

Satellite imagery was proven to be a useful complementary tool for identifying light pollution spots. It is a quick and efficient method for determining critical locations. Less noticeable pollution sources (e.g. department store skylights and some types of advertising lighting) can also been detected in the environment. The cost of the satellite imagery as well as the need to be mindful of favourable weather conditions when taking the images can be a drawback of this method.

The critical spots identified in the city of Karlovy Vary demonstrated the use of lighting in excess of the recommended illumination intensity, improper routing or insufficient shading of light directed outside the target area of interest. Such use of light is inefficient for both visual and safety purposes and should be restricted to the maximum extent possible. A significant failure was found in the application of lighting systems used for architectural and advertising purposes. These types of lighting are intended to perform only a complementary role within an urban settlement. We expect that by reduction and correct adjustment we will achieve a reduction in light pollution of the area, energy savings and an improvement in the visual comfort of the users.

Acknowledgements

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Analysis of aerial imagery of Cologne, Germany, in 5 spectral bands

Theme: Measurement and Modeling

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Introduction

On December 20, 2021, we acquired imagery of Köln, Germany in 5 wavelength bands ranging from the ultraviolet to the near infrared (Fig. 1), over an area of several hundred square kilometers. In this work, we examine the relationship between land use, building type, and light emissions in the different wavelength bands, following methods similar to those presented in Kuechly et al. (2012). The major advances over previous work are the expansion from one to five spectral channels, and new methodology for creating mosaics with different look directions.

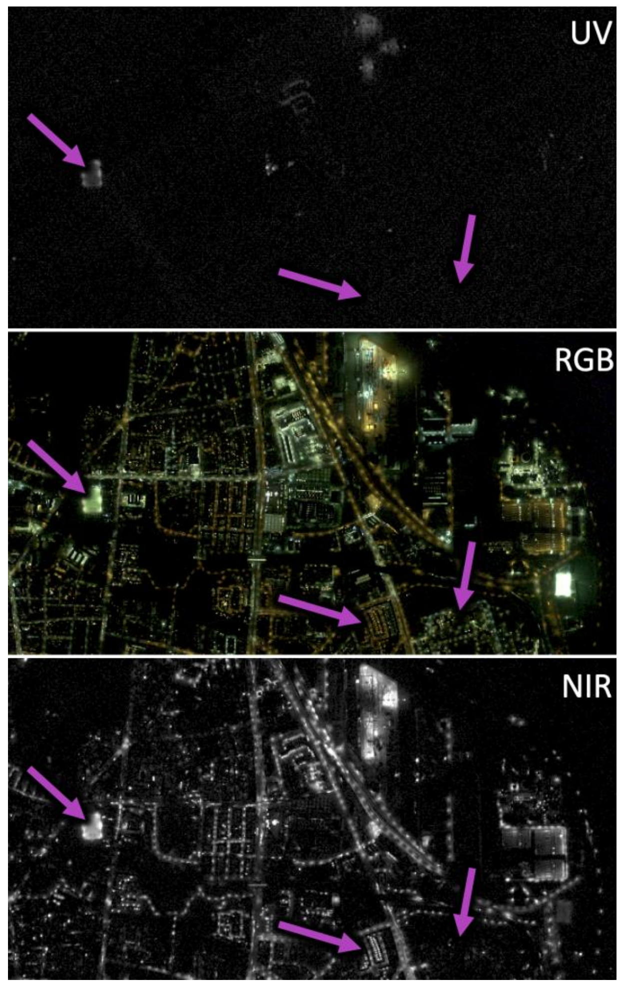

Fig. 1: Images of part of Cologne in five spectral bands, ultraviolet (top), visible red, green, and blue (middle), and near infrared (bottom). The arrows indicate three areas with greatly differing spectra.

Methods

Images were acquired using four cameras: a Pro-EM-HS:1024BX3 with a 16 mm lens (UV), a Nikon DS4 with a FX 50 mm lens and a Nikon Z7 with a FX 2 0mm lens (both visible), and a Teledyne Photometrics Kinetix with a 24 mm lens(NIR). Images were taken roughly every five seconds apart, with visible band images cycling between three different apertures in order to capture an expanded dynamic range. Images were automatically georeferenced based on position (GPS) and orientation of the camera systems using new python code based on the same principles as in Kuechly et al. (2012).

We developed new stitching algorithm produce the mosaics. In the new algorithm, a desired direction is specified, and the angle of emission is compared to this look angle for every pixel in every image. For each position on the ground, all photographs are examined to find the image for which the view direction most closely matches the desired emission direction, and this image's data is added to the mosaic. We have produced mosaics for emission primarily towards zenith, and also for emission at 45° relative to zenith for the 8 major compass directions (Fig. 2).

For the attribution analyses, we used an ALKIS® land use map (Amtliche Liegenschaftskataster-informationssystem - Official Real Estate Cadastral Information System). At the time of writing, we planned to use 15 distinct land use categories in our analysis. We also performed a complementary analysis on light emissions from 20 different building types.

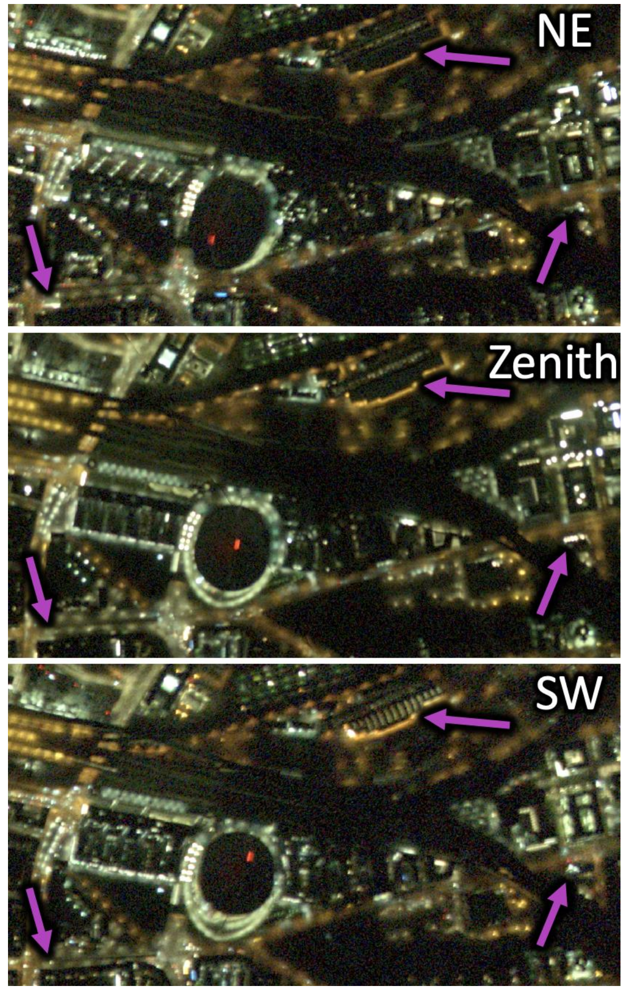

Fig. 2: Images of the region near the Lanxess Arena in Cologne, acquired from three different look directions: from the northeast (top), from the zenith (middle), and from the southwest (bottom). The arrows indicate light sources that are only visible from one of the three look directions.

Discussion

Our presentation will mainly focus on an overview of the results of our spatial analyses, in particular examining the extent to which different land use categories or building types are characterized by different spectra from each other. We will also report on the degree to which the contributions of emissions observed at higher slant angles to different land use classes match or differ from the nadir view.

Finally, we will also present examples of lights that saturate the camera even at our smallest aperture, demonstrating the extraordinary dynamic range of nighttime emissions at high resolution.

Acknowledgements

This work was undertaken within the CALEC project, with funding from Stadt Köln.

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Steadily increasing light pollution from artificial satellites in the night sky worldwide, and in astronomy research images

Theme: Society

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Modelling Future Satellite Light Pollution

In Lawler, Boley, & Rein (2022), we presented models of what the night sky will look like with light pollution from 65,000 satellites, as viewed from different latitudes, different seasons, and different times of night. In this night sky model, satellites have been placed on the orbits 4 operators (SpaceX Starlink, OneWeb, Amazon Kuiper, and China's StarNet/GW) have stated they plan to use (as of late 2021). The reflection model is calibrated to observations of Starlink satellites measured by a 1.8m telescope located at latitude 50°N in July 2021 (Boley et al. 2022), when Starlink satellites are visible all night long due to orbital and Solar geometry.

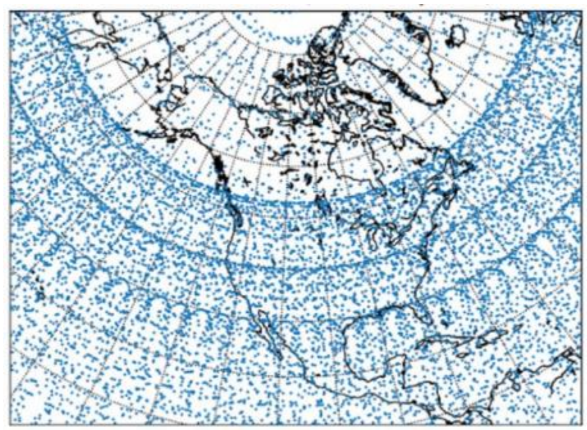

Fig. 1: A snapshot of the instantaneous distribution of 65,000 satellites on the orbits planned by their operating companies as of 2021. Adapted from Lawler, Boley, & Rein (2022).

All code for the models used in this work is public: https://github.com/hannorein/megaconstellations/ and simulation movies are available here: https://uregina.ca/~slb861/satcon.html

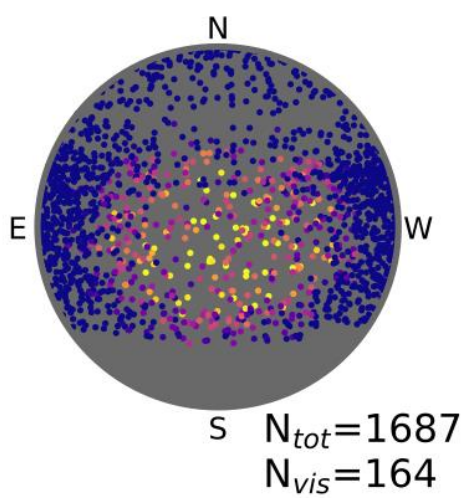

Fig. 2: The number, position, and brightness of satellites predicted in an all-sky view from latitude 50N on the June Solstice. All coloured dots are sunlit satellites, and pink, orange, and yellow dots are naked-eye visible. Adapted from Lawler, Boley, & Rein (2022).

Our models show that satellite light pollution will be worst at ~50°N and S, where solar geometry and the orbits chosen by operators combine to make potentially hundreds of naked-eye visible satellites all night long near the Summer Solstice. From latitude 50°N on the June Solstice, for example, one in 15 naked-eye-visible stars in the sky will actually be a moving satellite. Meanwhile, from latitude 20°N (Hawaii, where many research telescope are located), there are about 3 hours of no sunlit satellites within 30 degrees of zenith on the June Solstice, and longer satellite-pollution-free periods for the rest of the year.

We show that placing satellites on higher orbits (~1200km altitude, where OneWeb is operating) reduces the number of naked-eye-visible satellites, while increasing the number of sunlit satellites in the sky for a large range of latitudes, affecting more research telescope sites. Conversely, placing satellites on lower orbits (~550km altitude, where Starlink is operating) produces more naked-eye-visible satellites, but visible from a smaller range of latitudes. There is no singular orbital altitude in Low Earth Orbit (LEO), where these companies want to operate, that will help protect the night sky for all users.

These light pollution predictions are dependent on satellite engineering. If satellite companies make it a priority to reduce satellite reflectivity, and/or to use fewer satellites to provide service, the disruption to the night sky could be dramatically lessened. Starlink demonstrated that they have the ability to greatly reduce brightness from average V-mag ~ 4.5 to V-mag ~ 6.5 by adding visors. However, the 2nd generation Starlink satellites are almost 10x as massive (the size of Ford F-150s) and do not include visors, but instead include new anti-reflection coating, which astronomers will soon discover the efficacy of in our new data.

Measuring Current Satellite Light Pollution

We have begun preliminary measurements of the impact of bright satellite streaks in astronomical research data from the LiDO (Alexandersen et al. 2023) and CLASSY (Fraser et al. 2023) Surveys, both using the wigde-field Megacam instrument on the Canada-France-Hawaii Telescope. LiDO gathered about 70 hours of data in 5 minute exposures in two large blocks on the sky to discover new high-inclination trans-Neptunian Objects (TNOs) between Feb. 2020 and July 2023. CLASSY gathered over 150 hours of data in 5 minute exposures from 5 different blocks on the sky, starting in Aug. 2022, with the goal of detecting the smallest and most distant TNOs known.

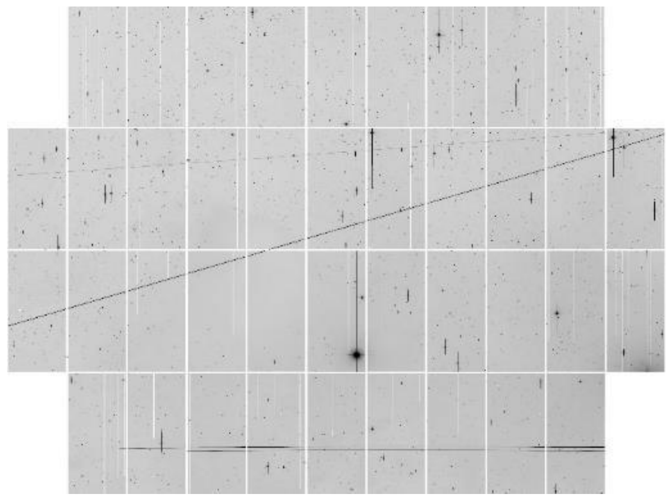

Fig. 3: A publicly available, unprocessed CFHT Megacam image (in negative) from 2021 with 4 visible satellite streaks, oriented diagonally and horizontally across image. (Vertical lines are chip gaps and "bleeding" from bright stars in the image.)

During the time period over which these two surveys have operated, SpaceX has launched well over 4,000 Starlink satellites (McDowell, 2023), and we expect that the impact to wide-field astronomical surveys will be dramatic as the number of bright satellites in LEO continues to increase.

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Artificial light at night affects crickets' gene expression and circadian behavior

Theme: Biology and Ecology

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Introduction

Many animals depend on light detection for their temporal adaptation and synchronization to the earth's diel and seasonal cycles. Perceiving the light rhythmicity and entraining to it is crucial for hormonal, physiological, as well as gene expression regulation. It synchronizes sleep and key behaviors, including foraging, predator avoidance, courtship, and mating.

Artificial Light at Night (ALAN), an anthropogenic pollutant, refers to changes in light intensity, spectrum, and exposure. ALAN disturbs the perception of the light cycles, and negatively affects various behaviors, daily activity patterns, and molecular processes of many animals, including insects (Borges, 2022; Owens & Lewis, 2018).

The nocturnal field cricket (*Gryllus bimaculatus*, Fig. 1) has been widely used as an insect model in neuroethology studies, and for characterization of the circadian clock (Tomioka & Matsumoto, 2019). Following exposure to changes in illumination patterns, it expresses temporal shifts in its stridulatory and locomotor activity, and circadian gene expression (Loher, 1989; Tomioka & Matsumoto, 2019). Moreover, we have recently reported that lifelong exposure to even dim ALAN (low intensity of 2 - 5 lx) disrupts the synchronization of stridulation and locomotion behaviors within the same individual and among the population (Levy et al., 2021). Following these findings, we studied two further aspects of the effects of ALAN in the cricket model: (i) changes in transcriptional factors following exposure to a pulse of ALAN, and (ii) the effects of ALAN on stridulation behavior in a semi-natural environment. Our findings in both research projects indicate a light intensity dependent transcriptional and behavioral response, depicting the alarmingly wide range of influences of ALAN on insects.

Fig. 1. A male, adult, *Gryllus bimaculatus* cricket.

Methods

Crickets were reared under a 12h light:12h dark cycle (LD, white fluorescent light). Males 3-7 days post adult emergence were removed from the breeding colony and placed in the relevant experimental setup. In the molecular experiment, crickets were exposed to a 30-minute light pulse of 2, 5 or 40 lx during the night. One hour following the light pulse, crickets were sacrificed, and RNA was extracted from four tissues. The relative expression of five circadian clock associated genes was assessed using qPCR and compared using a Nested ANOVA.

In the semi-natural experiment, crickets were placed outdoors and exposed to shaded natural lighting conditions. Individuals were subjected to one of seven different ALAN treatments: from LD (light < 0.01 lx), and up to constant light of 1500 lx. A Swift autonomous recording unit above each enclosure recorded the cricket's stridulation for 14 consecutive days and nights. For each specimen, the periods of the daily activity rhythms were calculated, and their median compared using the Kruskal-Wallis test.

Results and conclusions

The results of the molecular experiment indicate a gene, tissue, and light intensity-dependent transcriptional response. Even a dim light pulse elicited tissue-dependent up- or downregulation of expression in some of the genes inspected. The strongest effect was observed in the optic lobe, the cricket's pacemaker, where a linear discriminant analysis clearly revealed a substantial difference between the LD and all ALAN treatments (Fig. 2). A strong effect was manifested in the brain, too, where the expression of opsin-Long Wave (opLW), cryptochrome1¬-2 (cry), and period (per) was significantly upregulated ($p < 0.05$ for each).

In the semi-natural experiment, crickets under LD stridulated at night, presenting a behavioral rhythm of 24h. While the control crickets were synchronized to the LD cycle, an increasing proportion of the crickets exposed to the various ALAN intensities (>5 lx) demonstrated free-running behavior (presenting an endogenous rhythm, not synchronized with the environment). The median period of stridulation activity differed significantly between LD conditions and treatments >100 lx intensity (Kruskal-Wallis test, $p < 0.05$). These light-intensity dependent changes in activity rhythms resulted in loss of synchronized stridulation behavior between individuals and therefore among the population, potentially affecting courtship and reproduction behavior in the field cricket.

These findings demonstrate the multi-level effects of ALAN, indicating that even exposure to dim ALAN may profoundly affect insects at the molecular and behavioral levels. We further present here a clear effect of ALAN on internal, transcriptional responses and on stridulation activity of the individual and the population, under semi-natural conditions. We present crickets as an insect model representing possible effects of ALAN on many other nocturnal, ground dwelling creatures.

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Changes in the Association Between GDP and Night-Time Lights During the COVID-19 Pandemic: A Subnational-Level Analysis for the US

Theme: Measurement and Modeling

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Introduction

Night-time light (NTL) data have been widely used as a proxy for the economic performance of regions [1]. These data are advantageous over the traditional census approach due to their timeliness, low cost, and consistency. Recent studies [2,3] explored monthly NTL composites produced by the Visible Infrared Imaging Radiometer Suite (VIIRS) and revealed a dimming of light in countries during the lockdowns due to the COVID-19. A visual inspection of the VIIRS-recorded NTLs in March 2020, when COVID-19 started in the U.S., shows a sharp decline of NTL (Fig. 1, top), compared to the corresponding pre-pandemic periods (Fig. 1, bottom).

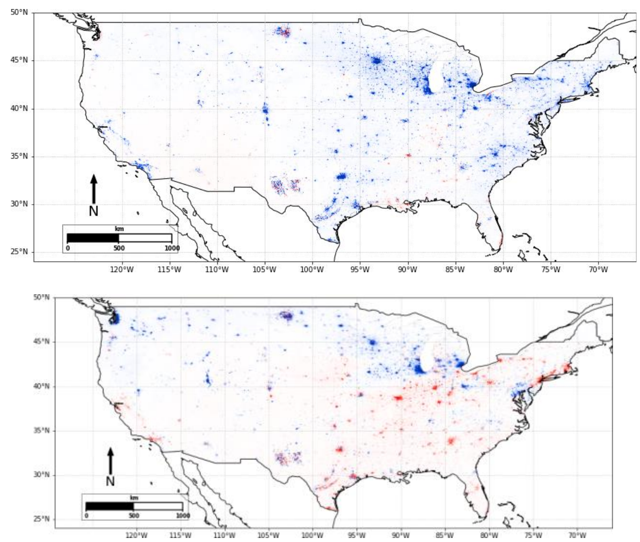

Fig. 1: Changes in night lights: *after* the COVID-19 pandemic, Mar. 2020 vs Feb. 2020 (*top*), and before the pandemic, Mar. 2019 vs Feb. 2019 (*bottom*).
Notes: Blue and red pixels stand respectively for dimmer and brighter NTL signals. We excluded from the analysis Alaska, Hawaii, and Puerto Rico states due to their geo-locations and data inaccuracy contributed by volcanic activities and auroras.
Source: Authors' calculations based on VIIRS data from the Earth Observation Group [4].

This paper aims at examining to which extent NTL data can serve as a proxy for the economic performance during crisis times, assessing the pandemic-induced state-level GDP losses, and investigating the links between socio-economic characteristics and economic impact.

Methods

The analysis was conducted in several steps. *First*, we filtered out the NTL with low cloud-free coverage and low average radiances to avoid background noise. We used a stray-light corrected version of the monthly cloud-free composites of the VIIRS Day/Night Band NTL data collected by NASA and NOAA and distributed by the Earth Observation Group [4]. The utilized NTL data are of 15 arc-second (~500 m at the Equator) spatial resolution and report averaged through month daily observations of NTL radiance in nW/cm2/sr [4].

Second, we examined relationships of the latitude-adjusted NTL data with state-level GDP over the pre-pandemic period (2014-19) on a quarterly basis. To check whether NTL data remain a reliable proxy for GDP during the pandemic, we developed a linear mixed effects model:

$$\log(GDP_{i,t}) = \alpha + \beta \log(SoL_{i,t}) + \sum_{q=2}^{4} \delta_q Q_q + \gamma Year_{\text{adj}} + \mu_i + \epsilon_{i,t}$$

where log(x) stands for the natural logarithm of x; $SoL_{i,t}$ the sum of lights in the i^{th} state for the t^{th} time period; Q_q the quarterly dummies using Q_1 as a reference and is implied to account for seasonal NTL changes; $Year_{adj}$ the year minus 2013 (so the series starts with a value 1 in the year 2014) and is implied to account for long-term dynamics of NTLs; μ_i the time-invariant state effects; $\epsilon_{i,t}$ the error. We then extended the model to 2020-21 with additional interactive terms of year-quarter dummies:

$$\log(GDP_{i,t}) = \alpha + \beta \log(SOL_{i,t}) + \sum_{q=2}^{4} \delta_q Q_q + \gamma Year_{\text{adj}} + \sum_{q=1}^{4} \rho_q Y_{2020} Q_q + \sum_{q=1}^{4} \phi_q Y_{2021}\, Q_q + \mu_i + \epsilon_{i,t}$$

Third, we assessed the economic loss compared with the counterfactual GDP estimate (in the absence of COVID-19). We used the model built for the period of 2014-19 to predict GDP for each quarter of 2020-2021. We then compared them with the corresponding actual GDP values to calculate three metrics to measure economic impact: maximum loss, total loss, and the number of quarters until recovery to 2019 Q4 GDP level. *Finally*, we examined the association between socio-economic characteristics and the magnitude of loss and speed of recovery by performing a cross-section analysis at the state level. The dependent variables include three metrics measuring economic impact, while the independent variables include GDP per capita, racial composition, and sectoral composition.

Conclusions

Our results showed that NTL data remain a reliable proxy for the economic development at the sub-national level even under external shocks. The magnitude of loss due to COVID-19 as well as the speed of recovery varied widely, with most states the ratio of maximum quarterly loss ranging from ~10% to ~15% of the pre-pandemic level in Q4 2019, and the total loss ranging from ~5% to ~15% as of GDP-2019. As of Q4 2021, 42 out of the 49 states recovered to the 2019 Q4 GDP level. The states with a lower initial pre-pandemic GDP per capita, a higher share of low-paid services jobs with limited remote work possibility, and a higher minority ratio suffered larger economic loss and less speedy recovery post-pandemic. Our study added value by using the NTL to measure changes in the quarterly GDP at the sub-national level in the U.S. before and during the pandemic.

The findings provided new insights of using NTL to overcome information gaps, particularly for countries and regions where traditional socio-economic measures are unavailable, infrequent, or inaccurate. This helps policymakers take swift and informed action to assist the most vulnerable in stressful periods.

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Illumina-Light v2, the PC version of Illumina

Theme: Measurement and modeling

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Illumina is one of the most precise and reliable light pollution models at the time of this writing. It estimates hyperspectrally the radiance and irradiance received from direct light and first and second order scattered light. It takes into account the heterogeneity of light sources (spectral emission, light output pattern) and the blocking effect of obstacles. It also takes into account the reflection off the ground and the orography of the terrain. The results obtained by the model have been validated in several studies [2][3][4].

This model, however, has been hardly used outside the developing team. There are two main reasons. The first reason is that it takes weeks (for a light pollution expert) to learn how to handle all the variables and files that the model requires. And second, because it is designed to be run in a CPU cluster, a kind of facility not available for many.

Illumina-Light aims to solve those problems. The first version was presented last year in the LPTMM conference and the IAU General Assembly with a good acceptance by the community. Illumina-Light is a simplified version of Illumina designed to be run in a domestic laptop. It is managed from a user-friendly visual interface that allows the user to estimate the sky brightness for the zenith direction in any location desired in less than ten minutes (8 CPU laptop). Moreover, Illumina Light is prepared to integrate natural sky brightness models, such as Gambons [5], in order to provide a total sky brightness value that can be compared to measurements.

We present here an improved version of the Illumina-Light ALAN model. In the first version the model only computed the radiance in the V band of the Johnson's system. This new version includes the B band, the photopic and the SQM response. Another major improvement of the new version is the possibility to compare the radiance observed with different lighting scenarios. In this sense, we used the new version of the model to study two cases. First, the city of Tucson, Arizona, where most of the lighting was changed from HPS to LED between 2015 and 2017. This case was already studied and documented by Barentine et al. [6], we used their work as a reference for validation. Second, a small town in Extremadura (Spain), Villaverde de Burguillo, experienced a controlled black-out during an hour in June 2022. The changes in sky brightness were well documented at several distances from the town with 22 SG-WAS photometers [7].

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Night Watch, a New Earth Observation Mission Idea

Theme: Technology and Design

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Night Watch is a new concept for a night-time visible band observation satellite that received European Space Agency (ESA) support through the inaugural round of its New Earth Observation Mission Ideas (NEOMI) program. This new initiative from ESA aims to expand the Earth Observation (EO) community, attract more ambitious and bolder mission proposals, mature science and technology missions to reduce risk for selected missions, and to grow and diversify the community of EO scientists and leaders.

The NEOMI projects are not linked directly to an actual mission, rather it is an enabler to develop and design a new mission idea. The duration of the NEOMI is one year, at the end of which the design of Nightwatch will be completed. However, the intention of both ESA and our group is to use the knowledge gained to apply for ESA satellite missions - even before the NEOMI is over. In particular, our group hopes to lead the development of an Earth Explorer proposal for the next call.

Our project addresses the very limited number of satellites specifically designed for measuring the nocturnal radiance of Earth in the visual band. Although not designed specifically for night-time observation, the only current satellite sensor with daily near-global coverage is the Day/Night Band (DNB) of the Visible Infrared Imaging Radiometer Suite [1]. However, its data is far from ideal for most night-time studies. Fine details about lighting configuration and location are lost due to a spatial resolution close to 750 m per pixel. Also, it does not provide any spectral information (colors), as it has only a single band. Unfortunately, that band extends from 500-900 nm, which means it has no sensitivity to the critical blue part of the visual range (400-500 nm). This is a major problem at the moment, because it misses the blue peak of LED lights that typically is between 420 and 460 nm. A small number of other satellites are able to acquire night light data (including astronaut photographs from the ISS [2]), but this data is typically uncalibrated, not regularly acquired, with major gaps in many regions of the world (particularly the Global South), and (especially in the case of commercial satellites, such as the Jilin-1 series or CESAT by Canon) not freely available.

While the Nightwatch concept is still in development, we anticipate that it would obtain high spatial resolution images (10-100 m), in a multiband approach (R, G, B and broadband), covering the spectral band from 400 to 900 nm to allow comparison to VIIRS DNB. Depending on final decisions regarding resolution, it may be possible to obtain near global coverage with a revisit time shorter than one month. The duration of the mission is expected to be at least five years, although the development team has a strong preference for a longer duration (approaching 10 years) in order to allow observation of lighting change over time.

The list of possible applications for this satellite concept is long. Our group has so far conducted interviews with representatives from 13 different groups or application areas, with further interviews planned. These interviews have indicated a great interest across diverse fields, including urban planning and development, socio-economic research, ecology, energy, human health, legislation, light pollution modeling, meteorology, building stock and material flows. We expect this list of application fields to grow even before the construction of the actual satellite, for example via outreach activities such as discussions at the ALAN conference.

One of the main challenges for the collaboration is in selecting a single, or at most a small number, of science applications which will drive the instrument technical requirements from among the diverse set of possible applications. While the mission concept will eventually focus narrowly on these specific science applications, it is our expectation that the satellite will deliver data that benefits many or most of the diverse application areas.

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Migration in the spotlight: A comparative investigation of behavioural responses to artificial light at night in nocturnal migrant and non-migrant songbirds

Theme: Biology and Ecology

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Introduction

One of the most rapidly growing forms of environmental pollution, artificial light at night (ALAN) deserves much more consideration in the context of global stressors. Nocturnal migratory songbirds are particularly vulnerable to ALAN from its high concentration within the migratory flight paths of birds, the wide range of behavioral and physiological consequences from exposure, and the high sensitivity and dependence of nocturnal migrants on changing photoperiod and low-level light. The objectives of this study were to quantify through captive experiment if ALAN alters the propensity of nocturnal migrant songbirds to migrate, hypothesizing that nocturnal migrants are more sensitive to changes in ALAN during migration, using behavior as an indicator.

Methods

In spring of 2021, we captured two nocturnal migrant species, Gambel's white-crowned (*Zonotrichia leucophrys gambelli*) and White-throated sparrows (*Z. albicolis*), and a nonmigratory comparison species, the house sparrow (*Passer domesticus*). In the spring, summer, and autumn, we completed captive, behavioral experiments at the Facility for Applied Avian Research (FAAR, University of Saskatchewan, Saskatoon, Saskatchewan, Canada). Birds were housed in individual cages within indoor climate-controlled aviaries following natural photoperiod and temperatures. In each season, we recorded their behavior over a four-day period using infra-red video cameras. At night, the birds were exposed to a dark treatment (< 0.01 lux) as control for two days, and then one of four ALAN treatments (0.15 lux, 0.5 lux, 1.5 lux, 10 lux) for another two days in a crossover design. We analyzed their activity using animal motion-tracking software, and developed an ethogram for behavioral observations, recording both normal and migratory-specific behaviours. All statistics were analyzed using general and generalized linear mixed effects models.

Results and Conclusions

We found that the 24-hr activity of migrants increased at high ALAN intensity (10lux), though nonmigrants were not affected by any ALAN treatment compared to dark. Furthermore, in each season the nocturnal activity of migrants increased as ALAN intensity grew, strongest in the stationary summer season (Fig. 1). Behaviorally, we found that migrants showed a threshold response in migratory-specific behaviours, increasing with ALAN intensity up until 10 lux, where nearly all migratory-specific behavior ceased despite greater overall activity in the cages. Comparatively, nonmigrants were unaffected by ALAN exposure.

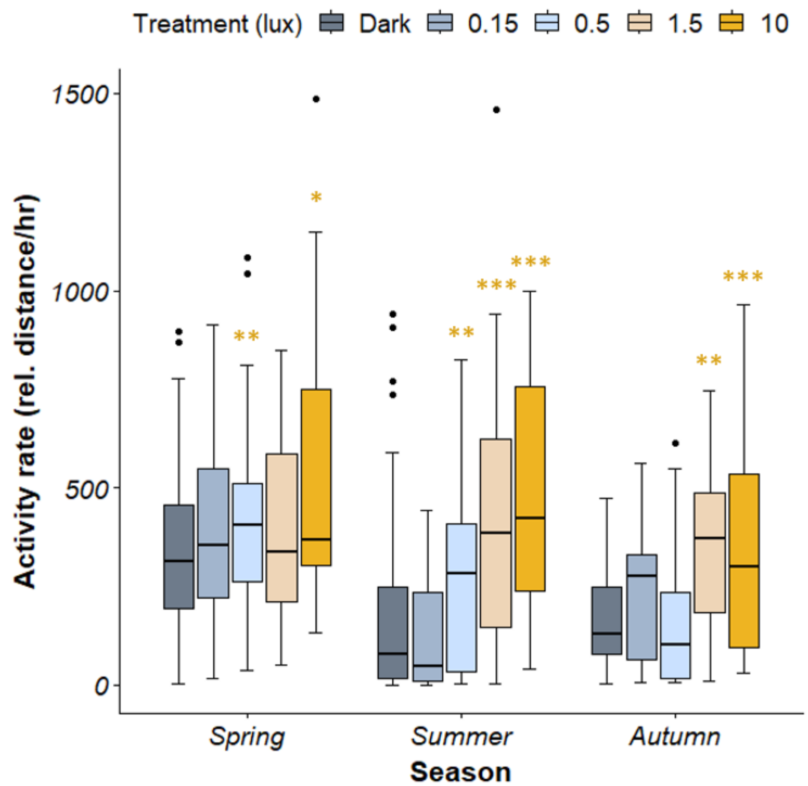

Fig. 1. Nocturnal activity rate of migrants across three seasons by ALAN treatment. Significance of model estimates indicated by * p<0.05, ** p<0.01, *** p<0.001.

Our findings did not directly support the hypothesis, as it appeared birds were more sensitive during the summer stationary period; however, the impact of even slight changes in migratory behavior (as we found) cannot be undervalued. Artificial light is known to alter the perceived or apparent photoperiod animals' experience. As the timing of activity and behavior is regulated by internal bodily rhythms, we believe ALAN interferes with the perception of daylength and nightfall, altering the expressing of behavior set-forth by circadian rhythmicity. This is important as proper regulation of feeding and flight cycles during migration is critical for arriving to the destination at the appropriate time and fitness level, and even for surviving migration at all. Understanding how ALAN alters the behavioral patterns of animals, and consequences of such dramatic changes, will help conservation scientists pursue action to improve night-lighting conditions globally as new methods show we may have vastly underestimated the rate of growing light pollution.

High inequality of artificial light due to commercial and sports lighting in Hong Kong

Theme: Measurement and Modeling

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Artificial light at night (ALAN) is a form of anthropogenic phenomenon. Although it is essential for human activities, overuse of ALAN leads to environmental degradation, bringing adverse effects on vegetation, animals, and humans. Using a collage of high-resolution nighttime images taken by Jilin-1 satellite, we investigated the ALAN and its distributions in the 67 District Council Constituency Areas (referred to as districts) of Hong Kong, one of the brightness or most light-polluted cities in the world. The images covered approximately 60 km^2 land and water area and only a fraction of the 452 districts in Hong Kong. The 67 districts covered one million residents, about 14% of the city's population.

The overall emission was dominated by blue light (44%), as compared to the green (35%) and red (21%) colors. Geographically speaking, a highly disproportionate distribution was found, showing a long-tail distribution (Figure 1). We measured a Gini index of 0.756 in the studied area in blue light, which was 0.146 higher than the expected value had the ALAN was equally distributed. This is consistent with the finding that almost half of the light emission from the entire metropolis came from the districts of Central (19%) and Tsim Sha Tsui (16%), characterized by the bustling commercial activities, and the Happy Valley district (12%), dominated by the horse track facility.

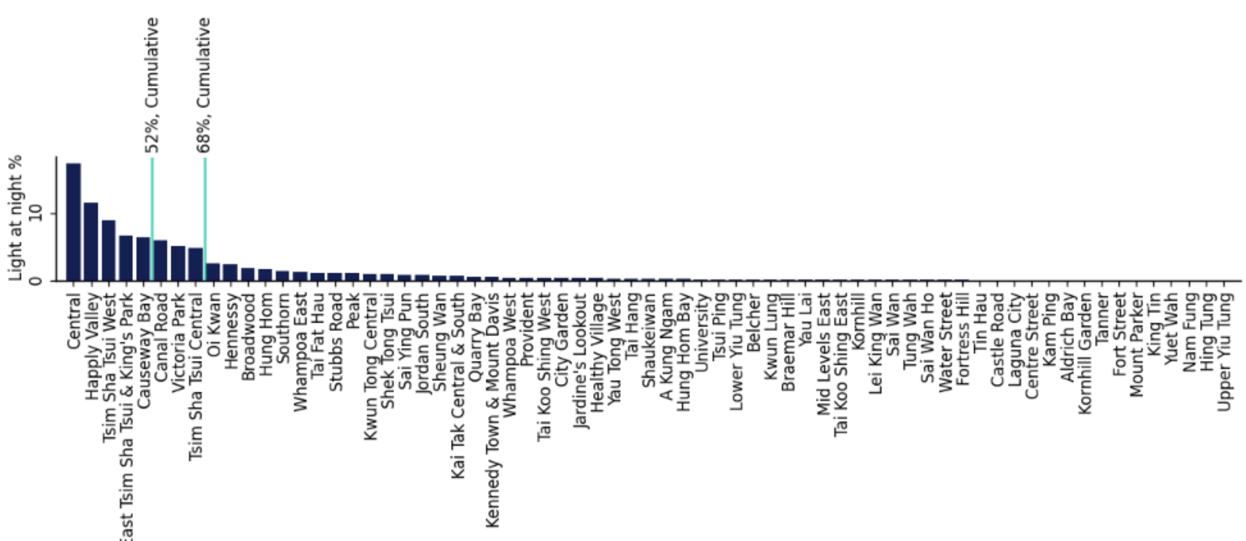

Fig. 1: Percentage of ALAN by district, showing a long-tail distribution. Five out of 67 districts already reached 52% of the total light emission cumulatively, and eight districts reaching 68%.

Light emission from buildings accounted for 42%, compared to parks/sports-related (17%) and streets/others (41%). Light emission from buildings includes two parts, either from active light sources or passive ones. Active light sources include external decorative lighting like LED signboards and interior lighting emitted from windows. Passive light sources are light reflected by walls because of an overbright environment. Figure 2 shows a case study in a high-rise residential building (Kwan Yick Building, hereafter called the Building) in a residential area. The light source from another residential building lit up the walls of the Building, making the Building visible from nighttime satellite imagery. In this case, the passive light source the Building was like the Moon, and the other building with the light source was like the Sun – both contributing to increased ALAN. From the photo taken inside the Building, we can see how the LED signboards affected the building environment.

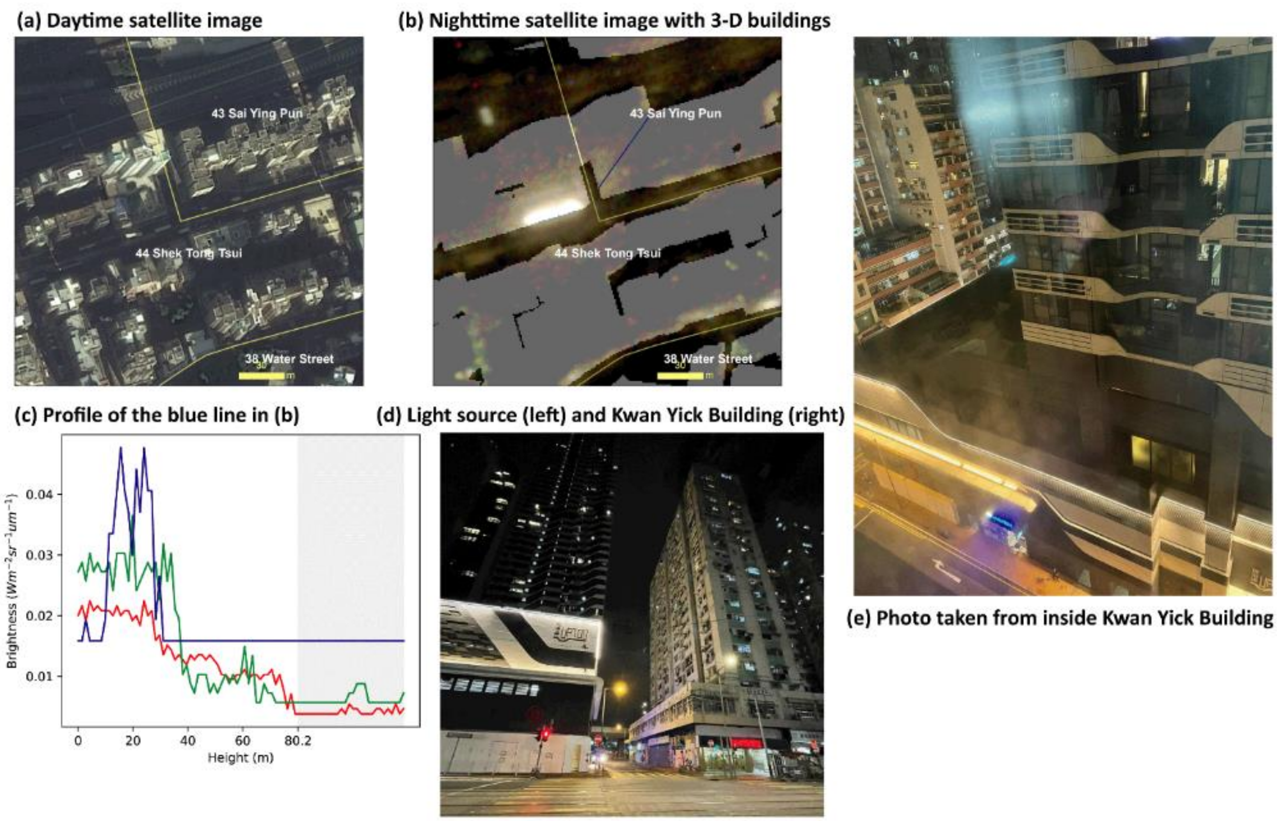

Fig. 2: Case study of the lighting environment of the residential high-rise Kwan Yick Building (hereafter referred to as the Building). *(a)* daytime satellite imagery for reference. *(b)* nighttime satellite image, overlapped with 3-D building structures. The blue line marks the vertical direction from ground floor to the rooftop of the Building. Note there is a single major light source on the left, which was a series of signboards shown in (d). *(c)* Light profiles along the vertical line; reached maximum at around 20 meters, 5^{th}-6^{th} floor. *(d)* The Building (right) and the nearby signboards (left). Even without active light sources, the walls of the Building reflected the light of environment and appeared to be bright in satellite imagery shown in (b). *(e)* Photo taken through a window of a residential apartment inside the Building to highlight the impact by the nearby LED signboards.

Restoring Darkness from Grass Roots

Theme: Society

G. MacMillan,[1,*] T. Conway[1] and M. Mahon[1]

As of January 2023, the number of dark sky places that have been certified by the International Dark Sky Association reached 200[3]. Embarking on the journey to dark sky status requires a significant commitment for all parties involved and the results can be very rewarding, particularly to remote and rural societies as a vehicle for sustainable tourism. However, achieving accreditation is only the start of the journey. Given the continuous spread of anthropogenic light pollution, dark sky supporters and advocates must remain vigilant in tackling the ongoing challenge of restoring and protecting dark sky places. This is made even more difficult in the absence of international legislation coupled with the flood of poor-quality lighting products onto the domestic market.

Fig. 1. Rae Goddard Studios, commissioned by Mayo Dark Skies Community

As a case study, from a practitioner's perspective, I will present the work being undertaken in Mayo Dark Sky Park and the surrounding communities striving to preserve dark skies, looking at the challenges and successes but ultimately calling for access to good quality dark sky lighting for the domestic markets. Without it, no amount of goodwill towards dark sky friendly lighting will tackle the practical needs of society in creating a balanced after-dark environment.

Methods

As part of an employment-based PhD scholarship at Mayo Dark Sky Park, I explore community led initiatives in dark sky tourism, through interviews, workshops and practice led public engagement activities. I will share extracts of the research project, noting emerging themes in values of darkness and lighting – assessing the delicate balance of light and dark between humans and non-humans.

This work is funded by the Irish Research Council, in partnership with National Parks and Wildlife Service.

[3] https://www.darksky.org/our-work/conservation/idsp/

Attractiveness of Ephemeroptera insect order to light colour temperature

Theme: Biology and Ecology

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Introduction

Lighting the night became ubiquitous at the end of the 19th century and, thanks to technological advances, is now widespread (Falchi *et al.*, 2016). Artificial light at night was proven to have an effect on human circadian cycle - the alternance of night and day that has physiological effects – and then on health and behaviour (Navara & Nelson, 2007). There is as well an effect on the vision of stars that is blurred (Falchi *et al.*, 2016). Anthropogenic light is therefore synonymous with light pollution (Bullough, 2021; Riegel, 1973). This light pollution also has an impact on plants (Singhal *et al.*, 2018), birds (Degen *et al.*, 2022), fishes (Foster et al., 2016) or insects (Seymoure et al., 2021).

Insects represent 80 % of animal biodiversity (Mawdsley & Stork, 1995). If we add to this their high attractiveness to artificial light (Seymoure *et al.*, 2021), they take the lead role for light pollution studies. The Ephemeroptera order seemed interesting to us as the adults have two kinds of eyes. Females possess lateral eyes, as males have an additional dorsal eye (Horridge & McLean, 1978). Their vision, and maybe attractiveness to artificial light, might be different. It is indeed the case in bibliography with mostly the females attracted by street lamps (Egri *et al.*, 2017).

Our goal here is to evaluate the attractiveness for different artificial light sources. Spectral power distribution (SPD) from 360 to 780 nm influences the correlated colour temperature (CCT). The correlation between CCT and spectral distribution is not unique, but we can consider CCT as a discriminating factor. Furthermore, CCT definition lies on physics and has very few anthropic biases. The idea is to combine the insects eye response (action function) with SPD to quantify light attraction. For some studies, the ecological impact of color temperature does not exist on mayflies (Durmus *et al.*, 2021; Pawson & Bader, 2014) but they stopped their observations and calculations to 6500 K. This abstract is a preliminary work carried out in the framework of the PhD thesis entitled "Quantitative evaluation of the impacts of anthropogenic light pollution on biotopes and nocturnal fauna".

Methods and results

Starting from classic photometric definitions, adapted to insects' vision, we have chosen seven LED lamps, all with different colour temperature between 2500 K and 9000 K. The spectra of LEDs are coming from LAPLACE databases, then normalized for a maximum of 1. The visual functions of dorsal eye (Horridge & McLean, 1978) and lateral eyes (Durmus *et al.*, 2021) were extracted from these studies, also normalized and gave some action functions A(λ) (fig. 1).

In our study we defined, among others, a similarity factor, ξ_θ, between the SPD and the action function. This factor is defined as the scalar product between SPD and A(λ). The closer this value is to 0, the weaker is the correlation and so the less attractivity effect is expected. On the contrary, the closer the result is to 1, the stronger is the correlation between the two functions, and then the more impact of light on insects is anticipated. The calculations were made for each eye type and for each LED, figure 2 shows our results. It can be seen that the lateral eyes are more sensitive to light till ~6000 K but then the tendency is reversed, on the opposite, dorsal eyes seem to have a different reaction to light that can help to explain the observed different behaviors of male and female Ephemeroptera.

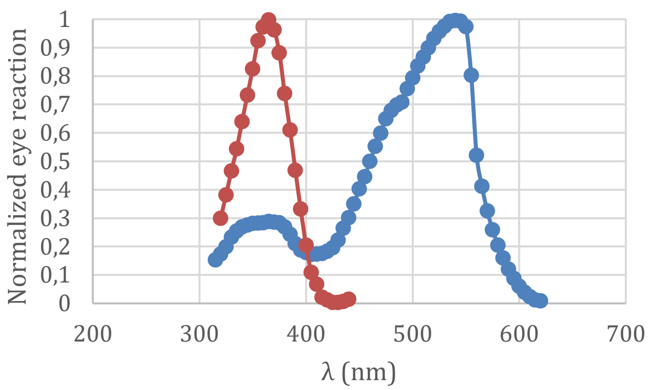

Fig.1: Normalized spectral visual responses of Ephemeroptera's lateral eyes (blue) and dorsal eye (orange).

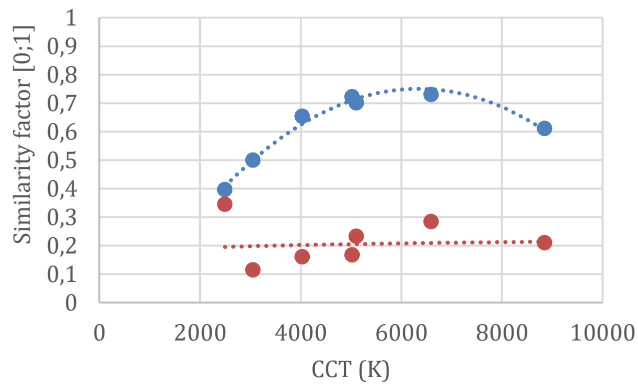

Fig.2: Trend line of the similarity factor, ξ_θ, allowing to deduce attraction of insects to different CCTs, for the lateral eyes (blue) and the dorsal eye of male mayflies (x150) (orange).

Conclusions

Here we investigate the relation between the color temperature of LEDs and the reaction of the dorsal and lateral eyes of Ephemeroptera. It seems that for an increasing colour temperature, reaction of the lateral eyes is increasing too. But when a certain level is exceeded, this attractiveness decreases. The dorsal eye tends to have different reaction, but the similarity factor is too low for us to say that there is an impact. Colour temperature is only one among multiples light indicators. Many others need to be investigated in order to be able to quantitatively assess the attractivity of light pollution on insects. This is the objective of our future work.

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The effect of the Moon on the night sky brightness

Theme: Measurement and Modeling

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Introduction

The Moon is the main source of natural light during a significant part of the nighttime. Except when it is near the new moon phase, its magnitude is higher than the magnitude of any other natural source. Furthermore, the moonlight is far to be constant: the Moon phase cycle introduce a high, but predictable, variability of the night sky brightness pattern throughout the month, not only in the brightness itself, but also in the hours of the night when the sky is illuminated by the Moon. Needless to say, all of this has a huge impact on the wildlife. As an example, the moonlight helps to the navigation during the migration of many animals, in particular birds. Other species have adapted their reproductive cycle to the lunar cycle. And the hunting activity of the predators increases on moonlit nights.

In this work we propose a tool to modelling the Moon brightness at any time that can be used for ecological studies as well as for general purpose studies of the night sky brightness, including the effect of the light pollution under moonlit conditions. The model uses the spectral irradiance model of Kieffer and Stone (2005) to compute the direct irradiance of the Moon. In this way, it allows to get the Moon brightness in any passband, if the transmission function is known. This applies not only to the photometric systems used in astronomy, but also to the animal's spectral sensitivity curve. The model also accounts for the effect of the scattering in any line of sight, providing an all-sky map of the brightness of the moonlight sky. Some brightness indicators, such the global horizontal irradiance, the average upper hemisphere radiance and the average full sphere radiance are also provided. The model is not limited to the time when the Moon is above the horizon. The introduction of high order scattering makes it possible to calculate the effect of the Moon on the brightness of the sky in lunar twilight conditions. The model will be integrated in GAMBONS, a model of the natural sky brightness (Masana et al, 2021). It is also foreseen that the model can be executed as a web application by any user.

Methods

The model of the Moon irradiance that we propose is based on the spectral irradiance model of Kieffer and Stone (2005). This model was developed to the radiometric calibration of Earth-orbiting instruments, and works from 350 to 2450 nm. The spectral radiance is multiplied by the filter transmission curve (or spectral sensitivity curve in the case of animals) and integrated to obtain the Moon brightness in any given passband, in a process identical to that described in Masana et al. (2021).

The effect of the scattering is then introduced. While for the Moon above the horizon a first order scattering is enough to get a reasonable result, high orders are needed if we can model lunar twilight conditions, when the Moon is below the horizon and no direct light reaches the observer. The successive orders of scattering method (see for instance Kocifaj, 2018) and ray tracing methods (Spada et al. 2006) are shown to be appropriated to deal with twilight conditions.

Putting all together, our model provides an all-sky map of the Moon brightness in any given passband, as well as several brightness indicators.

Conclusions

We have developed a model to compute the all-sky map of the Moon sky brightness in any given passband. The model is not limited to the time when the Moon is above the horizon, but it also works in lunar twilight conditions. The model can be especially useful in ecological studies, when the effect of the Moon brightness in the wildlife wants to be analyzed.

The model will be integrated in GAMBONS and provided as web application.

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The Gaia4Sustainability project

Theme: Measurement and Modeling

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Introduction

The Gaia4Sustainability project aims to develop a robust, reliable, and straightforward framework for estimating the night sky brightness. It consists of a set of implementations (web service, stand-alone program and open-source measurement device) devised for any interested stakeholder to accurately evaluate the impact of light pollution on, for example, environmental activities.

Gaia4Sustainability is a Proof-of-Concept project granted by the Spanish Ministry of Science and Innovation in the 2021 call and it is currently under development.

Methods

The presence of excessive artificial lighting at night and the consequent disruption of the natural day-night cycle has a pernicious effect on many species, as well as on the human health. To measure the light pollution levels is mandatory to know the brightness of the natural night sky, without the contribution of the artificial lights. This *natural brightness,* variable with time, can be modeled from the contribution of the natural light sources to the night sky (integrated star light, zodiacal light, the galactic and extragalactic background light, and the atmospheric airglow), taking into account the terrestrial atmosphere extinction and scattering. This provides a realistic image of the night sky for a given place and time. High quality photometry provided by the (ESA) Gaia satellite allows a computation of the contribution of the integrated star light. The resulting model can, then, be used as a reference value of the natural sky brightness (in cloudless nights), or to know the expected natural levels of sky brightness at pristine areas.

Apart from the model of the natural night sky brightness, the *Gaia4Sustainability* framework includes the design and construction of a cheap and easy-to-build photometer, named FreeDSm, based on open software and low-cost hardware. It will include several connectivity options and the ability to collect positioning information and measure light pollution, with the capacity to share data on the platform, if desired. Currently, FreeDSm is based on a Raspberry Pi Zero and on an Adafruit TSL2591 module, although additional and optional modules will follow.

The measurements from the FreeDSm photometer will be compared with the expected brightness of the natural night sky to assess the light pollution levels.

Conclusions

Gaia4Sustainability project propose a twofold methodology (modelling and low-cost measuring) to evaluate the light pollution levels with a reliable, easy to use, and straightforward methodology. The project intends contributing 1) to widely spread the acquisition of measurements; 2) achieve a greater engagement of social agents; and 3) raise generalized awareness on the light pollution problem.

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Artificial light at night: an underappreciated effect on phenology of deciduous woody plants

Theme: Biology & Biology and Ecology

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Introduction

Plants use natural light as an environmental cue on location, the time of day and year, and the surrounding environment (Basler et al., 2012). Photoperiod (i.e., daylength) determined by the natural cycles of light and darkness provides a consistent and reliable signal for plants to initiate seasonal phenological stages, such as leaf-out and flowering (Rathcke et al.,1985; Richardson et al., 2013). However, the photoperiodic cue for plants has been profoundly disturbed by artificial light at night (ALAN) (Bennie et al., 2018). Urbanization, electrification, population growth and socio-economic development together cause an extensive expansion of ALAN in terms of both density and spatiotemporal distribution (Kyba et al., 2017). The lack of understanding on ALAN effect may lead to considerable uncertainties in the projection of future changes in phenology under urbanization and climate change, and would hinder a comprehensive understanding of anthropogenic influences on terrestrial ecosystems. The main aim of this study is to use this new ALAN product to investigate the influence of ALAN on phenology of deciduous woody plants in the conterminous U.S.

Methods

We focused our analysis on two phenological stages, breaking leaf buds in spring and colored leaves in autumn, obtained from the USA National Phenology Network dataset in the conterminous United States during 2011-2016 (Fig. 1). We examined the differences in phenology at sites with and without ALAN while controlling temperature using the VIIRS Black Marble DNB ALAN product (VNP46A4, https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/products/VNP46A4/) and "Topography Weather" (TopoWx) climate dataset. We extracted the ALAN values for each phenological site each year based on the latitude and longitude of the site. We further investigated the confounding effects of temperature and ALAN on phenology with the consideration of species effect using a linear mixed model. Finally, we estimated phenological changes by the year 2100 under increasing ALAN and climate warming, using temperature simulations from 24 climate models of the sixth phase of the Coupled Model Intercomparison Project (CMIP6).

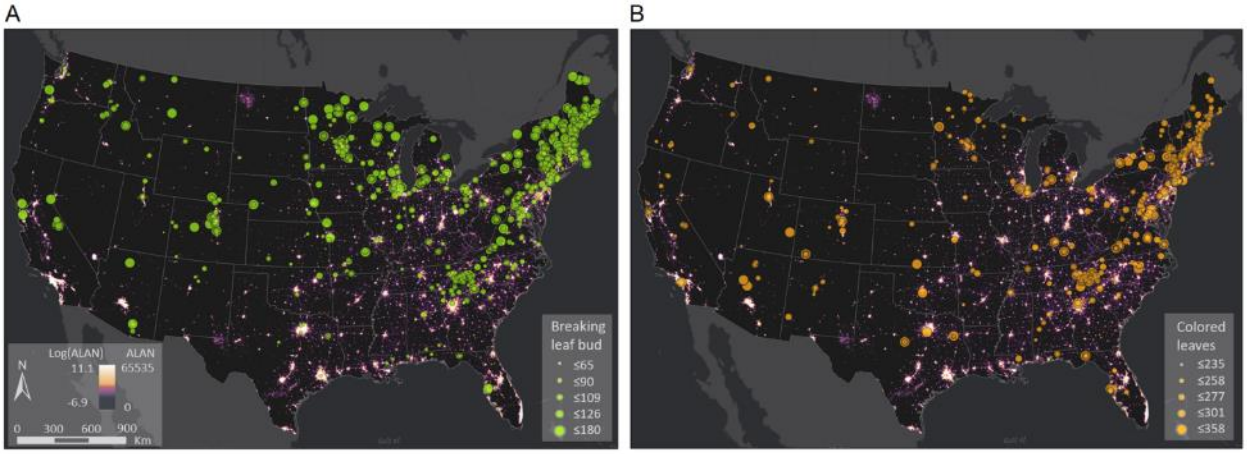

Fig. 1 Spatial patterns of the breaking leaf buds (A) and colored leaves dates (B) under ALAN.

Conclusions

We found that (1) ALAN significantly advanced the date of breaking leaf buds by 8.9 ± 6.9 days (mean ± SD) and delayed the coloring of leaves by 6.0 ± 11.9 days on average; (2) the magnitude of phenological changes was significantly correlated with the intensity of ALAN ($P < 0.001$); and (3) there was an interaction between ALAN and temperature on the coloring of leaves, but not on breaking leaf buds. We further showed that under future climate warming scenarios, ALAN will accelerate the advance in breaking leaf buds but exert a more complex effect on the coloring of leaves. This study suggests intensified ALAN may have far-reaching but underappreciated consequences in disrupting key ecosystem functions and services, which requires an interdisciplinary approach to investigate. Developing lighting strategies that minimize the impact of ALAN on ecosystems, especially those embedded and surrounding major cities, is challenging but must be pursued.

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Involvement of melatonin in brain plasticity and nocturnal motor activity in birds

Theme: Biology & Biology and Ecology

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Introduction

Artificial light at night (ALAN) disrupts the cycle of light and has vast biological impacts. In birds, ALAN effects on physiology and behavior could be mediated by melatonin (MEL), which is secreted during the night, suppressed during daytime, and important for the circadian and temporal organization in vertebrates (Gahr & Kosar, 1996). In birds, MEL suppression under ALAN conditions is known to significantly affect fundamental biological processes in behavior and physiology. In addition, in our recent publications (Moaraf et al., 2020a,b) we demonstrated that ALAN, at ecologically low intensities, has deleterious effects on several aspects of brain plasticity. However, little is known about the involvement of MEL in these processes. We used zebra finches (*Taeniopygia guttata*), which are diurnal birds, to study whether MEL mediates the effects of ALAN on brain plasticity and nocturnal motor activity.

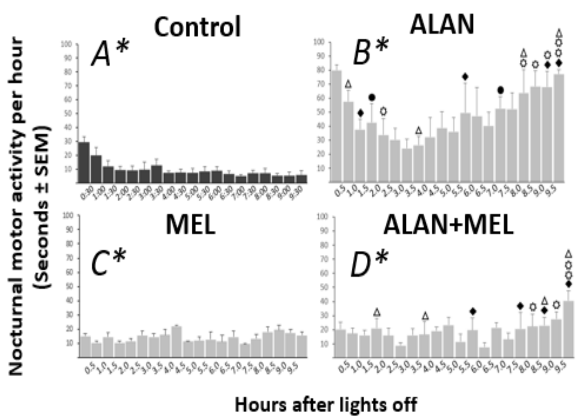

Fig. 1: Nocturnal motor activity (seconds / hr; mean ± SE) in the experimental groups, during the last stage of the experiment. Letters with asterisks indicate significant differences between groups. Each symbol represents a feeding event of an individual bird (see text for details).

Methods

Adult male zebra finches (90-360 days old) were housed in individual cages. During the first three weeks of the experiment all groups (N=8/group) were exposed to dark nights. Then, **Controls** remained under dark nights for 6 weeks; **ALAN** group was exposed to ALAN for 6 weeks; **MEL** group was exposed to dark nights for 3 weeks followed by 3 weeks of dark nights and MEL administration; and **ALAN+MEL** group was exposed to ALAN for 3 weeks and ALAN and MEL administration for further 3 weeks. ALAN intensity was 5 lux, and MEL was applied by using an alcohol-based melatonin infused cream (26μg/ml), administered on the necks of the birds. Nocturnal locomotor activity was recorded by using an infrared detection system at three time points: during the initial exposure to dark nights, then during ALAN exposure, and finally during ALAN+MEL treatment. Plasma MEL levels were measured every three weeks by radioimmunoassay.

At the end of the experiment, brains were extracted and processed for histology. We focused on lateral medial striatum (lMSt) and medial striatum (mMSt), which receive motor and sensory inputs, respectively. Selected sections within these regions were used for immunohistochemistry and stained with the neuronal marker DCX, which enables to detect recruitment of new neurons in these regions.

Results and conclusions

Birds in the Control and MEL groups showed little nocturnal motor activity during the entire experiment. In the ALAN group, birds were more active when exposed to ALAN, and their activity even increased with longer ALAN duration, indicating progressive sleep disruption. In the ALAN+MEL group, nocturnal motor activity initially increased during ALAN exposure, but decreased when MEL was applied, indicating that MEL can attenuate the effect of ALAN. Fig. 1 presents the results for all groups, during the final stage of the experiment.

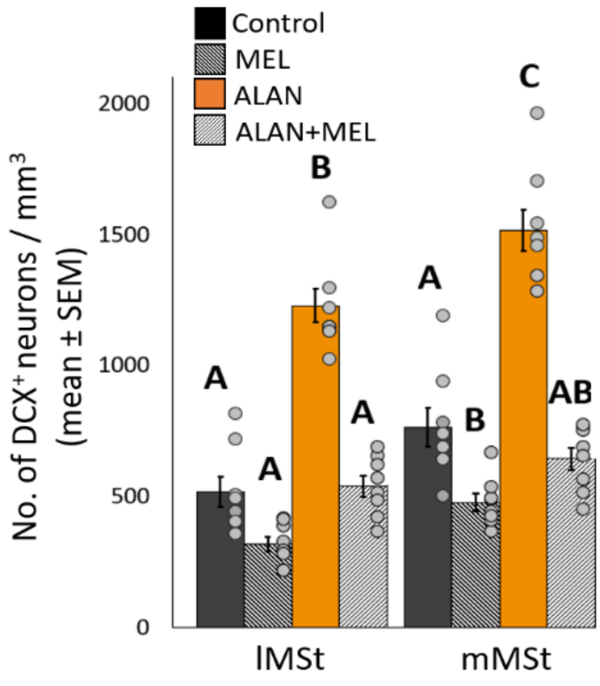

Fig. 2: Neuronal recruitment (number of new neurons mm^3; mean ± SE) in the lMSt and mMSt, in brains of birds in the experimental groups. Letters indicate significant differences between groups.

ALAN increased new neuronal recruitment in both sub-regions of MSt, lateral (lMSt) and medial (mMSt), compared to Controls and MEL that were similar (Fig. 2). It has been shown that exercise can increase neuronal plasticity (e.g. Van Praag et al., 1999), and therefore the increased nocturnal motor activity that we observed under ALAN might be associated with increased neuronal recruitment. In the ALAN+MEL group neuronal recruitment was similar to Controls in both sub regions, which might indicate that MEL can attenuate the effects of ALAN in the brain.

Taken together, our findings add to the notion of the deleterious effects of ALAN on physiology and behavior and indicate that these effects might be attenuated by supplementation with MEL.

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Developing a Generalisable Monte Carlo Radiative Transfer Model for the Study of Artificial Light at Night (ALAN)

Theme: Biology & Ecology

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Studying the large-scale spatial and temporal variation of ALAN has remained an Earth observation problem for decades. Satellite platforms allow the sampling of large areas in regular cadence. The data they yield provides adequate spatial and temporal granularity for studying the large-scale impacts of ALAN (e.g., Gaston et al. 2021). However, as very little of the light received on-orbit is direct emission, its spectral characteristics are dominated by the surfaces off which it has reflected, and the atmosphere through which it travelled, making it problematic to recover the true distribution of light as experienced by organisms at or near ground level.

A second approach to the study of intensity fields is through field measurements. Their brightness can be measured using cosine-corrected lux-metres, and spectral characteristics using spectrographs. However, these methods discard spatial information, as they only sample a single observable. Nilsson & Smolka (2021) propose a camera-based method to capture a light field, allowing sampling of the directional variation of a local lighting environment at a single point. However large, city-scale datasets using this method are prohibitively time-consuming and expensive. To make in-roads to answering many of today's pressing ecological questions, we require a method of light field estimation that can provide the coverage and cost-effectiveness of satellite data, while yielding the granularity of spectral and spatial variations offered by fieldwork campaigns.

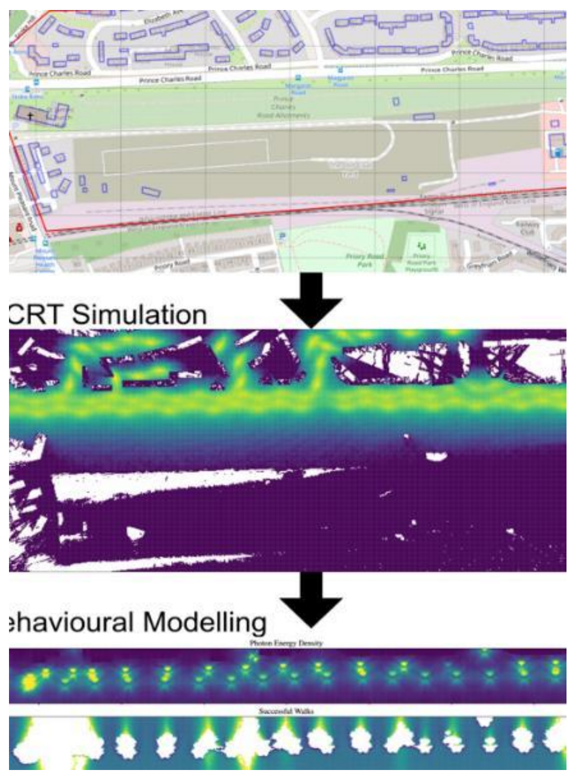

Fig. 1. A schematic of our workflow, showing the study area for our digital twin, the resulting MCRT simulation output for a hypothetical distribution of lanterns, and the resulting behavioural modelling across the simulated road.

Hence, we introduce a generalisable Monte Carlo Radiative Transfer (MCRT) model that enables us to produce physically-motivated forward models of the light intensity field within an ecologically interesting environment. This method has been used extensively in astrophysics for decades to simulate the light field within complex, astronomical environments (e.g., see Harries et al. 2019, upon which the design of our model is based, for examples). We use readily available LiDAR raster data and geospatial vector data to construct digital twins for the urban environment. Our digital twins consist of triangular meshes of the terrain and buildings, which scatter and reflect the incident light physically based on its material. We then mirror the real-world placement of luminaires with physically-motivated emission spectra and intensity distributions. Finally, we perform MCRT calculations of photons through the system to reconstruct the light field within the given simulated environment.

In this presentation, we will demonstrate the application of this model to understanding the movement of animals through a modelled lighting environment, using random walks. We will also explore how we have validated this technique, and how we can adapt this model to study other ecologically interesting problems.

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Sustainability in urban artificial lighting systems

Theme: Social sciences and humanities

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Introduction

Energy management is one of the major concerns of urban sustainability and climate change agendas worldwide (United Nations, 2022). Artificial lighting in Latin American cities such as Mexico City is a main topic not only in terms of energy consumption but also in citizen security. The artificial lighting system in such a big city is complex due to existence of multiple and non-linear interactions among ecological resources and processes, formal and informal institutional arrangements, technological artefacts, and social practices (Bauwens, 2017). Socio-ecological problems such as light pollution, insufficient lighting, and energy waste are symptoms of the unsustainability of the lighting system (Cetto and de Celis, 2021; Pérez et al.; Kumar, 2018).

The aim of this work is to identify the main factors of change and resistance of the artificial lighting system in Mexico City and to determine how those factors play a role in the current and possible future states of the lighting system in terms of sustainability.

Mexico City faces critical socio-ecological problems that have given rise to many sustainability studies on topics such as informal settlements in conservation land, water management, and air pollution. However, to date there are no studies that address the sustainability of its lighting system as a complex socio-ecological system despite its enormous social, political, economic, and environmental importance in the energy sector of the city.

Methods

To address challenges in such complex artificial lighting systems and to approach sustainable cities, there is a prior need to establish parameters of what sustainability is and how to measure it in these systems. A suitable framework to assess the state in terms of sustainability of a complex system in the context of its past development is given by the adaptive cycles metaphor proposed by Holling and Gunderson (2002). Based on a review of a wide array of fields, Sundstrom and Allen (2019) argue that adaptive cycles are ubiquitous in complex adaptive systems because they reflect endogenously generated dynamics because of processes of self-organization and evolution.

Following the proposal of Holling and Gunderson (2002), an adaptive cycle describes system movement through a 3-dimensional state space defined by system potential, connectedness, and resilience. System potential is referred to the range of options available for future responses of the system. Connectedness is concerned with the relationships between system elements and processes, and the degree to which elements are dominated by external variability, or by relationships that mediate the influence of external variability. Finally, resilience refers to the degree of disturbance a system can buffer without moving into a new regime, or basin of attraction.

To achieve the objectives of this work, we characterized the historical states of the lighting system of Mexico City in a period between 1325 (year of its foundation) and 2022 using a coupled heuristic and computational method based on the approaches of Escamilla et al. (2021) and zu Castell and Schrenk (2020) respectively to operationalize the adaptive cycle metaphor of Holling and Gunderson (2002).

Conclusions

We found that the main factors of change and resistance in the artificial lighting system of Mexico City have not been the same in different historical periods. Nowadays, the sustainability of the system is affected by a conflict of interest in the governance structure of the city. Although the potential is high, the resilience and connectedness of the lighting system is at an all-time low. However, the current state of the system implies that the possible solutions to address symptoms of system unsustainability, such as light pollution, insufficient lighting, and energy waste, can be applied on a large scale with minimal economic, environmental, and political cost.

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Turning off the lights: using aerial photography to quantify the impact of public lighting in a medium-sized city

Theme: Measurement and Modeling

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Abstract

The measurement and quantification of stray light is an issue that has slowly come to the forefront of environmental protection and photometry over the last fifteen years or so. The negative effects of artificial lighting are becoming increasingly apparent, but there has long been a lack of standardized metrics to address the problem of how to measure and describe ALAN levels, and thus how to describe their impact on the environment, human health or astronomical observations.

In April 2021, when the free movement of citizens in the city of Brno was restricted in the evening and night hours due to the COVID-19 epidemic, there was a good opportunity for an experiment consisting of switching off all public lighting or other lighting points under the management of the Brno Technical Networks. In total, more than 42,000 light points were switched off in order to determine the total contribution of public lighting to the artificial luminance of the sky in a city of approximately 400,000 inhabitants (Brno, South Moravia, Czech Republic) by means of ground and aerial measurements.

Ground measurements made with luminance analyzers have already been evaluated (see (1)) - and have shown that the contribution of public lighting to the luminance of the night sky in a city the size of Brno is approximately 45%. For a quick reference, see Figure 1:

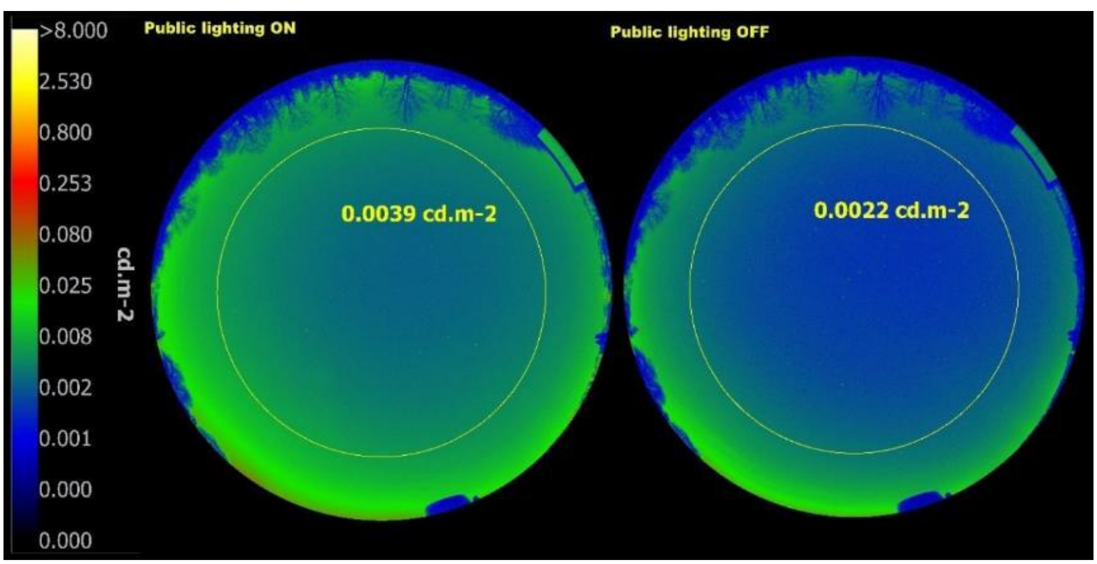

Fig. 1: Difference in zenith luminance with public lighting switched off.

The images in Figure 1 were taken using a LumiDISP 3 luminance analyzer based on a Nikon D7500 DSLR equipped with a Sigma FE 4.5 mm F2.8 lens with spectral correction filter.

As mentioned above, the measurements were taken not only from the ground but also from the air. A low-flying Vulcanair P68, equipped with a Nikon D800 camera and a Sigma 35mm F1.4 lens, took detailed pictures of the entire cadastral area of Brno during a flight of about three hours. The result was 246 images, each with a resolution of 36.3 MPx. This imaging was then repeated about six months later, this time with all public lighting in operation. In this way, we have obtained valuable data that shows us in which parts of the city the public lighting systems cause the most light spillage into the upper hemisphere, and where they are in the minority in relation to commercial and private entities.

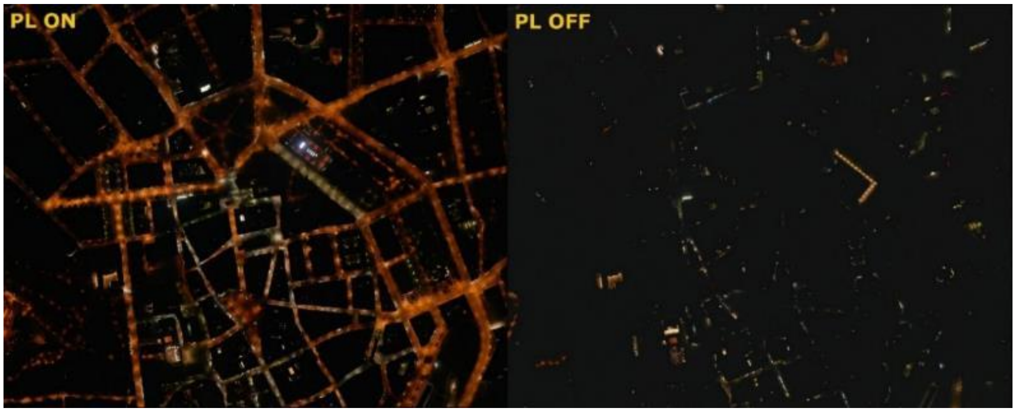

Fig. 2: Aerial view of the center of Brno with public lighting on and off.

In this paper we will therefore evaluate these aerial images and try to combine them with ground measurements where possible. However, the problem is that the measurement technique used for the aerial photographs in question was not equipped with a filter to correct the spectral sensitivity of the CMOS chip used, and this sensitivity therefore does not correspond to the sensitivity of the human eye, described by the function *V(λ)*. Despite this problem, these image sets are undoubtedly valuable data that can provide insight into the impact of lighting systems on the artificial luminance of the night sky.

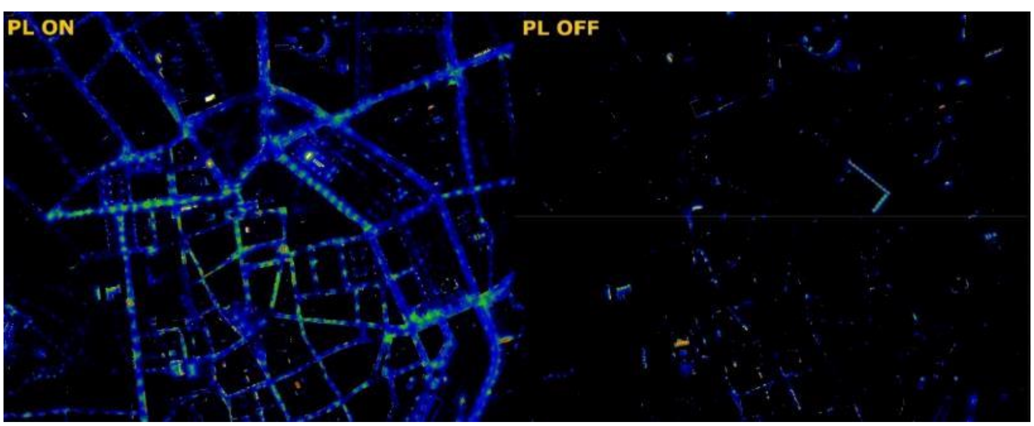

Fig. 3: Figure 2, converted to relative luminance values.

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The focus on metabolic and circadian health under dim light at night conditions

Theme: Health

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Circadian clocks represent an internal timekeeping system, which orchestrates temporal synchrony of individual physiological processes in the body and simultaneously maintains their synchrony with behaviour and a solar cycle. The circadian system drives the circadian rhythms at multiple levels of metabolic regulation, from gene expression, nutrient-sensing signals, metabolic hormones to a rest/activity cycle. This complex control enables anticipation of metabolic requirements and matches them with an appropriate phase of the day. However, global light pollution and modern lifestyle associated with artificial light at night (ALAN) exposure can compromise circadian timing function by mistimed light information. The main concerns are adverse health effects, as circadian disruption is considered a risk factor for civilization diseases, such as metabolic syndrome, cardiovascular disorders, or cancer.

In our experiments, we have examined circadian-dependent physiological and molecular links between dim ALAN and development of metabolic dysfunction in rats. To model light pollution, we use low-level light (~2 lx) during the entire night. Thus, adult male Wistar rats were exposed either to the control light/dark (LD) regime of 12:12 h with 0 lx during the night or dim ALAN. Depending on the experimental design, the length of ALAN exposure ranged from 2 to 10 weeks. Our main finding was that dim ALAN promoted accumulation of triacylglycerols (TAG) in the liver (Okuliarova et al., 2020). This was associated with upregulated expression of lipogenic enzymes (fatty acid synthase, acetyl-CoA carboxylase, and stearoyl-CoA desaturase 1) and glucose and fatty acid (FA) transporters (*Glut2* and *Cd36*), indicating enhanced de novo synthesis of FA and increased glucose and FA uptake into the liver. The observations paralleled suppressed FA synthesis in the adipose tissue and deregulated plasma adipokine levels, pointing out disturbed metabolic function in adipocytes with a potential impact on the liver metabolism (Okuliarova et al., 2020). Moreover, we found increased expression of important metabolic transcription factors, peroxisome proliferator-activated receptors alpha and gamma (*Pparα* and *Pparγ*) in the liver and adipose tissue, respectively. Since a wide spectrum of metabolic genes exhibit circadian oscillations and are directly controlled by the main clock proteins, in our recent paper, we analysed daily rhythms of various metabolic parameters under dim ALAN regime (Rumanova et al., 2022). We found disturbed rhythmicity especially in the hepatic expression of metabolic sensors, such as *Pparα*, PPARγ coactivator-1 alpha, sirtuin 1 and liver X receptor α, suggesting that a compromised crosstalk between metabolism and the circadian clock can significantly contribute to ALAN-induced metabolic effects.

In addition to the circadian clock, the metabolic state of the body also drives rhythmicity in metabolic sensors and metabolic pathways. Our data showed that dim ALAN eliminated daily rhythms in plasma metabolites, including glucose, TAG, and cholesterol (Rumanova et al., 2022). Thus, we analysed a detailed profile of plasma lipids, focusing on total FA. In this experiment, rats exposed to dim ALAN were simultaneously provided with 10% fructose (FRU) in drinking water to increase the metabolic burden. We found that dim ALAN did not change total FA levels in the circulation but affected composition of FA in a phase-of-day-dependent manner (Fig. 1). Specifically, a percentage of saturated FA (SFA) increased during the active phase (ZT18, ZT0=onset of the light phase) in ALAN rats, especially due to an increase of stearic acid. During the passive phase (ZT6), ALAN lowered proportion of monounsaturated FA (MUFA) and increased proportion of omega-6 polyunsaturated FA (ω6 PUFA), mainly arachidonic acid, which exerts the proinflammatory effects.

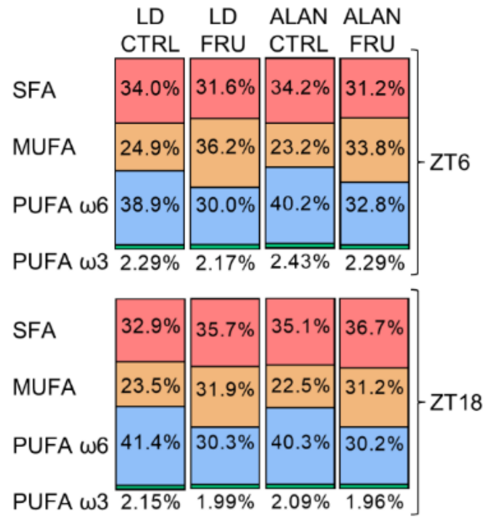

Fig. 1: Profile of plasma fatty acids in rats exposed to dim ALAN and increased fructose intake, as measured during the passive (ZT6) and active phase (ZT18) of the day. Abbreviations are explained in the main text.

It has been consistently shown that dim ALAN supresses nocturnal melatonin levels and even eliminates its rhythmic pattern in the blood (Okuliarova et al., 2022). Interestingly, nocturnal melatonin levels were also reduced in response to FRU intake, indicating further mechanism of how metabolic burden can compromise circadian timing function.

Together, our results demonstrate that ALAN can increase lipid storage in the liver through impaired homeostasis in lipid biosynthetic pathways and disturbed metabolic rhythms, accounting for a potential linking mechanism between light pollution and metabolic health risk.

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Assessing the Impact of LED Lighting Transition on the Night Sky and Biodiversity in Montevideo: A Collaborative Study Between Academia and Policy Makers.

Theme: Biology & Biology and Ecology

Governance & Regulation

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Introduction

The continuous urban expansion inevitably leads to the advancement of artificial light in areas that were previously under a natural lighting cycle. Artificial light at night has become an increasingly pressing problem in urban areas, as it not only has ecological implications, affecting the visibility of the night sky and biodiversity, but it is also a component of high societal demand. The increasing use of LED technology globally has opened doors to debate about the potential environmental impacts of the use of this light source, its contribution to light pollution and its ecological effects. This creates great pressure on political decision-makers regarding lighting in public spaces.

The city of Montevideo is currently in the process of transition to LED luminaires, therefore this study aims to deepen the assessment of the environmental impact of artificial night lighting in public spaces, as an input for decision-making. It aims to strengthen the link between the academic community and the Municipality of Montevideo through the Technical Unit of Public Lighting, dependent on the Department of Urban Development. The study will focus on two main axes: astronomical and biological. This project represents a contribution to the environmental considerations in the elaboration of the Lighting Master Plan of the Municipality of Montevideo. On this occasion, we will present the preliminary results of the experimental phase that will start in February 2023.

Methods

The study will be carried out using an experimental design that compares the effects of lighting before and after the switch to LED luminaires on the night sky brightness and the biodiversity of birds and insects. Specific methodologies will be used for each axis.

Astronomical axis: Measurements will be taken at different points in the city of Montevideo (urban and rural areas) and will also be recorded at the sampling sites of the biological axis. The intensity of the light source will be recorded at different angles (vertical towards the pavement, horizontal, etc.) following international recommendations. Each location will be visited once a month and a sequence of measurements of the night sky background will be taken using a sky photometer, starting at the end of astronomical twilight. Weather conditions, particularly the presence of clouds that can affect measurements, as well as other relevant atmospheric factors, will be recorded.

Biological axis: Birds: Diversity and abundance sampling will be carried out in 4 urban areas, within each area 5 control sites (sodium light) and 5 treatment sites (LED) will be sampled. A total of 20 control sites and 20 treatment sites will be sampled. Nest sampling and sound recordings will also be carried out in spring. Insects: Sampling will be carried out in common with birds, both for nocturnal and diurnal insects. For nocturnal insects, 5 points will be sampled monthly at one site in each zone (20 control points, 20 treatment points), using glue traps. For nocturnal insects, the same areas shall be sampled at the same frequency, using box traps.

In order to ensure the validity and reliability of the results, a control group will be maintained with traditional sodium lighting for the first 12 months of the study, after which the lighting will be switched to LED. Standardized measurement protocols will be used, and data will be analyzed using statistical methods to identify any significant differences between the control and treatment groups.

Conclusions

The results of this study will provide valuable information on the impact of transitioning to LED lighting, on the night sky and biodiversity of birds and insects, in the city of Montevideo. This project represents two innovative approaches: a) a collaborative interaction between academic researchers and decision-makers; b) the evaluation of the environmental impact of LED lighting by considering the interactions between different components of the urban ecosystem, such as the night sky, birds, and insects.

It is expected that this experimental approach will allow to extract conclusions that serve as input to the Technical Unit of Public Lighting, to have precise knowledge about the environmental impact of switch lighting in the urban ecosystem. Based on these results, evaluate which technological actions can be implemented to consider these effects, without detriment to the service provided to citizens. Therefore, this collaboration between academic researchers and the Technical Unit of Public Lighting aims to contribute to decision-making in public policies related to city lighting.

Night shift work, sleep deprivation and COVID-19 risk in a population based cohort in Catalonia (the COVICAT study)

Theme: Health

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Introduction

Emerging evidence links circadian disruption and sleep deprivation induced by light at night with infectious disease outcomes. We examined the association of exposure to night shift work and sleep duration with SARS-CoV-2 infection and COVID-19 disease in a cohort study in Catalonia, Spain.

Methods

We contacted 9,722 adult participants from a population-based cohort study in Catalonia (the COVICAT study) between June and November 2020. We drew blood samples from 4,154 participants (serology cohort) and measured immunoglobulin M (IgM), IgA, and IgG antibodies against five viral-target antigens to establish infection to the virus and levels of antibody response among those infected. We defined COVID-19 disease using self-reported hospital admission, prior positive diagnostic test, or more than three self-reported COVID-19 symptoms after contact with a COVID-19 case. We assessed current night shift work (yes, no), night shift work frequency (<3 nights/month vs ≥3 nights/month), night shift work duration (>3 months vs ≥3 months) as well as current sleep duration (≤5, 6, 7 (ref), 8, 9 hours) and changes in sleep duration compared to before the pandemic. We calculated log-binomial Relative Risks (RR) adjusting for individual-level covariates such as age, sex, education, type of survey.

Results

Cohort participants were 51% women and on average 55.3 yrs old (SD 7.9). Among all participants, 489 (5.0%) had COVID-19 disease. In the serology cohort 754 participants (18.1%) were seropositive. Short sleep duration (≤5 hours) was associated with increased risk for COVID-19 based on symptoms (RR 1.57; 95%CI 1.17-2.13). This result was similar among participants with confirmed infection in the serology cohort. Sleep duration before confinement was not associated with COVID-19 risk. Participants that reported a decrease in their sleep duration compared to before the pandemic presented an increased risk of COVID-19 (RR 1.58, 1.29-1.94). Night shift work was associated with a higher risk for COVID-19 disease: adjusted RRs were 1.45 (95%CI 0.96-2.21). Associations of night work with COVID-19 disease were more pronounced among participants with more intense shift work schedules (>3 nights/month: RR 1.56; 0.99-2.47) and longer exposure to night shift work (>3 months of night shifts: 1.77; 1.12-2.79). Additional analysis evaluating severity of COVID-19 disease will be presented at the conference.

Conclusions

Our data indicate that night shift work and sleep deprivation may be risk factors for COVID-19 disease. These results are in line with a body of literature suggesting that light-at-night induced circadian disruption and sleep deprivation can lead to poor immunological responses to infections and more adverse disease outcomes. These findings have implications for the prevention of COVID-19 disease and other respiratory viral infections in shift workers and the general population.

Rotating night shift work, sleep and thyroid cancer risk in the Nurses' Health Study 2

Theme: Health

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Introduction

Night shift work has been associated with breast, prostate, and colorectal cancer, but evidence on other types of cancer is limited. Thyroid cancer is the most common endocrine malignancy with rising incidence among women. We prospectively evaluated whether rotating night shift work, sleep duration, and difficulty falling or staying asleep are associated with incident thyroid cancer risk in the Nurses' Health Study 2 (NHS2). We also assessed the joint effects of shift work and sleep disruption on thyroid cancer risk.

Methods

We assessed rotating night shift work (≥3 nights a month) history (cumulative number of years) updated throughout follow-up (1989-2015), and sleep characteristics (assessed in 2001) in relation to thyroid cancer incidence. Cox proportional hazard models, adjusted for potential confounders were used to calculate hazard ratios (HR) and 95% confidence intervals (CI) for a) shift work history, b) sleep duration, and c) sleep difficulty. We further stratified the analyses of night shift work by sleep duration and DFSA.

Results

Over 26 years of follow-up, 588 incident cases of thyroid cancer were identified among 114,534 women in the NHS2 cohort. We observed no association between night shift work history and increased risk of thyroid cancer (1-4.9 years: HR 1.19, 95% CI 0.98, 1.44; 5-9.9 years: HR 1.13 95% CI 0.86, 1.48; ≥10 years: HR 1.10, 95% CI 0.78, 1.54; P_{trend}=0.55). Difficulty falling or staying asleep was suggestively associated with higher incidence of thyroid cancer when reported sometimes (HR 1.26, 95% CI 0.95, 1.67) and all or most of the times (HR 1.35, 95% CI 1.00, 1.81; P_{trend}=0.03. Among participants reporting short sleep, night shift work history of 10+ years was associated with a 2-fold increase in thyroid cancer risk (HR 2.23; 95%CI, 1.08-4.06). Shift workers with short shift work history (<5 years) and sleeping difficulty had an increased risk of thyroid cancer (HR 1.95; 95% CI 1.03, 3.67).

Conclusions

We found modest evidence for an increased risk of thyroid cancer in relation to sleep difficulty and joint effects of night shift work and short sleep or sleep difficulty.

ALAN impacts aquatic-terrestrial resource exchange and invertebrate community composition

Theme: Biology & Ecology

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Aquatic and terrestrial ecosystems are linked through the reciprocal exchanges of materials, termed resource subsidies. An important component of these resource subsidies is mobile invertebrates, with invertebrates of aquatic origin moving into terrestrial ecosystems, and vice versa, providing critical resources for predators in both systems, including fish, birds, bats and spiders (Baxter et al., 2005, Parkinson et al., 2020). These invertebrates are potentially impacted by anthropogenic factors, such as artificial light at night (ALAN) and with 41% of aquatic and terrestrial insects declining in abundance and 33% of aquatic species considered threatened (Sanchez-Bayo and Wyckhuys, 2019), determining the impact of ALAN on these organisms is increasingly crucial in order to effectively conserve insect communities, and the aquatic and terrestrial habitats that maintain them.

With 22% of Earth's coastlines exposed to artificial light (Hölker et al., 2010) ALAN is potentially affecting ecosystems across aquatic and terrestrial realms, and the exchanges of resource subsidies between them. Additionally, the world-wide transition to LED lighting has shifted the spectral composition of lighting technology towards blue light (Falchi et al., 2019), potentially increasing the effect of ALAN on organisms sensitive to these wavelengths. The impact of ALAN on littoral and riparian invertebrate communities is still poorly understood in many ways, including how differing wavelengths impact resource subsidies and community structure, and how ALAN affects the quantity and quality of resource subsidies.

To better understand the impact of LED lighting on invertebrate resource subsidies between aquatic littoral and terrestrial riparian systems, we experimentally elevated ALAN levels by installing replicated light treatments of different spectral composition in the littoral and adjacent riparian zone of a Michigan (USA) inland lake. These treatments consisted of purple (410 nm), green (530 nm), red (630 nm), neutral white (4000 k) and a dark control, each replicated six times, with three replicates installed in the littoral zone and three in the riparian zone. Each installation was comprised of battery-powered, LED strip lighting mounted horizontally on the underside of an L-shaped stake, with light projecting directly downward. Invertebrates were collected overnight below the lights using pan traps, which consisted of 0.25 m^2 plastic containers filled with approximately 5 cm of a water/soap mixture.

Fig. 1: Aerial view of the study site at dusk. Photo Credit: Sarah Griffith.

We evaluated invertebrate community composition using non-metric multidimensional scaling and multi-response permutation procedures and found significantly different communities under differing wavelengths of light. The purple treatments in both littoral and riparian habitats were dominated by aquatic insects, specifically Trichoptera and Ephemeroptera, and traps in purple treatments also had significantly greater overall invertebrate abundance, with invertebrates 188% more abundant than in dark controls. Purple treatments also had greater family richness than other treatments but were significantly less diverse than controls and red treatments.

In addition to evaluating the impacts of ALAN on community composition, we also compared white treatments to dark controls to examine potential effects of ALAN on invertebrate biomass being exchanged between systems. Biomass per hour of ALAN per trap was 156% greater in white treatments than dark. Autochthonous invertebrate abundance and biomass (i.e., the biomass of aquatic insects originating from the environment in which they were trapped) were also greater in white traps relative to dark controls. Allochthonous invertebrate abundance (i.e., insects originating from an outside habitat) was greater in white traps, while there was no difference in allochthonous biomass/ALAN hour between treatments, as on average allochthonous insects in traps were significantly smaller than autochthonous insects. Riparian traps also attracted a greater number of allochthonous insects than the littoral traps, with allochthonous input 173% greater into the riparian ecosystem.

In our study we found that not only does wavelength-specific ALAN affect community metrics of littoral and riparian invertebrate communities, but by analyzing resource subsidies in terms of biomass/ALAN hour/area we also found that white, broad-spectrum LED lights increased invertebrate input into both riparian and littoral systems. These results improve understanding of the ecosystem-level implications of ALAN on these susceptible communities. Although previous research has demonstrated invertebrate attraction to ALAN, specifically at shorter wavelengths, here we demonstrate a distinction between short- and long-wavelength impact on abundance, richness and diversity of invertebrate communities of both aquatic and terrestrial origin. Additionally, by categorizing invertebrate input as autochthonous or allochthonous we are able to more clearly see the directional influence of ALAN on both biomass and numerical response of these vital invertebrate resources.

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Spectral Radiance Measurements of Skyglow at Urban and Remote Sites

Theme: Measurements and Modeling

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Introduction

Anthropogenic light in the night sky is a growing concern with increased urbanization and use of light at night. It is critical to be able to quantify absolute skyglow radiance levels, spectra, and source locations in order to identify the lighting technologies and applications contributing to light pollution. Absolute sky radiance levels enable before and after comparisons to determine the impacts of new construction or effectiveness of light pollution mitigation efforts. Identification of skyglow source locations enable targeted mitigation strategies. Understanding the lighting technologies contributing to skyglow helps in analyzing lighting applications and usages that affect sky radiance.

Methods

A spectral radiometer measurement tool developed by Night Sky Metrics[1] was taken to various sites in the United States to measure absolute spectral radiance across the visible spectrum. These data were collected at various elevation angles to observe the change in light levels from the horizon to the zenith. The measurement results were evaluated to determine light source locations and the lighting technologies contributing to observed skyglow. Measurements were taken in: California at Channel Islands National Park, Santa Barbara, and Cuyama Valley; Oregon at Driftwood Beach State Park; Hawaii at Kaloko-Honokōhau outside of Kona, Mauna Kea Observatories, and Volcanoes National Park; and Georgia at Lookout Mountain. At this time, additional measurements are planned at Great Smoky Mountains National Park in Tennessee.

Evaluation of data collected at these remote and urban locations shows clear trends. Urban skyglow measurements show spectral signatures and the relative contributions of various lighting technologies, including LED, high pressure sodium, and metal halide. Measurements taken at different distances from city sources show wavelength-dependent atmospheric scattering of the emitted light with shorter wavelength light scattering and attenuating much more than longer wavelengths, as expected[2]. For urban settings, spectral measurements can show the skyglow impacts of urban growth, changes to lighting infrastructure, or lighting mitigation strategies. In darker, remote places the measurements show clear airglow emissions at expected wavelengths[3]. In addition, the impact of light trespass from neighboring cities can be identified and characterized with quantitative data to inform best lighting practices to preserve dark skies in priority locations such as Mauna Kea and the National Parks.

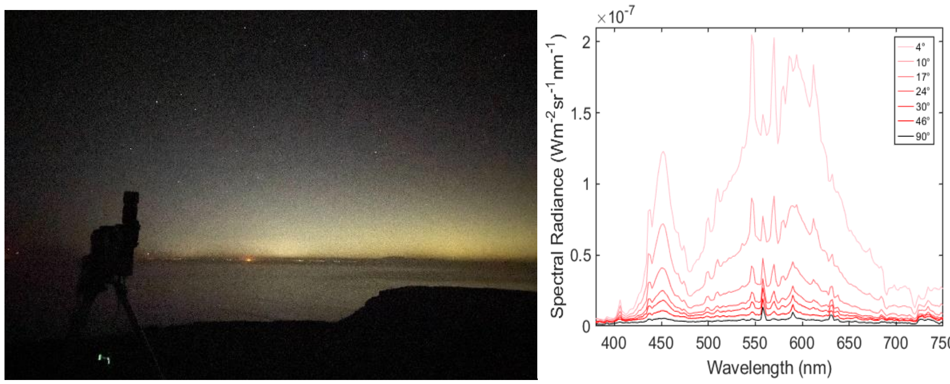

Fig. 1: Photograph and spectral radiance measurements towards Los Angeles from Channel Islands

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KID – Keep it Dark
A trilateral Interreg project for measuring sky brightness in the Wadden Sea:

First Results of single and multi-band comparison measurements

Theme: Measurement and Modeling

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The Wadden Sea of the North Sea stretching over The Netherlands, Germany and Denmark is recognized since 2009 as an UNESCO World Heritage site due to its unique large area (10 000 km²) of tidal sand, salt marsh, and mud flats (Watt). Activities, research and protection in the three countries are coordinated through a Trilateral Wadden Sea Plan with a working plan that is updated every 5 years by the environmental ministers of the countries.

The North Sea coast belongs to the darkest regions in the Netherlands. Therefore, two International Dark Sky Parks have been recognized by the International Dark Sky Association IDA in the Netherlands with the nature park Boschplaat on the island of Terschelling and in the National Park Lauwersmeer.

Measurements of sky brightness on the German islands of Spiekeroog and Pellworm as well as in Eastern Frisia gave some of the darkest values in Europe with different instruments. In 2021 both islands were accepted as International Dark Sky Communities by IDA. In Denmark the small island of Mandø is also applying for an International Dark Sky Park status.

In the action plan for the Wadden Sea Area for 2018 – 2023, the Leuwarden Declaration, the reduction of light emission was formulated as one action. To detect changes of light emission, a reliable and accurate measurement program will be necessary.

A first dark sky monitoring program in the region with about 40 stations with SQM-LUs and Raspberry Pi is run by the Astronomical Institute of the University of Groningen in the province of Groningen/The Netherlands and some in Germany. It was financed by the program "Donkerte van de Wadden" and these measurements are available on washetdonker.nl to the public.

With the support from the Common Wadden Sea Secretariat an application for a measurement program for the new Interreg small-scale projects under priority 3 "Sustainable North Sea Region: Protecting against climate change and preserving the environment" with limited duration till February 2024 was formulated. Partners are the Astronomy Department of Aarhus University and Medical Radiation Physics of Oldenburg University under the leadership of the Astronomical Institute of Groningen University.

Main aim is to develop accurate measurement systems that are adapted to the salty Wadden Sea climate, have high accuracy to detect changes on short time scales and can be operated autonomously. While Groningen had experience with the SQM measurement network, Oldenburg is running a network of all-sky meteor cameras (Fripon and Allsky7).

The major goal of the project is to suggest suitable detector systems for the reliable usage in the harsh environment of the Wadden-Sea. Therefore, one of the main tasks of the project is the long-time comparison of different single- and multiband detectors as well as zenith, allsky and horizon measurement-systems at dedicated locations in the area.

In this work first results of the long-term measurements will be presented. We show comparisons between different Allsky-systems (both single and multi-band) as well as SQM, TESS and Allsky-Camera systems.

It is expected that based on the experiences a larger scale measurement network could be installed in the Wadden Sea region.

Disaggregating the effects of daytime and nighttime light exposures on obesity, overweight, prostate and breast cancer morbidity worldwide

Theme: Health

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Introduction

The rates of hormone-dependent cancers, such as breast cancer (BC) in women and prostate cancer (PC) in men and overweight and obesity in both genders are currently on the rise worldwide. Although these types of morbidity are not necessarily linked, they might have similar underlying causes, such as aging, lack of physical activity, and unhealthy food consumption. Empirical studies have also linked these types of morbidity to several environmental risk factors, such as insufficient sunlight exposure, linked, in turn, to vitamin D deficiency (Alfredsson et al., 2020), while other studies emphasize the effect of prolonged exposure to artificial light at night (ALAN) (Haim and Portnov, 2013). However, sunlight and ALAN are interlinked, as the lack of sunlight is often compensated by ALAN, especially in northern latitudes. Yet, whether the excessive ALAN exposure, potentially resulting in circadian disruption and MLT suppression, or insufficient exposure to sunlight, resulting in vitamin D-deficiency, is associated stronger with human morbidity remains largely unclear. The present study aims to narrow this knowledge gap, by contrasting sunlight and ALAN exposure data with BC and PC morbidity and overweight/obesity data available for 100+ countries worldwide, while controlling for potential confounders, such as *per capita* GDP, GINI inequality index, and unhealthy food intake.

Methods

Data on adult overweight and obesity rates for individual countries worldwide were obtained as ASRs from the World Health Organization database, separately for females and males. Concurrently, BC and PC incidence rates were obtained as ASRs from the Global Health Data Exchange database. To account for the geographic patterns for population distribution, solar radiation and ALAN intensities were population-weighted using the methodological approach suggested in Kloog et al (2008). To account for disease latency, ALAN for BC and PC were lagged by 10 years, while ALAN data for obesity and overweight were lagged by 2 years, considering a shorter latency period expected for these health conditions.

Results

As the study revealed, geographic patterns of BC/PC and ALAN exhibit considerable similarities, with the highest BC and PC rates observed in the regions, where ALAN levels are at their highest. The geographic patterns of overweight and obesity are also similar to those of ALAN, with these health conditions being more common in the regions with high ALAN exposures, viz., North and South America, the Middle East, North Africa, Australia, and Oceania. Moreover, all the morbidity types under analysis were found to be significantly and positively associated with ALAN ($p<0.05$), but not with solar radiation exposure, which was found to affect PC rates only ($p<0.05$), but not BC, overweight and obesity ($p>0.1$).

Conclusions

The present analysis is an ecological study aimed to disentangle the effects of ALAN and solar radiation on three types of morbidity: BC in women, PC in men, and overweight/obesity in both genders. Although the study was performed for countries, not for individuals, it might improve our knowledge about the etiology of the above diseases, thus helping to spearhead public health policies. In particular, as the present study reveals, ALAN exposure is significantly associated with all the morbidity types under analysis, while the links of these diseases with solar radiation are weaker. This finding may necessitate regulatory measures that would reduce ALAN exposure, both indoors and outdoors. There are several ways to minimize the effect of ALAN on natural ecosystems and humans, including the use of dimmers and smart lighting control devices that turn off when they are not needed, shielded luminaires that minimize ALAN spillover to neighboring areas (Bara et al., 2022), and limiting lighting level on streets and roads to the levels that consider personal safety and road safety, but not lead to extensive and unneeded lighting (Svechkina et al., 2020). There is also a need for follow-up individual-level studies, aimed to verify our results against individual-level data, while controlling ALAN and sunlight exposure estimates for potential individual-level confounders.

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Using multi-source data to capture the impacts of Earth Hour 2021 in Hong Kong

Theme: Measurement and Modeling

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Earth Hour is an annual lights-out event organized by the WWF (World Wide Fund for Nature) to raise public awareness and encourage actions on environmental protection. The event was first launched in 2007 to turn off lights at 8:30-9:30 p.m. local time on the last Saturday of March, and ever since has become the most popular public event for environmental protection. In 2021, to see the impacts of Earth Hour on external lighting, specifically about where and which lights were out, we conducted a large survey using multi-source data in Hong Kong – one of the brightest or most light-polluted cities in the world. Seven types of open or volunteered crowdsourcing image or video visual data were collected from 120 traffic cameras, 27 weather cameras, 2 panoramic 360 cameras, 1 wide-field camera, 1 all-sky camera, 5 cellphones of volunteers, and 1 onboard-of-tramway video-recording camera. By comparing the before-during-Earth-Hour images/videos, we identified 122 individual buildings that participated in Earth Hour 2021. The number was the minimum estimated participated number since 1) within a building there were many shops and 2) even with multi-source data we only covered a small fraction of the urban areas.

We demonstrate in detail the promising capabilities of these open or crowdsourcing data in monitoring Earth Hour. Figure 1 shows images from two traffic cameras before, during, and after Earth Hour. Impacts of Earth Hour on the brightness of urban environments are easily observed by subtraction of two images (before – during Earth Hour). From the 1st row of Figure 1, we can see how the lights-out from the left-side building affected the wall brightness of the right-side building. With lighting traveling through windows, residents living in the right-side building will be affected. Figure 2 shows images from a weather camera. We observed a significant number of high-rise commercial, office, and even residential buildings that were lights-out.

Fig. 1: Using traffic cameras to capture lights-out and reduced brightness in the city.

Fig. 2: Using weather cameras to capture lights-out and reduced brightness in the city.

While it is promising to use multi-source data to monitor impacts of Earth Hour on the light environment, we acknowledge that limitations exist, primarily focusing on the automated processing of these massive multi-source visual data. To reduce labor costs, we managed to develop an AI model to automatically identify light sources, with limited accuracy (Figure 3). Through this survey, we recognized the benefits of multi-source open or crowdsourcing data in monitoring impacts of Earth Hour. Most lights-out events in Hong Kong were from signboards or LEDs that were not related to essential lighting but commercial advertisements. The findings here further provide evidence that reducing light pollution level in cities is possible and necessary for sustainable development.

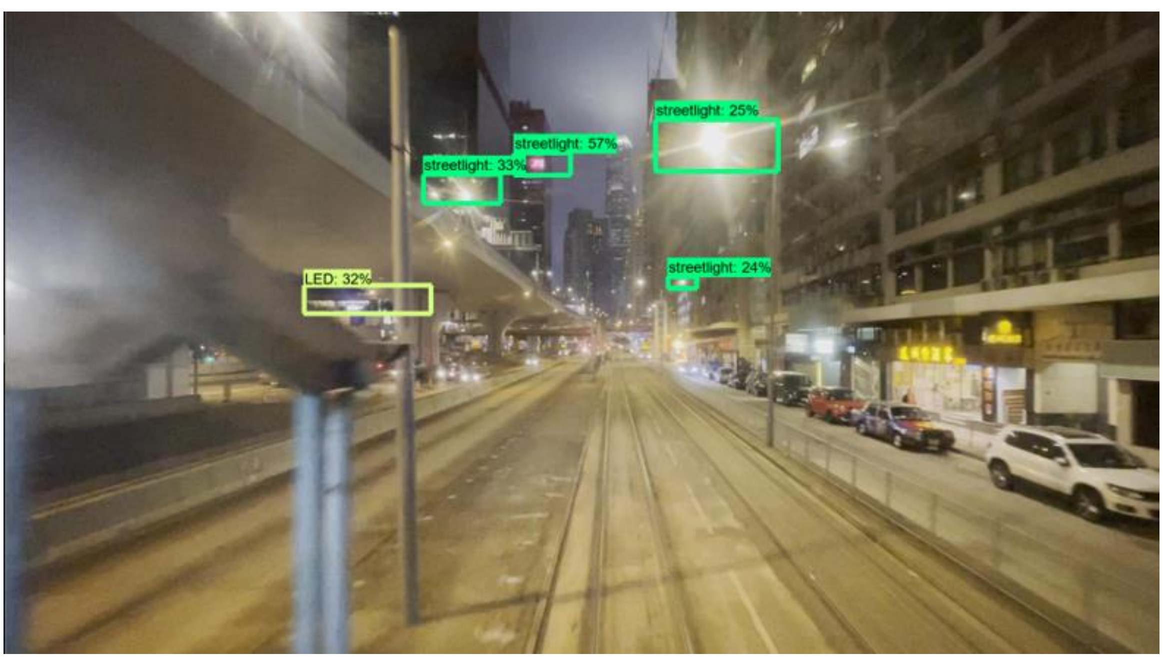

Fig. 3: Demo using artificial intelligence to identify light sources at night.

A decade of SQM light pollution measurements in Austria

Theme: Measurements and Modeling

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We will review and reflect on our development in measuring night sky brightness in Austria. Since the installation of the first Sky Quality Meter (SQM) at the Vienna University Observatory (Puschnig et al. 2014), we have achieved several milestones that comprise i) the establishment of a government-run night sky brightness monitoring network (Posch et al. 2018), ii) the quantification of the instrumental "ageing effect" (Puschnig et al. 2021), i.e. the time-dependent change in sensitivity of radiometers such as SQMs, iii) an empirical model to correct for the impact of the atmosphere (Puschnig et al. 2023) and iv) spectroscopy of the night sky to track changes in the colour of skyglow.

In the talk we will focus on long-term trends of light pollution assessed from SQM measurements obtained at more than 20 locations, covering rural, intermediate and urban sites. In particular, we will show the importance of an "atmospheric/meteorological correction". The composition of the atmosphere (e.g. aerosol optical depth, particulate matter), the state of vegetation and surface albedo have strong impact on the night sky brightness. As a result, any set of measurements may be biased (leading to spurious trend results) due to the fact that the measurements were likely obtained under different atmospheric conditions. Hence, observed variations in night sky brightness may only reflect changing atmospheric conditions rather than changes of the sources of artificial light at night themselves. We correct for the impact of the atmosphere using an empirical atmospheric model based on publicly available COPERNICUS satellite data. Figure 1 shows clear-sky, ageing corrected SQM measurements obtained at one of our sites (top panel) as well as our predictive atmospheric model (mid panel) and the residual (bottom panel). The Figure shows that – under clear sky – atmospheric variations may lead to zenithal night sky brightness variations of up to 0.6 mag $arcsec^{-2}$ at the given site and that one would overestimate the trend without taking into account atmospheric modeling.

Our modeling approach further allows us to investigate the importance of different atmospheric parameters, revealing that surface albedo and vegetation have by far the largest impact. Additionally, the night sky brightness is sensitive to black carbon and organic matter aerosols at urban and rural sites respectively. Snow depth was found to be important for some sites, while the total column of ozone leaves impact on some rural places.

From our large set of measurements, we find that light pollution at urban and rural regions increases at a rate of approximeately 2 per cent per year. However, the intermediate regions, show a much stronger increase of almost 4 per cent (corresponding to doubling times of less than 20 years). This may be explained by the fact that the installation of additional lighting points in urban areas contributes relatively less to the night sky brightness, as in urban areas the overall brightness level is already extremely high. On the other side, when intermediate areas develop, new or upgraded lights have a much larger impact, as it is relatively darker than in urban areas. More so, in rural regions. There, even only few additional lights may have a recognizable impact.

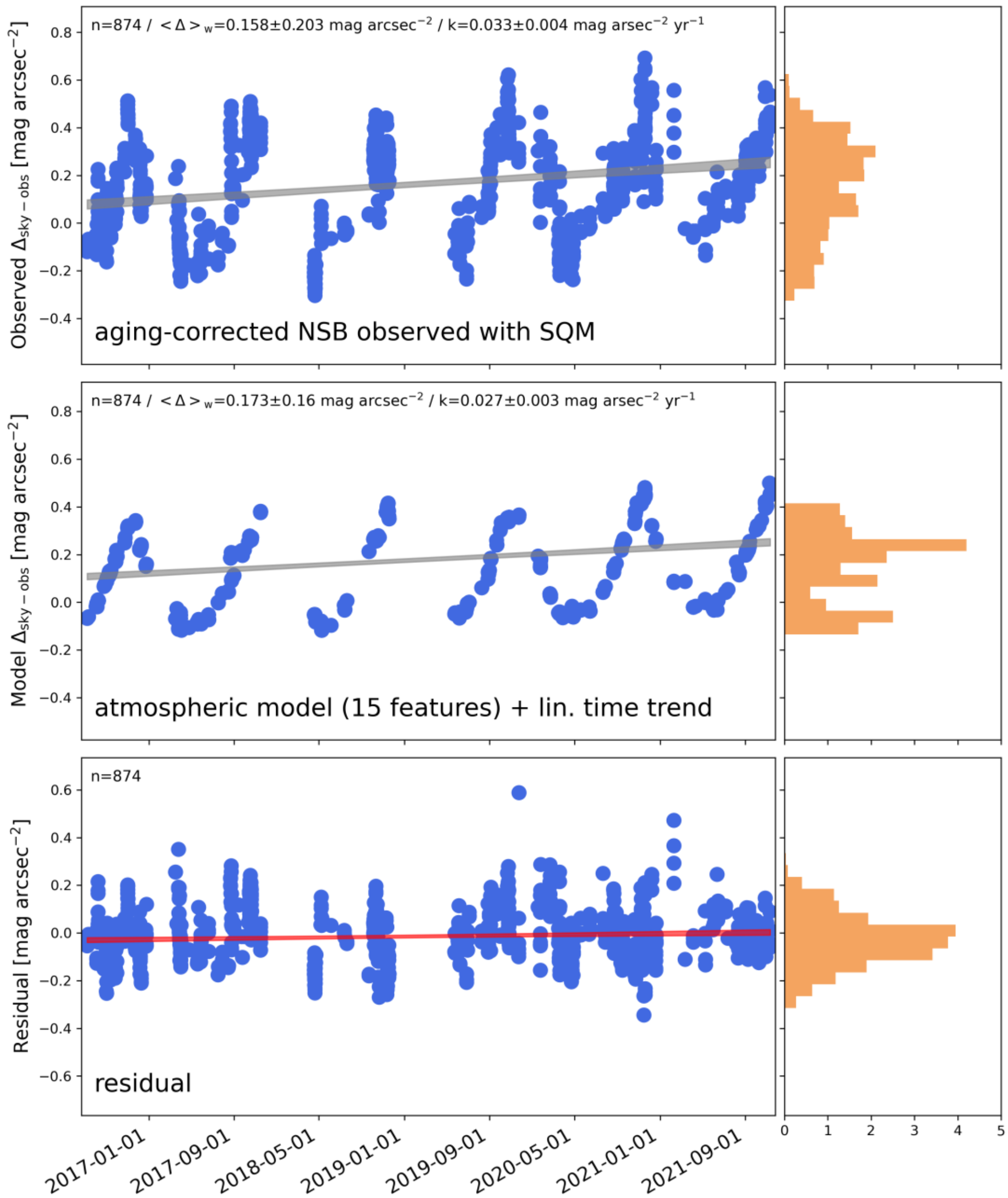

Figure Fig. 1: The top panel shows observed clear-sky, ageing-corrected night sky brightness measurements from 2016 to 2021 for one of our sites. The mid panel is a predictive atmospheric model with an additional linear time-trend and the bottom panel the residual (model-observation).

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Light pollution monitoring in an urban ecological sanctuary of the Great Salt Lake

Theme: Measurement and Modeling

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Light pollution is an unfortunate side effect of increased development and urbanization across the globe (Hölker, et al. 2010). Fortunately, unlike other alarming pollutants, artificial light at night (ALAN) can be significantly and immediately reduced when lights are turned off or shielded.

In partnership with the Great Salt Lake Audubon (GSLA) and affiliated Dark Skies program, we are designing protocol for long-term monitoring of ALAN in the Gillmor Sanctuary, an ecological preserve near Salt Lake City, Utah. Our primary objectives are to (1) establish multiple sites where remote sensing equipment can be deployed in the sanctuary and (2) collect and evaluate data assessing ALAN at these locations. Our goal is to develop an affordable, easily implementable methodology of collecting data for continued ALAN monitoring to share with other researchers and conservation organizations concerned with documenting light pollution.

The Gillmor Sanctuary is a 3,597-acre preserve located on the shores of the Great Salt Lake that provides critical habitat for migratory and non-migratory birds (Audubon, n.d.). While this area is physically protected from development and has undergone habitat restoration, its night skies are threatened by encroaching artificial light. The closest geographical producers of nighttime light are currently a state prison (dist. ~1.1 mi/1.8 km) and the Salt Lake International Airport (dist. ~6.6 mi/10.6 km). This area will be further impacted by a large commercial shipping hub (The Utah Inland Port, dist. ~4.3 mi/6.9 km) that is undergoing construction. With approval from the GSLA, we will place monitoring equipment in the sanctuary and collect preliminary data to evaluate both the logistics of equipment deployment (e.g., location, frequency of data collection, etc.) and the light pollution at these various locations within the sanctuary. This project will help establish an affordable methodology for long-term light monitoring, determine a baseline of ALAN exposure for the preserve, and identify trends in light pollution across time. These protocols will also help understand how ALAN changes as the area continues to be developed.

Fig. 1: Gillmor Sanctuary Photo by Lia Rabellino

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LUNA Technical Requirements enable energy-efficient outdoor lighting that mitigates light pollution

Theme: Governance and Regulation

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Anthropogenic light at night (ALAN) from outdoor lighting is increasing year over year (Kyba et al., 2017; Sánchez de Miguel et al., 2021) affecting both terrestrial and marine ecosystems, and is exacerbated by phosphor-converted (pc-) white outdoor LED lighting using blue-emitting chips. Outdoor LED lighting is more energy efficient and controllable than incumbent technologies such as high-pressure sodium (HPS) and low-pressure sodium (LPS), but the increased amount of short wavelength (blue) radiation in pc-white LED luminaires is known to potentially contribute to a wide range of deleterious impacts. Furthermore, as populations grow and outdoor LED lighting continues to become more efficient and cost-effective, per-capita light usage may also increase rather than decrease, further increasing ALAN and impeding necessary decarbonization goals. To reduce ALAN, multiple specification and application strategies are needed, including specification of controllable (including dimmable) luminaires with little to no uplight, that have low correlated color temperatures (CCTs) (e.g., 2200 K – 3000 K), lumen output to provide minimum maintained average illuminance or luminance targets and no higher, and shields as needed. One emerging solution to reducing ALAN, especially in environmentally sensitive areas, is to specify non-white light (NWL) LED luminaires, such as pc-amber and direct-emission (de-) amber LED luminaires to minimize the spectral impact outdoor lighting has on ALAN. Currently, communication, specification and differentiation of "amber" luminaires across stakeholders is unexpectedly problematic due to a wide variety in LED chip and luminaire terminology and a lack of standardization in chromaticity metrics and nomenclature as well as inconsistent institutional metrics and thresholds.

Indeed, stakeholders use lighting standards and certified products lists to ensure that LED luminaires can be consistently measured and evaluated, and these standards insufficiently address NWL sources and other related metrics needed to allow stakeholders to use a consistent framework (Fig 1.) (Radetsky, 2022).

Fig. 1: Some of the SDO activities needed to standardize NWL sources and support a consistent framework for ALAN.

The DesignLights Consortium (DLC) recently published its LUNA V1.0 Technical Requirements (TRs) (DesignLights Consortium, 2021) which sets performance criteria for specific categories of pc-white outdoor LED luminaires so that various stakeholders, including energy efficiency programs, cities and municipalities, and outdoor lighting decision makers can be confident that their selections save energy and follow best environmental practices for nighttime lighting. The DLC's V5.1 TR and associated SSL qualified products list (QPL) is used by North American energy efficiency programs as a basis for custom and prescriptive incentives for LED luminaires. Over 100,000 outdoor LED luminaires are currently DLC listed as meeting V5.1 and these products all achieve or exceed the TR thresholds for luminous efficacy, color rendition, lumen and color maintenance, however, most would not meet the superseding LUNA V1.0 TRs due in part, to their high CCTs (above 3000 K).

Outdoor LED luminaires meeting the LUNA V1.0 TR have corresponding distribution, spectral and controllability thresholds in order to minimize light pollution, and in addition have to meet the remaining SSL) Version 5.1 TRs.

This presentation will provide an overview of the LUNA V1.0 TRs and the reasoning behind the criterion metrics and thresholds for spectrum, distribution and dimming. LUNA V1.0 does not yet allow NWL outdoor LED luminaires to be eligible for listing performance data due to a lack of standardized metrics and/or thresholds for NWL sources in terms of efficacy, color rendition and sky glow potential (DesignLights Consortium, 2022; Radetsky, 2022). A proposed specification structure for NWL sources has recently been published (Esposito & Radetsky, 2023), and this presentation will provide an overview of the recommendations therein.

Conclusions

Market transformation is needed to shift outdoor LED luminaires to be more dark sky friendly. To enable market transformation, stakeholders need to be able to select outdoor lighting that meets meet their holistic goals of providing useful and desirable illumination, reducing energy use, supporting decarbonization efforts and mitigating light pollution. SDOs are encouraged to develop better standards for white and NWL outdoor lighting, and more specific design guidance so that stakeholders can better predict which products and design choices meet these goals. As a result of better standards, more capable lighting application software and tools will become available. A proposed specification structure for NWL sources for outdoor lighting provides a starting point for lighting standards development organizations (SDOs) to use to update their standards, to support the specification of energy efficient outdoor lighting that minimizes light pollution.

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An Urban Dark Sky Oasis: working with the community to reduce light pollution

Theme: Society

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Four years ago, our research group initiated a project to create an urban starry night oasis in the parc du Mont-Bellevue in Sherbrooke, Quebec, Canada, a city of 200,000 inhabitants. Such a protected area will give citizens the opportunity to reconnect with a quality starry sky and a living environment respectful of flora and fauna.

Through this project, several collaborative research projects were implemented with the collaboration of Sherbrooke's educational institutions, the City of Sherbrooke, the citizen community, and several community organizations. In addition, in September 2022, the area received Urban Night Sky Park (UNSP) accreditation from the International Dark Sky Association (IDA).

In this presentation, we will discuss:

- the key steps that allowed the establishment of such a protected area in the heart of a large city;
- how the citizen community has been sensitized and is contributing to the protection of the night integrity;
- the process that led to the UNSP-IDA accreditation.

As an example, we have implemented a nighttime integrity district near the Oasis. This serves as a model for good nighttime private lighting practices. Figure 1 shows a portion of the neighborhood during the lighting conversion (white bulb to 1500K PC-amber bulbs). This neighborhood has been the subject of several media news reports. Consequently, many citizens in Quebec want to initiate such a project in their neighborhood to contribute to the reduction of light pollution.

Fig. 1. The photo on the left shows a student changing a light bulb in a ball-type light fixture. To reduce light pollution, we have chosen to act on the intensity and color of the lighting (1500K, 5 and 7 W). The photo on the right shows the change in lighting in the nocturnal integrity neighbourhood.

Behavioral response of freshwater macroinvertebrates to the predation risk is altered by artificial light at night

Theme: Biology & Biology and Ecology

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Introduction

Artificial light at night (ALAN) has been recognized as one of the anthropogenic factors driving changes in the behavior of organisms in the wild. Nocturnal species may be particularly vulnerable to ALAN and the consequence of their exposure to light may be reduced activity and lower ability to forage or mate. This effect can be enhanced in the presence of a predator threat.

We conducted two independent laboratory experiments to test how ALAN will affect macroinvertebrate behavior in the presence and absence of a predator cue. We tested two species which are involved in the fragmentation and processing of coarse particulate organic matter (e.g. leaves) in streams: a gammarid *Gammarus jazdzewskii* (Amphipoda) and caddisfly *Lepidostoma hirtum* (Trichoptera).

Methods

The experiments was carried out in circular dishes (10 cm in diameter) placed in a water bath filled with water at a temperature of 15°C maintained by the aquarium cooler. In each dish, we placed 3 stones (mean surface area of a patch 14.5 cm^{-2}) serving as shelters. Animal behavior was recorded with an overhead digital infrared-sensitive video camera. Macroinvertebrates were exposed to the following light treatments: (i) darkness as a control, (ii) cool white LED light (4000 K, Philips) (for gammarids), (iii) warm white LED light (2700 K, Philips) (for caddisflies) and (iii) high pressure sodium (HPS) light (2000 K, SON-T Philips) (for both species). Light intensity was 2 lx (measured on the water surface) and corresponded to nocturnal light levels found in urban waters (Perkin et al., 2014).

We placed a single gammarid or a group of 4 caddisflies to the experimental dish. After 15 min of their acclimation to the arena, we started the video recording. The caddisfly and gammarid behavior was recorded for 1 and 2 h, respectively.

To test macroinvertebrate behavior in the presence of a predator cue, we followed the above-described procedure, however, before the start of the experiment, we added a conspecific injury cue which is an indicator of predator threat (Smith and Webster, 2015). The injury signal was prepared by crushing several gammarids or caddisflies with a mortar and a pestle. Then we added 80 ml of distilled water to the mortar and filtered the suspension through gauze to remove the animal carcass. We added 10 ml of the filtered cue water to each experimental dish immediately before placing macroinvertebrates.

Macroinvertebrate behavior was tracked by the software EthoVision 10.1. We estimated time spent in movement and time spent in the shelter by both species. For caddisflies, we additionally checked if light and predator cue affected their grouping behavior.

Results and conclusions

The presence of ALAN and predator cue modified macroinvertebrate behavior.

Both gammarids and caddisflies spent less time in movement in the presence of light and this effect was independent of the light type and predator threat.

The shelter use depended on a light*predation cue interaction and macroinvertebrates responded in a species-specific manner. In the absence of the predation cue, gammarids spent in shelter less time in darkness than in both light treatments. In addition, they stayed in shelter for a longer time in the LED than in HPS light. In the presence of the predation cue, there were no differences in shelter use between the light treatments, and, surprisingly, gammarids exposed to the LED light used shelters for a shorter time than in the absence of predation cue. This indicates that artificial nocturnal light can be a source of disorienting signal for gammarids and thus increase their susceptibility to predation.

In the absence of the predation cue, there were no differences in shelter use in caddisflies between the light treatments, but, when the predation threat was present, caddisflies spent significantly more time in shelter under LED light than in other light treatments. There was no effect of light or predator cue on the grouping behavior of caddisflies.

Our results show that the response of macroinvertebrates to the presence of a predator in the environment was affected by nocturnal illumination. This response also differed depending on the spectral composition of ALAN, as LED light in our experiment was most disruptive to macroinvertebrate behavior. Therefore, the biotic context as well as the quality of artificial light should be taken into account when interpreting the effects of ALAN on organisms.

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On the Association between Night-Time Light and Characteristics of the Buildings' Shape: Volume vs Lateral Surface Area

Theme: Social Sciences & Humanities

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Introduction

Emissions of artificial night-time light (NTL) are often used as a proxy to an urban extent. A traditional approach is to explain the variation of NTLs by the aggregated footprint area of the buildings. In their recent article, Shi with co-authors (2020) argue that light emissions are better correlated with the *volumes of buildings* (compared to just the *footprint areas*) in the cities across the UK, the USA, and several countries of the European Union. It seems plausible that the *lateral surface area* of buildings might be an even better predictor, due to the more accurate proportionality of this indicator to the windows of the buildings, emitting NTL, which is caught by the satellites in the open space. The present study aims to check this assumption.

Methods

In the analysis, we proceed from the two sources. The first one refers to the Urban Atlas, reporting the footprints and the heights of buildings of the European cities in 20212 (UA, 2022).. The second one is a year-2012 VNL V2 product for NTL radiance – a raster layer reporting by each its pixel total light emissions from the corresponding areas of ~0.5 km^2 (VIIRS, 2022). In the analysis, we examined central areas of 38 European capital cities. Within each city, we estimate correlations between pixel-level NTL intensity and two characteristics of the built-up environment: the volumes and lateral surface areas of the buildings located in the corresponding pixels. We afterward analyze the differences between the two groups of cities (those with stronger 'NTL – buildings lateral surface area' association vs. those with stronger 'NTL – buildings volume' association) in terms of the density of the built-up area, and average pixel-level buildings' footprint area, perimeter, height, and compactness.

Results

Among the examined 38 cities, higher Pearson's correlations between pixel-level NTL intensities and the corresponding sums of buildings' lateral surfaces (compared to the sums of buildings' volumes) are observed for seven cities only: Bucharest, Lisbon, Riga, Skopje, Valetta, Vilnius, and Warsaw. For the remaining 31 cities, the correlations emerged stronger between pixel-level NTL intensities and the corresponding sums of buildings' volumes.

While comparing the two groups of cities via independent samples *t*-test, the difference in the means emerges as statistically significant (p<0.01) in terms of:

1) The average number of buildings per pixel (33±7 vs. 65±8 correspondingly for cities with stronger 'NTL – buildings lateral surface area' and 'NTL – buildings volume' associations)
2) Average building area (559±66 m^2 vs. 336±19 m^2 correspondingly for cities with stronger 'NTL – buildings lateral surface area' and 'NTL – buildings volume' associations)

3) Average building perimeter (95±5 m vs. 73±3 m correspondingly for cities with stronger 'NTL – buildings lateral surface area' and 'NTL – buildings volume' associations)

Our results indicate that the buildings in the first group of cities (that is, with stronger 'NTL – buildings lateral surface area' association) are generally more dispersed, and larger. Fig. 1 reports the map of the center of Skopje as an example of a city with relatively larger and sparsely located buildings; while Fig. 2 illustrates the opposite example, depicting the center of Brussels with relatively small and densely located buildings.

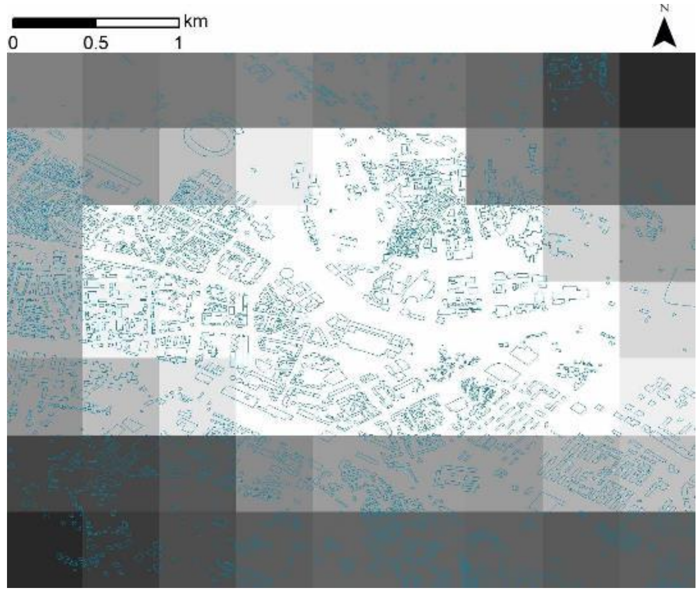

Fig. 1: For larger and sparsely located buildings, higher correlation with NTL is observed for total *lateral surface area* of the buildings: Central area of Skopje as an example

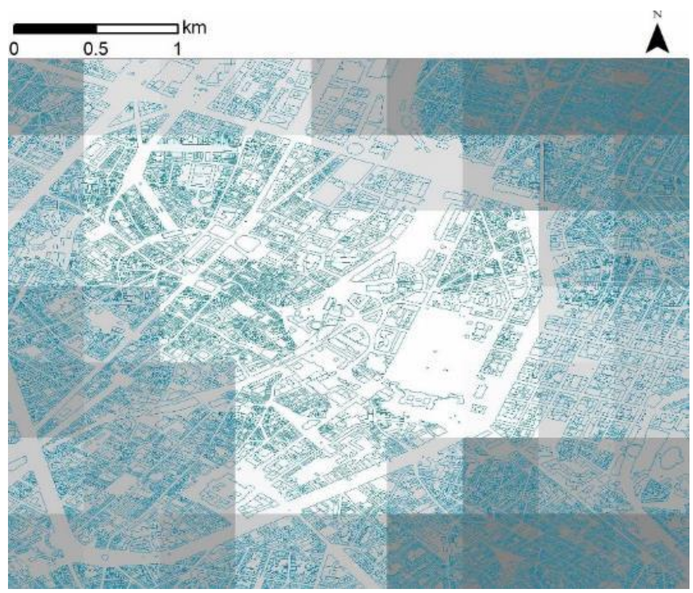

Fig. 2: For smaller and densely located buildings, higher correlation with NTL is observed for total volume of the buildings: Central area of Brussels as an example

Conclusions

Our analysis shows that a stronger association between the emitted light and the lateral surface area of the buildings is observed in the cities with the built-up area with relatively large and sparsely located buildings. In the cities with a denser built-up area and smaller buildings, the emitted NTL better correlates with the volumes of the buildings. It seems plausible that lateral surface area, all other things being equal, should behave as a more informative predictor of the emitted light since it better represents the area of windows which are actually the genuine source of light emitted in the residential area. However, in densely built city blocks, the short distances between the buildings probably lead to a depletion of light intensities emanating to outer space. We assume that using the thresholds for the density of built-up areas and/or sizes of the buildings in a certain urban area would help to use the most appropriate proxy and better explain NTL variance in residential areas of the cities.

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Dark Sky Places, Native Spaces: Mesa Verde as a Model for Critical Indigenous Involvement in Dark Sky Parks

Theme: Social Sciences and Humanities

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Though the dark sky movement is a relatively new factor in global environmentalism, the ecological and cultural systems it seeks to advocate for and protect are ancient. The success of the movement has manifested in many ways, perhaps most charismatically through the creation of 201 certified Dark Sky Places since the program started in 2001, a majority being in the form of parks (International Dark-Sky Association 2023). The full implications surrounding the importance of protecting dark skies are still being explored, with newfound emphasis in including the field of Native American and Indigenous studies being highlighted by a recent article labelling light pollution as a form of cultural genocide (Hamacher, De Napoli, and Mott 2021). With the "whitewashing of the night sky," Indigenous traditions, knowledge, and ways of being are disproportionately threatened while Indigenous peoples are treated as afterthoughts or excluded in the process of creating and implementing transdisciplinary solutions to the threats of artificial light at night.

This exclusion parallels other well-documented examples of the marginalization of Native people and knowledge from parks, environmentalism, and the sciences more generally. It is arguable that all parks, but certainly those in settler-colonial nations (such as the United States, Canada, Australia, and New Zealand), are located on stolen Native lands. Parks resulted from the violent and intentional dispossession of Native title to land and the forcible removal—if not outright extermination—of Indigenous peoples (Spence 1999). Clashes over the siting of astronomical observatories atop sacred mountains such as Mauna Kea in Hawaii or Dził Nchaa Sí'an/Mount Graham in Arizona also acutely highlight the tensions between astronomical science and Native peoples. Chronically, astronomy also lags behind even other physical sciences in engaging Native Hawaiians and Native Americans, with the decadal survey of the National Academies of Science, Engineering and Medicine finding a "systemic failure" in the field to cultivate a diverse professional community (National Academies of Science, Engineering and Medicine 2021).

There is therefore a critical need to explore models of partnership between parks and tribes with relation to outreach and educational opportunities if the dark sky movement seeks to learn from and do better by Native communities than its historical antecedents. One dark sky park, Mesa Verde National Park, is unique in being the first national park created in the United States, and one of the first globally, that was established to primarily protect cultural as opposed to natural resources. The park maintains relationships with 26 federally recognized tribes. Mesa Verde sought assent from its 26 associated tribes before pursuing IDA dark-sky certification and works with these tribes to produce dark sky programming. Drawing from Smith's (1999) *Decolonizing Methodologies* and mindful of Tuck and Yang's (2012) critique that "decolonization is not a metaphor" (and therefore should result in tangible beneficial outcomes to Native communities and sovereignty), I examine Mesa Verde's process as a potential model that aspiring dark sky parks can draw from and that existing parks can emulate. If dark sky places are on Native land, their full potential and vitality cannot be realized without Native people.

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SDGSAT-1, JL1, ISS: Intercalibration process and first mosaic

Theme: Measurement and Modeling

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Introduction

Synthetic photometry is a technique used to predict the observed flux of a celestial object, such as a star or galaxy, in different photometric bands (e.g. U, B, V, R, I, etc.). This is done by using a model of the object's physical properties, such as its temperature, composition, and surface gravity, and simulating the object's spectrum. The simulated spectrum is then convolved with the transmission function of the chosen photometric band to calculate the object's flux in that band. This process is repeated for each band of interest, resulting in a set of predicted magnitudes or fluxes that can be compared to actual observations. Synthetic photometry is useful for studying objects that are too distant or faint to be observed directly, as well as for understanding the physical properties of a wide range of celestial objects. Same technique has been applied on the data on the ISS and VIIRS to predict the signal of different bando or to correct the lack of colour information of VIIRs using the color data of the ISS.

Other new satellites, like the SDGSAT-1 and the JL1 satellites, neither have same spectral bands as the ISS. Using the Synthetic photometry, we have predicted the relationships to intercalibrate them with the ISS.

Also, using the predicted values of the ideal light sources, we have been able to reduce the striping and artifacts on the SDGSAT-1. Using this dataset, currently have been developed a preliminary mosaic of the Iberian peninsula at 40 m of resolution.

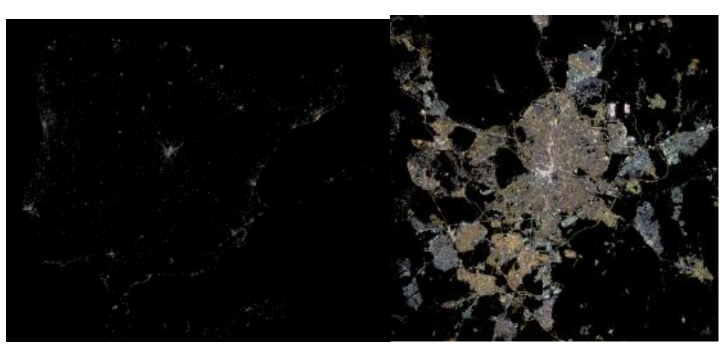

Fig 1. Calibrated images from SDGSAT-1 for the Iberian Peninsula already processed. Left: mosaic of the Iberian peninsula, Right: detail of the city of Madrid

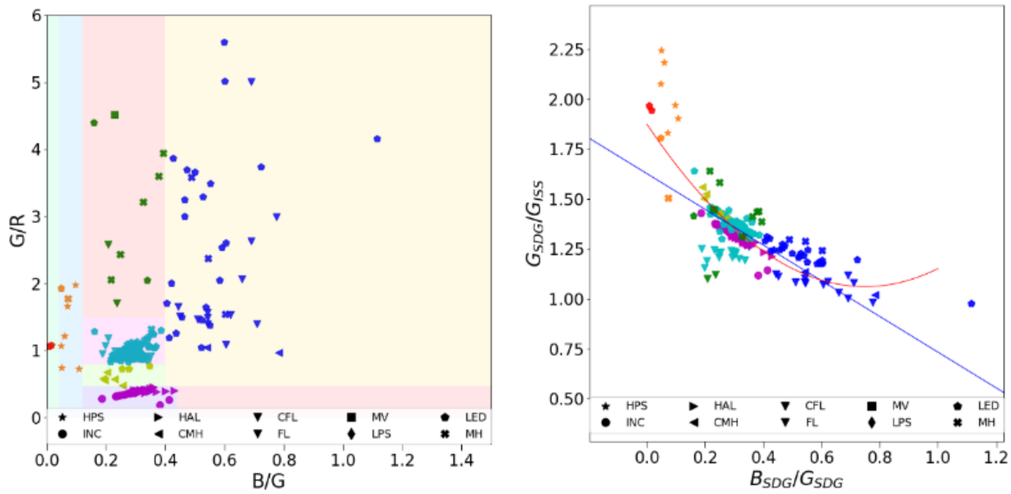

Fig 2. Left. Predicted values of the typical street lighting. Right. Predicted relationship for the SDGSA-1 B and G bands and the G ISS band.

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The association between night shift work and breast cancer risk in the Finnish twins cohort

Theme: Health

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Introduction

Breast cancer is highly prevalent yet a more complete understanding of the interplay between genes and probable environmental risk factors, such as night work. remains lagging. Using a discordant twin pair design, we examined the association between night shift work and breast cancer risk, controlling for familial confounding.

Methods

Shift work pattern was prospectively assessed by mailed questionnaires among 5,781 female twins from the Older Finnish Twin Cohort. Over the study period (1990-2018), 407 incident breast cancer cases were recorded using the Finnish Cancer Registry. Cox proportional hazards models were used to calculate hazard ratios (HR) and 95% confidence intervals (CIs) adjusting for potential confounders. Within-pair co-twin analyses were employed in 57 pairs to account for potential familial confounding.

Results

Compared to women who worked days only, women with shift work that included night shifts had a 1.58-fold higher risk of breast cancer (HR=1.58; 95%CI, 1.16-2.15, highest among the youngest women i.e. born 1950-1957, HR=2.08; 95%CI, 1.32-3.28), whereas 2-shift workers not including night shifts, did not (HR=0.84; 95%CI, 0.59-1.21). Women with longer sleep (average sleep duration >8 hours/night) appeared at greatest risk of breast cancer if they worked night shifts (HR=2.91; 95%CI, 1.55-5.46); Pintx=0.32). Results did not vary by chronotype (Pintx=0.74). Co-twin analyses, though with limited power, suggested that night work may be associated with breast cancer risk independent of early environmental and genetic factors.

Conclusions

These results confirm a previously described association between night shift work and breast cancer risk. Genetic influences only partially explain these associations.

Untangling the effects of time and light on wolf spider foraging efficiency

Theme: Biology and Ecology

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Light dictates animal behavior through light dependent systems such as circadian rhythms and vision. Circadian rhythms dictate metabolism and motivate foraging whereas visual abilities guide foraging, mating, and other behaviors. Most daily behaviors of arthropods are cyclical and entrained by light environment. We investigated how low levels of artificial light at night that match irradiance of different lunar phases affects wolf spiders (*Rabidosa spp*) foraging behavior and activity patterns. We collected 112 wolf spiders in early November in Missouri and housed each spider individually in a laboratory setting. Each spider was exposed to the appropriate LD cycle (10:14) for November in Missouri and during the dark phase was exposed to one of five different lighting conditions (starlight (~0.001 lux), quarter moon (~0.01 lux), full moon (~0.1 lux), nautical twilight (~1 lux), or the equivalent lunar condition (~0.001 lux up to 0.1 lux) depending on the day. Each spider was exposed to these light conditions for 1 month. Once per week, we tracked wolf spider activity for two days using infrared videography and automated tracking with Streampix. After activity was recorded, each spider underwent a foraging trial in which they had 15 minutes to forage on 4 flightless fruit flies under their respective light condition. Again, using automated tracking with Streampix and infrared videography, we quantified the functional responses of each spider's foraging abilities. Through the functional response, we were able to compare differences in both attack rate and overall attack success across the five treatments. We also compare movement types (e.g. Levy, Ballistic) of each spider across the five treatments. Our analysis then tests how different levels of light at night (both natural intensities and intensities that match different exposure to ALAN) affects activity patterns, movement, and foraging (i.e. fitness) for one of the most important nocturnal mesopredator clades in terrestrial ecosystems: wolf spiders. As artificial light continues to increase, these findings illuminate the importance of natural light cycles on animal behavior and ecology.

NASA's Black Marble Products and Tools in Monitoring Event-driven Changes in the Outdoor Artificial Nighttime Lighting

Theme: Measurement and Modeling

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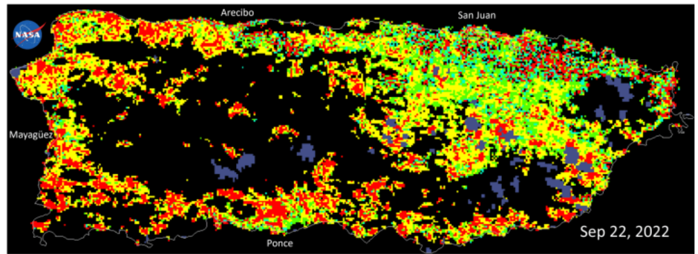
Assessing electricity access and reliability is a crucial socioeconomic indicator for understanding a society's health, well-being, and productivity. Lack of short- and long-term electricity access due to blackouts or damage to the electricity infrastructures could lead to detrimental social, economic, and health consequences. NASA's Black Marble Nighttime Lights Product Suite (VNP46), due to its automated collection, daily global coverage, and ability to capture data at the source, has been successfully used for monitoring abrupt as well as long-term changes in outdoor artificial nighttime lights (Román et al., 2018).

Black Marble products correct the extraneous sources of noise in the observed nighttime light radiance signals and are available on daily, monthly, and annual composite scales. VNP46A1 product offers daily, top-of-atmosphere, at-sensor nighttime radiance whereas VNP46A2 product provides a daily BRDF corrected NTL observation. VNP46A3/A4, monthly and annual composite products respectively, are also BRDF corrected observations, and values are generated for various view angles as well as snow conditions which help to minimize uncertainties attributed to view geometry and snow cover (Wang et al., 2021). We also have a value-added product, Black Marble HD, derived from fusing Black Marble Level3 products, along with Lansdat8 and high-resolution base layers (Román et al., 2019). It is a visualization product at ~30m that is optimized for data dissemination and decision support functions, including disaster risk reduction, humanitarian response, preparedness, resilience, and sustainable development (Enenkel et al., 2018). For instance, during Hurricane Ida in 2021, Black Marble HD images (Fig 1) were utilized to assess the widespread loss of electricity access as well as the pockets of the city that had backup power (the central city, airport, and Valero refinery). This visual assessment of outage impacts from the storm aids various partners who are working to deliver emergency aid to local communities.

Fig. 1: Outdoor lighting change during Hurricane Ida, 2021, New Orleans – The baseline image (before the storm) was from August 9th and the "after" image was from August 31st, the day after the storm made landfall in the Gulf of Mexico.

Generating these impact maps in terms of disaster response and recovery efforts is not just to compare before and after impacts images, but to try to develop, refine, and evaluate satellite-based assessments of electricity restoration efforts following a major event, based on Black Marble NTL along with other ancillary data, on the hazard exposure and vulnerability. For example, during Hurricane Fiona, which had a devastating impact on Puerto Rico in 2022, citizens of the island endure significant infrastructure damage. Fierce winds, torrential rainfall, and widespread flooding caused by the storm left roughly 100k of Puerto Rico's business and residential customers without power on the afternoon of September 22. Through Black Marble products, along with population data, we were not only able to quantify the outdoor illumination condition of Puerto Rico but also estimate the population affected by the storm (Fig 2). Fusing socioeconomic and population data with the nighttime light-derived metrics further helps us understand the interaction between power restoration rate and vulnerable populations. These analyses and results, when disseminated in real-time, can provide timely information to local communities and decision-makers, and assist communities in their long-term electricity management, infrastructure improvement, and economic development.



Color	Reduction in Outdoor Illumination	Radiance Decrease (%)	Population Affected on Sep 22*
Red	Very High	75 – 100	1,104,591
Yellow	High	50 – 75	1,082,513
Green	Moderate	25 – 50	618,195
Cyan	Low	10 – 25	267,603

* population source GPW-V4

Fig. 2: Assessing outdoor illumination condition of Puerto Rico and population affected after Hurricane Fiona on September 20th, 2022.

Our long-term goal has always been to provide necessary data/tools as well as capacity-building training/workshops at the stakeholders' level so they can perform their own analysis to help them take informed decisions. For that, we already have a few near-real-time data products disseminated through NASA's Land-Atmosphere Near-real-time Capability of EOS (LANCE) and some in the pipeline. One of them is Blue Yellow RGB composite which is a visualization product representing a "false color" with band combinations of (DNB-DNB-M15) improving the ability to determine whether changes in light are attributed to power outages or dense cloud cover as compared to earlier DNB products. Similarly, the near-real-time top-of-atmosphere radiance product, VNP46A1_NRT, is also available through the NASA's WorldView and the VNP46A2_NRT (BRDF corrected near-real-time products) will also be available soon. The Black Marble HD product and processing tool also transitioning to the Google EarthEngine platform along with the entire Black Marble L3 collection products expanding its user community and reach.

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Modern modelling – Design decisions and development of Illumina v3

Theme: Measurement & Modeling

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The Illumina model has been in development for over twenty years. It is one of the most complex radiative transfer models for uses in light pollution studies available. It explicitly accounts for multiple scattering in the atmosphere, ground reflections, obstacle blocking, terrain blocking, and many other parameters of the nocturnal environment that affect light propagation. However, this complexity comes at a cost: the amount of computing resources necessary to run even simple scenarios. This limits its usage by the scientific community. To address this issue, we developed a simplified version of the model with a graphical interface, Illumina-light. However, while this version allows obtaining results much faster than by using the full model, it is very limited in its capabilities. Another issue is the fact that the core of the model is developed in Fortran 77. While it is one of the best performing for scientific computing, this version of the Fortran language released in 1977 does not support modern advances in computing techniques, such as dynamic memory allocation and parallelism. It is also increasingly difficult to find programmers that are fluent with this nearly fifty-year-old language.

As such, we decided to significantly rework the Illumina model from the ground up. The choice of the language is the main design decision that affects the rest of the development. While modern versions of Fortran are still very well suited to efficient scientific computing, they suffer from limited IO capabilities for complex file formats such as georeferenced data. On the other side, Python is very versatile and benefits from a vast selection of packages, but it lacks the performance needed for our purposes. Luckily, it is possible to combine the two by compiling Fortran functions into Python packages. This is the method that the popular numerical computing package NumPy uses to accelerate vector operations. This hybrid approach allows us to use Python to orchestrate the processes and benefit from Fortran's speed for the compute heavy operations. Consequently, this is the modelling approach that was chosen for the development of Illumina v3. This rework of the model was also a great opportunity to standardize the project and to improve the documentation in order to ensure the project posteriority.

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Association between indoor lux measurements and outdoor wall brightness

in the high-rise urban environment of Hong Kong

Theme: Measurement and Modeling

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Hong Kong, along with many metropolitan cities, has a heavily built-up urban environment. A mixed-development model is often adopted, with the street level of these high-rise buildings reserved for business such as banks, restaurants, supermarkets, convenient stores, and barbershops while the higher floors consist of residential apartments (Figure 1). Light trespass is a severe problem faced by residents living in these buildings. On the other hand, for the majority of light pollution monitoring schemes, the measurements are conducted on the exterior lighting emissions. A question remains whether these outdoor measurements can fully reflect the impacts of light pollution in the indoor environments – where residents rest and sleep at night.

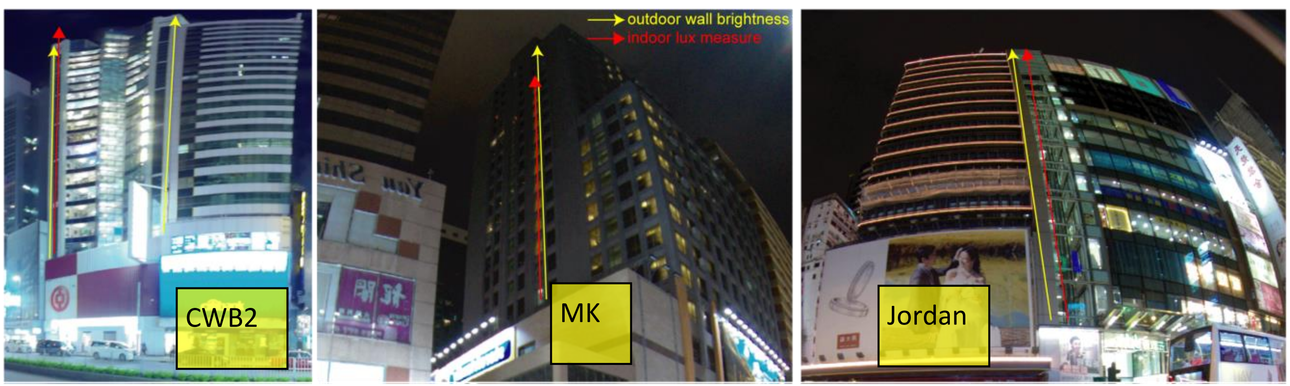

Fig. 1. Exteriors of the four buildings studied – yellow arrows indicate the locations from which outdoor wall brightness was extracted from 360 imagery, whereas red arrows indicate the route with which the indoor lux measurement was conducted. Measurements are taken in three mixed commercial-residential districts in Hong Kong, and from left to right, coded as CWB1, CWB2 (short for Causeway Bay), MK (Mongkok), and Jordon.

We conducted experiments to analyze the association between the level of outdoor lighting emission measurement and the light intensity (lux levels) experienced in the indoor environment in the high-rise buildings in Hong Kong. The impact of light pollution experienced in an indoor setting was measured with a lux meter pointing outside through a window, with a shielding applied to block the emission from interior lighting. The outdoor light measurement was assessed with the data number (DN) taken from 360 panoramic camera images taken from the street level. In this pilot study, the correlations between outdoor measurements and indoor lux assessments for 4 buildings in 3 districts are shown in Figure 2. Results show that the two measurements are highly correlated (R = 0.85 – 0.96). In particular, the wall brightness/lux values were larger at the lower floors that were affected the most by the ground shops and signboards. In the higher floors, the indoor light lux measurement became smaller, so did the wall brightness value in the imagery.

Our pilot study demonstrated a strong association between indoor lux measurements and outdoor wall brightness in the high-rise urban environment of Hong Kong. Based on our pilot study, panoramic imaging techniques that measure outdoor light pollution level from the street level can be taken as proxy of the lighting that enters into the indoor living environment which affects the residents living inside. Without going into the compartments and without disturbing the residents, a larger survey of light trespass can be conducted more easily.

In this pilot study, three of the four buildings studied (all except MK) are pure commercial buildings, even though they are all located in mixed residential-commercial areas. In a full study, we hope to survey a larger sample of different types of high-rise apartments in more diverse lighting environments. We hope that these results will not only help us to assess the seriousness of light trespass, but also help the government to identify light-polluted buildings. The specific regulations on ground-floor business activities and signboards can be targeted.

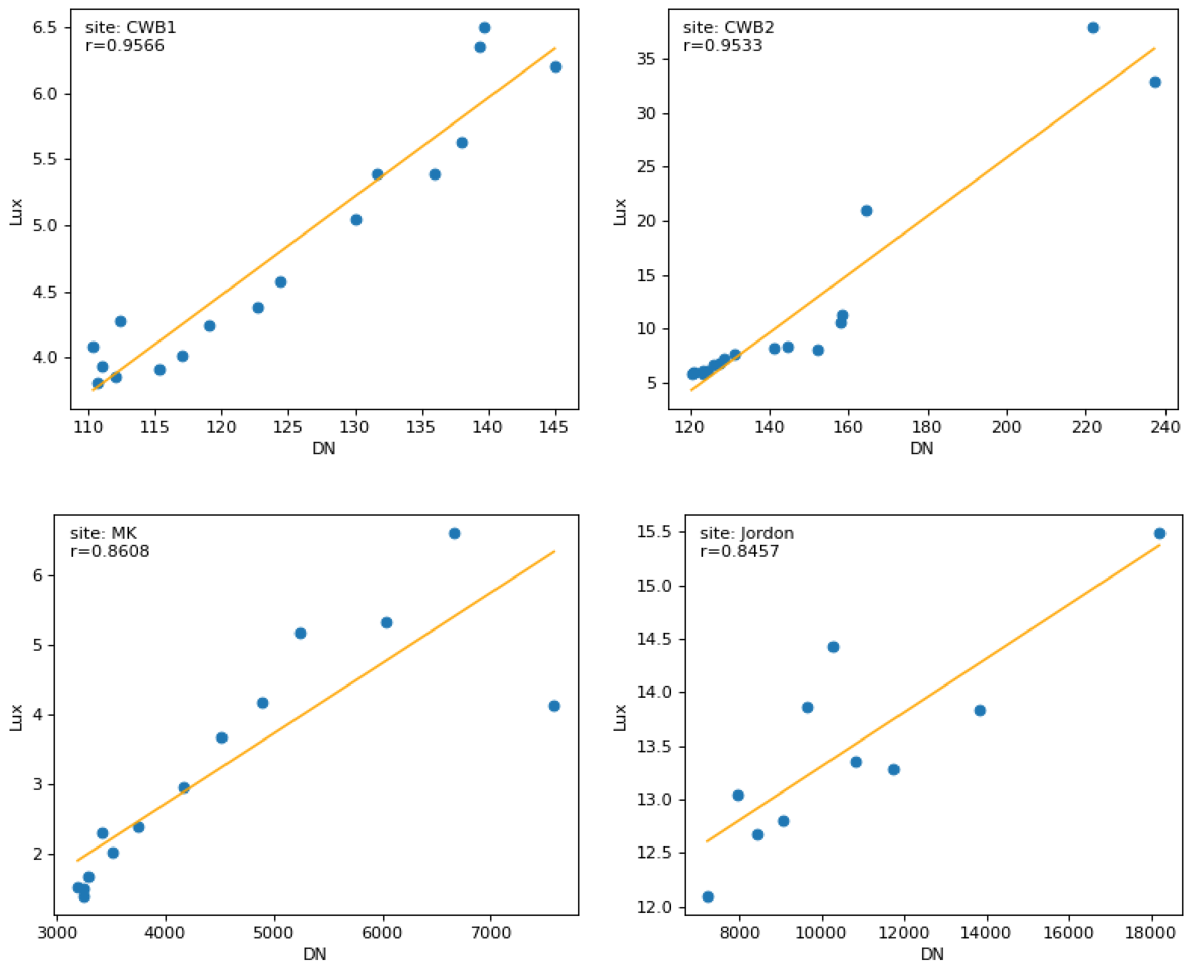

Fig. 2: Correlations between the indoor lux measurements (measured in Lux units) and the outdoor wall brightness extracted from the 360 panoramic images taken on the street level (reported as digital number, DN) taken from various heights from the ground of 4 high-rise buildings in 3 mixed commercial-residential districts in Hong Kong. The DN values were averaged from the RGB channels.

A tool to measure the effectiveness of sky glow regulations in Chile

Theme: Governance & Regulation

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Light pollution has a detrimental effect on astronomy as it decreases the ratio of the optical signal to noise. To address this issue, some countries have implemented regulations to control light emissions and their spectral content. Chile, which is home to many astronomical observatories, has updated its regulations. However, there are currently limited tools available to quantitatively evaluate the variation of light levels or its spectral content.

In this study, we have developed a set of technological tools to photometrically measure the amount of light and its blue content. These tools will assist the Environmental Ministry of Chile in evaluating the impact of the new version of the Chilean Light Pollution Regulation. The tools include a number of optical sensors in the visible range, a communication system, as well as a storage and visualization system for the data.

We have studied and compared optical sensors to obtain their characteristics and limitations. The chosen sensors were categorized based on noise and sensitivity at different light levels. A weather station and particulate matter sensor were also included to quantify the effects of weather conditions and air pollution. A first measurement campaign highlighted the difficulty of measuring very low light levels; thus, electronic and optical amplification are required to capture a greater amount of light. To detect blue light, mini-spectrometers and optical filters were used, allowing for a simple, albeit coarse, division of the spectrum.

The data is communicated, transported, and presented online using the MQTT protocol, which is efficient, fast, and suitable for the task. This tool lays the foundation for a future network of monitoring stations that can be used to evaluate the new Chilean regulations and collect dark sky data for further analysis and future studies.

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Intercultural Intelligence: How it can Help to Promote Better Lighting Design Practices in Countries with no Regulation.

Theme: Social Sciences & Humanities

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Fanny is a French native lighting designer with a Master in Applied Art as an educational background.

She has been exploring and learning about lighting design with a transversal itinerary through the industry – working successively for an Italian manufacturer, Mexican architects' studios, a French electrical material supplier, French, Vietnamese and Australian lighting studios, and currently an Australian engineering company. These opportunities brought her the past fifteen years to different locations, including Argentina, Mexico, Spain, France, Australia and her ultimate setup - Vietnam.

With a quite obvious attraction for unpredictable adventures, she has built her expertise as lighting designer collaborating with a large panel of talented and inspiring people, all connected by the same aspiration to create meaningful and successful projects. She has faced in many situations the cultural differences within her work environment with both client and colleagues and she's a strong believer that using differences creates high added value, creating stronger human connections and successful lighting projects.

Introduction

Vietnam's construction market is currently one of the most dynamic in Asia-Pacific region, re-shaping the nocturnal panorama of all cities with a frenzy emergence of completely new private neighborhoods and leading the urban development to a brightness competition between the different districts. A lot of resorts, commercial, and other hospitality projects are also investing sensitive areas such as seacoasts and natural reserves with an absolute freedom of action.

Vietnam doesn't have established standards yet within its construction industry nor a dedicated expertise to monitor the fast growth of its cities. Based on the World Atlas of Artificial Night Sky Brightness data, the lighting pollution trend has therefore dramatically increased the past few years and there is no positive signal for a close change toward this topic.

While it is tempting to identify this dysfunction as a domestic matter, with national investors surfing on a prosperous economic context to get fast money back, public institutions failing to control them, and a global unawareness of pollution long term consequences, we can't ignore that the construction market is nonetheless equally led by national and international consultants.

In fact, we can question the responsibilities but also the capacities of designers coming from countries with a higher consideration of lighting pollution to implement good practices within their Vietnamese projects.

Methods

By comparing and assessing tree lighting major study cases - an entertainment park on a top of a mountain (developed by Concepto, French lighting studio), a new neighborhood in a city suburb (developed by ASA Lighting Studio, Vietnamese lighting studio) and a new neighborhood in a city center (developed by Aurecon, Australian engineering company) - we will understand and identify how the cultural difference might influence the design output.

Core criteria such as lighting standard reference, service scope, communication tools, internal team organization, delivery package content, key priorities, client, and third parties' relationship will help to cross-check the strengths and weaknesses of each situation, questioning each one's unconscious bias and automatic habits.

Afterward, an introduction to Intercultural Intelligence concept will reveal how, by following a specific work methodology, we can generate significant benefits for individuals, teams, and companies. Researchs from sociologists such as Norbert Alter, Michel Sauquet and Martin Vielajus will be used to refine the first conclusion and elaborate an holistic approach. The selected projects will illustrate how to adjust toolkit and mindset but also the limits of this exercise effectiveness and the potential risks.

Conclusions

Skipping mutual learning through a design process involving multi-cultural consultants usually leads to frustrations and misunderstanding, especially when it comes to concepts such as lighting pollution which are more related to an appreciation than a factual number.

Most foreign designers won't adhere or monitor local requests as a local designer will do but importing or copy-pasting practices from one context to another also create most of the time counterproductive effects.

Intercultural Intelligence appears therefore as a valuable alternative which can address the previous matter by offering simple tools to help project teams building tailored design processes based on knowledge and expertise sharing exercises, improving design foundations, communication tools, risk management, and design execution.

If practices get mitigated and controlled by designers themselves, we can reasonably hope for a better management of light and reduce polluted situations in future projects.

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How skyglow determines the impact of streetlights on free-flying nocturnal pollinators

Theme: Biology & Biology and Ecology

Mona Storms[1]*, Tobias Degen[1], Oliver Mitesser[1], Zoltán Kolláth[2], Thomas Hovestadt[1], Gerrit A. Thiene[3], Alina Herche[1], Thomas Walter[4], Franz Hölker[5], Jacqueline Degen[1]

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Insect biodiversity declines worldwide which might result in the extinction of 40% of the world's insects species in the next decades (Sánchez-Bayo and Wyckhuys 2019). Nocturnal moths provide important pollination services (Walton et al. 2020) and because adult moths are known to fly towards light (positive phototaxis), their response to light pollution has been studied intensively (Boyes et al. 2021). However, the impacts of artificial light at night (ALAN) may go beyond simple declines in moth populations (van Langevelde et al. 2017).

ALAN is currently showing a profound change in spectrum and intensity leading to increased use of broad-spectrum white light worldwide, especially in citywide streetlight retrofits that are replacing old technologies (such as high-pressure sodium (HPS) lamps) with modern, energy-efficient light-emitting diode (LED) lamps (Almeida et al. 2014, McNaughton et al. 2021).

Experiments comparing the effects of HPS and LED streetlights have produced mixed results for species and orders. LEDs may have both, weaker (Eisenbeis and Eick 2011) or stronger (Grubisic et al. 2018, Pawson and Bader 2014, Rodríguez et al. 2017) impacts than HPS lamps. However, most studies have been conducted either in the laboratory or, if outdoors, with light traps.

The natural ambient brightness also has an influence on the flight of moths. The higher the moon, the more likely and faster reach males females (Storms et al. 2022). Furthermore, the moon eliminates the barrier effect for *Euthrix potatoria* (Degen et al. 2022). To our knowledge, no one has conducted experiments with HPS and LED streetlights in rural landscapes with free-flying nocturnal moths, so there is limited understanding of how transitioning from HPS to LED might affect these animals. Such an understanding is critical to conserving moths exposed to ALAN impacts.

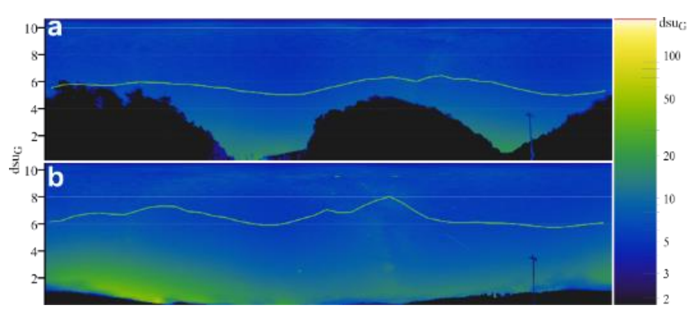

Fig. 1: Stitched high-resolution all-sky images after DiCaLum processing. The luminance heat map shows the panoramic view on a darker woodland field (a) and on a brighter open field (b). The green line indicates the mean vertical sky radiance for green channel radiance ($_{G}$) in the dark sky unit (dsu).

In this two-parted study, we released male moths of the species *Sphinx ligustri*, which were reliably attracted by females, and measured their flight duration till arrival at trapped females. A streetlight was installed on every flight route.

On the one hand we compared two different fields with higher (open field) and lower (woodland field) ambient brightness. In the darker field, most of the skyglow was obscured by the forest. We compared the influence of two conventional streetlights with HPS and white LED with 4000 Kelvin (K) on (i) male arrival probability at captured females and (ii) the successful males' flight duration. (iii) We further analyzed whether the response to artificial light (HPS and LED 4000K) is stronger in a darker environment than in a brighter environment.

On the other hand, we compared the influence of three LED streetlights, two conventional with 1800K and 4000K, and one special spectrum from Osram/Trilux with 2200K, relating to frequency of arrival and flight duration. All-sky photometry (Jechow et al. 2020) was used to measure sky brightness during the entire experiment period. The camera was attached to a robotic panorama head (iPANO AllView Pro Camera Mount) and took repeated pictures in the order north, south, west, east, zenith. The images were processed with DiCaLum (Kolláth et al. 2021) which allowed us to resolve the horizon more detailed and accurate than classic fisheye images do alone (Fig.1).

This study is the first to combine the improved full-sphere measurement with field experiments, enabling us to link flight behavior with the light environment in great detail. We found a significantly reduced arrival frequency of males at females when a streetlight was introduced on their flight path. Furthermore, this effect increased with the color temperature and varied as a function of ambient brightness. Thus, the behavior of free-flying nocturnal moths is affected by the light environment in multifarious ways, with artificial as well as natural light components being of particular importance.

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Impacts of artificial light at night on early life stages can shape communities and trophic relationships

Theme: Biology & Ecology

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Light cycles are a major structuring force in ecosystems driving large-scale processes like diel vertical migration and broadcast spawning across species and latitudes (1). Marine invertebrates are extremely sensitive to low intensity natural light throughout their life cycle. Larvae dispersal regulates the distribution of most benthic marine species; a life stage at which species can be particularly vulnerable to the environment (2). Larvae are sensitive to climate change induced ocean acidification and temperature both of which can have knock-on effects community composition and ecosystem processes (3). However, the impact of artificial light at night (ALAN) on the very beginning of marine life remains understudied (4) despite the crucial role of larvae in ecological networks and communities and the vast exposure to ALAN underwater (5). We will present novel insight into the impact of ALAN on temperate marine larvae. Better understanding of how ALAN influences early life stages can be an approach to scale up from individual to higher level ecological communities and processes.

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Simultaneous measurement of the sky glow using several Sky Quality Cameras in the surroundings of an observatory in Chile

Theme: Measurement and Modeling

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This paper presents the results of a study on night sky brightness in Chile, a country that recently implemented new regulations to protect its skies for astronomical purposes, the well-being of its citizens, as well as the biodiversity from the negative effects of light pollution. Chile, being one of the few countries with a comprehensive regulation on light pollution, concentrates a large part of the world's astronomical infrastructure.

The study, conducted using multiple "Sky Quality Camera (SQC)" systems, aims to quantify the local and regional effects of variations in sky brightness in the Coquimbo Region of northern Chile and to determine the effectiveness of the new regulations in protecting the night skies, the health and safety of the citizens and the biodiversity from light pollution. The SQC system, which was developed by Andrej Mohar, consists of a Canon DSLR camera with a wide-angle lens and post-processing software that can measure sky brightness, luminance, illuminance, and correlated colour temperature of the sky. The study involved taking continuous photographs at three different locations, including a point with minimal light pollution and two locations closer to sources of light pollution, starting before sunset and continuing for four hours after sunset. At each location, one SQC system was deployed to take photographs, resulting in a total of three SQC systems used simultaneously for the study. Although the cameras are calibrated, a synchronous measurement was also performed with all cameras at the same location, in order to have a common baseline.

The results, which are presented in graphical form, show the data as a function of time and geographical location, and compared different points in the sky. This research was conducted in collaboration with the Chilean Ministry of the Environment, as part of an effort to better understand and address the effects of light pollution in Chile, and to evaluate the effectiveness of the new regulations in achieving their goal in reducing the light pollution.

Teens using Photovoice to promote light pollution awareness

Theme: Social Sciences & Humanities

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Adler Teen Programs has engaged hundreds of high school students in the subject of light pollution. Teens help to track light pollution, design tools to collect data, and engage in light pollution advocacy projects. The Adler Planetarium's Youth Organization for Lights Out (Y.O.L.O.) is a light pollution awareness and civic action program for high school youth in underrepresented neighborhoods in Chicago, Illinois. YOLO is designed to motivate and empower youth by exposing them to knowledge about light pollution and teach them to become environmental activists within their own community. The program has adapted its methods and goals since its inception in 2017. Here we describe the use of Photovoice, a framework for using ethical photography to promote social change, in the 2022-23 YOLO program. Photovoice has successfully been implemented in environmental justice, environmental health, and air pollution educational projects.

Methods

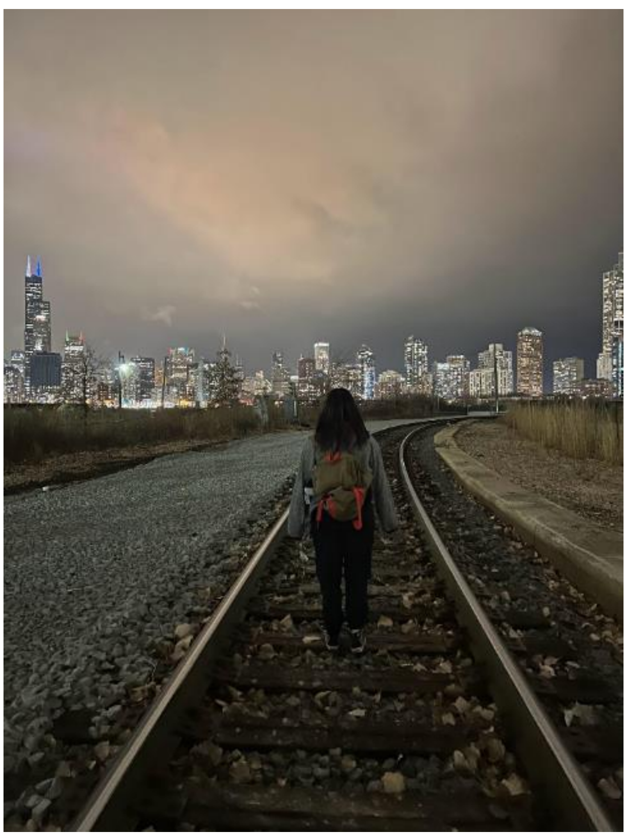

Fig. 1: SEQ Figure * ARABIC 1: Photovoice submission created by YOLO participant Kyle M. December 2022

Photovoice projects have three main goals: 1) enable participants to record and reflect their community's strengths and concerns; 2) promote dialogue and knowledge about important issues through group discussions; and 3) reach policymakers to encourage change. As part of the photovoice process, participants describe their photos using a method called "SHOWeD". This method is used to answer the questions, "What do we see?", "What is really happening?", "How does this relate to our lives?", "Why does this concern exist?", and "What can we do?". By responding to these questions, participants critically reflect on the situations captured through the photos in their own voices. After completing the SHOWeD method, participants create narratives describing light pollution concerns in their communities. Group discussions were used to identify and raise common themes that participants observed. Narratives and group discussions are also important to identify participants' preconceptions about light pollution. In this project, teens expressed preconceived notions about lighting, crime, and safety. Facilitators address preconceptions by sharing scientific data and inviting experts to speak in the sessions.

Conclusions

To effectively implement a photovoice project, facilitators should not begin with light pollution content before understanding the major social and environmental concerns of the community. For example, one of the first sessions of YOLO was a walk around the community led by the teens. Facilitators must establish a trusting relationship with participants so they understand why they should care about the issue of light pollution and fight for local changes. Partnerships with local organizations are also encouraged to enhance positive outcomes in the project. The photos and narratives are used to share the issue with the community at photo exhibits. The 2022 YOLO program presents two public photo exhibits, one in their community and another at the Adler Planetarium. A Light Pollution Photovoice Exhibit at the Adler Planetarium strives to inspire museum visitors to reflect and take action in their own communities. Public impressions and feedback are gathered at the exhibit to help gauge the impact their work has had and how to effectively communicate the issue of light pollution.

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Impacts of various combined streetlight characteristics on the abundance of nocturnal ground-dwelling arthropods

Theme: Biology and Ecology

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Introduction

In recent years, there has been a rapid growth of Artificial Light at Night (ALAN) worldwide, increasing by more than 2% annually (Kyba et al., 2017). In urban and suburban areas, direct light comes from street lighting, domestic and commercial sources, and can also be deflected from surrounding surfaces. Modern light pollution is no longer limited to urban centers, but also radiates outward along road networks and through the atmosphere, increasingly affecting otherwise pristine areas (Gaston et al., 2015; Gaston & Holt, 2018). ALAN has been identified as a primary driver of environmental change in the 21st century with critical consequences for both, ecological systems, and humans. ALAN causes a wide range of negative fitness-related ecological impacts and is a key driver of insect decline (Bolliger et al., 2020, 2022; Grubisic et al., 2018; Hölker et al., 2021; Owens & Lewis, 2018). Studies on the effects of ALAN on arthropods have focused primarily on flight active insects, while work on ground-dwelling arthropod species and communities is very limited. Furthermore, the majority of these studies have focused on responses to only a single light property, such as LED color or exposure level, and were mostly restricted to areas that are already affected by light pollution (e.g. Davies & Smyth, 2018; van Grunsven et al., 2020). To understand the impacts of ALAN on nocturnal ground-dwelling arthropod communities under real-world conditions and in more natural environments such as forests, it is crucial to perform field experiments that include multiple combined characteristics of LED luminaires.

Experimental set-up

Our experiment was conducted at three forest field sites in Switzerland. The study sites were not previously exposed to the direct influence of artificial light at night. At each site, the installed streetlights were at least 30m apart. The experimental setting consisted of two dark control sites and 13 LED streetlights mounted on aluminum poles at 2.5m height. Pitfall traps were installed at two distances to the streetlight poles: "close" at 1m (100% of the full light intensity) and "distant" at 4.3m (15% of the full light intensity) to sample ground-dwelling arthropods. Three different LED-colors (neutral white (4000K), warm white (3000K) and amber (2200K)), three light intensities (permanent dimming to 50% and 33% of full light intensity; 100% of full light intensity) and two luminaire shapes (increased horizontal light distribution (with a diffusor) and normal vertical light distribution (without a diffusor); Fig. 1) were selected as LED characteristics. Combining these properties, we obtained 13 different LED-light treatments and two additional dark control sites, resulting in 14 unique treatments per field site.

Fig. 1: Top row: Street lights without (left) and with diffusor (right). Bottom row: amber LED color temperature and neutral-white color temperature. Photos: Martin K. Obrist, WSL

Research objectives

The experiment was conducted over two years (2021-2022), to examine how the various combined streetlight characteristics (see Experimental set-up) affect the abundance and diversity of ground-dwelling arthropod groups, that are attracted to individual lights, at taxonomic and functional level. The overall objective was to gain a better understanding of (1) the impacts of ALAN on ground-dwelling arthropods as a function of different LED properties and (2) whether specific LED property interactions can amplify or mitigate negative effects of ALAN on ground-dwelling arthropods. Ultimately, by investigating the impacts of LED luminaires across multiple years, we will achieve a better understanding of the longer-term impacts of a range of street lighting properties on ground-dwelling arthropods.

Fig. 2: Streetlight with two pitfall traps (red flags)

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Gather Around Light – What Love and Compassion Can Do - About the positive impact of an informal voluntary network of people

Theme: Technology & Design

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Introduction

This abstract is about the community "Gather Around Light" or - how the After Hours Activities of an informal voluntary network can have an impact and change things into a better direction. How much diversity, open mindedness, curiosity, social care and mindfulness – say, love and compassion - have to do with it. And how the aspect of sustainability in lighting design and lighting technology has changed our path and perception.

Founded in the midst of the 2010th as Regular's Light Table for and from the lighting community in Berlin, for the first years, we shared monthly evenings in different gastronomical sights to exchange experiences and projects, learn, and have fun together, taking the passion for our profession into the After Hour.

Fig. 1: Gather Around Light – people and events 2016 – 2021, © Fig. people bw, color: Thomas Mehls, Roman Liebe, Sabine Hauff,; c: examples Regular Light Table, The Dark Art, Michael Immecke, Konstantin Klaas
Source: www.gather-around-light.net

Berlin in Brandenburg with Potsdam nearby – a large and vibrand city in creative, cultural, scientific, and economic means. Home of worldwide renowned Lighting Design and Engineering Companies; Scientific Research Institutions and Universities; Lighting Industries and their Sales Representatives. The base of a constant growing network, reaching far further than the area – an overview will be given in the presentation. From the very beginning many interesting and influential people and subjects – "just" from the field of lighting. Fulfilling but without real impact.
In 2016 we decided to get a step beyond. Inspired by a successfully executed event – the fairy tale cabin, a warm up venue for the PLDC 2017 in Paris – we opened up the curtains to lighting enthusiasts in neighboring fields – arts, music, social and environmental studies and more.
Our aim – to do something together and create a yearly venue. An unforgettable experience for the whole lighting field in and over the borders of Berlin. A core part of this – our regular meetings – are a place to feel good; of mindfulness and friendly fellowship that connects people and makes things happen – accompanied by a tasty bring along buffet. A good atmosphere to get things done.
As we are a solely voluntary group, this works by cooperating with partners and supporters in our network who take over the financial and administrative responsibilities when it comes to realizing things. We create the ideas and executing them with a lot of enthusiasm.
Accompanying this, we started a website and publish a regular newsletter for better communication and finally – information – as sharing knowledge is as important as the events.

In this spirit, we're continuing with our Regular's Light Table, discussing all kinds of subjects around the matter – more in the presentation. "Thanks" to the pandemie, we went online and have an even further reach into Germany, England, Austria, the Americas. Now, in post-pandemic times, we're mostly meeting hybrid to allow our further away fellows to join as well. With all our activities, **Gather Around Light** is a successful example for voluntary civil engagement and – how far you can get to doing what you love to do in good and cordial company. You are welcome!

Venues

2017: Märchenhütte / Fairy Tale Cabin
2018: Sternwarte Berlin: vom Galaktischen zum Irdischen
2019: Festival für urbane Lichtkultur (Festival of Urban Light Cultur)
2020/21: Science / Education: Workshop Licht und Emotionen / Light & Emotions
Regular's Light Tables – examples will be part of the presentation

What about the sustainability in Gather Around Light?

With the second venue in 2018, the subject Light Pollution made it into our focus - and hasn't left since. Among other presentations, Sibylle Schroer (IGB Berlin) as key speaker of the event "From Galaxy Down To Earth" introduced us to the consequences of artificial light on the environment and its habitats. This was not only a focus broadening experience for many, but also one that widened our network toward the institutes for environmental studies located in and around Berlin. We have" a direct line" to the environmental specialists now. Our view on our own work as lighting designers has changed and so has our way of doing lighting design.

The matter was subject of diverse Regular's Light Tables hence – i.e. by presenting Annette Krop Benesch's book "Licht aus!?" (Turn the light off!?). And Etta Dannemann's audio experience for star gazing sites, called "Visit Dark Skies" – a live changing invention for her. Etta turned her career path from beeing a lighting designer to an environmental entrepreneur.

We are proud of being pioneers in the relationship of Lighting Design and sustainability – at least on German ground. We make sure that all lighting designer within our network are aware of the significance of the subject. And many of us are now including the requirements for sustainable lighting design into their work in a different way than before. So – if you need competent consultancy concerning the matter – you can get that, just get in contact with us!

References

Gather Around Light: https://gather-around-light.net/; Regular's Light Tables: https://gather-around-light.net/past-and-presents/; Events: Vom Galaktischen zum Irdischen: https://gather-around-light.net/2018/04/20/licht-vom-galaktischen-zum-irdischen-an-der-archenhold-sternwarte-berlin/

https://www.youtube.com/playlist?list=PLJpzZbXQQ-plpV7oSfBKDYd2sikC5uMCA

Festival für urbane Lichtkultur: http://urban-lightculture.de/

Light & Emotions: https://www.youtube.com/watch?v=GZDMW8WSn90

https://www.rowohlt.de/buch/annette-krop-benesch-licht-aus-9783499634482

https://www.visitdarkskies.com/

Taking Action on Protecting Dark and Quiet Skies from Satellite Constellation Interference: the IAU CPS

Theme: Measurement and Modeling

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Summary

Since 2019, when the first Starlink satellite constellation was seen as a "string of pearls in the sky", it did not take long until optical and radio astronomers started seeing observations affected. The astronomical community has been self-organized since then and has been working very actively for the protection of the dark and quiet skies from satellite constellation interference.

The international Astronomical Union (IAU) has taken two lines of action to deal with this situation: first to seek the adoption of international guidelines from the UN COPUOS, and second to establish a Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (IAU CPS). While obtaining international guidelines may be a long process, good progress has been made in that respect. On the other hand, the IAU CPS seeks to develop a much more agile interaction, in a collaborative way between astronomers, industry and many other affected groups it seeks to implement mitigation measures in the short term.

In April 2022, the new IAU Centre for the Protection of Dark and Quiet Sky from Satellite Constellations Interference (CPS) began its operation. Considerable progress has been made in the analysis and initial implementation of mitigating measures. In particular:

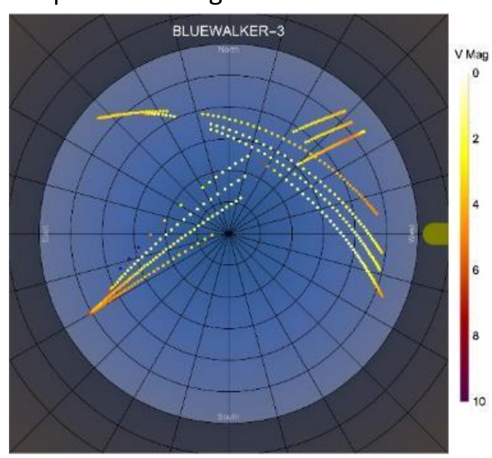

Fig. 1: Telescopic Observations of AST Spacemobile BlueWalker3 in December 2022 by Harry Krantz (U. Arizona)

- More than 275 external members (either individuals or institutional) have offered their collaboration to the CPS pro bono.
- A network of observers (mostly professi5#äonal or amateur astronomers) started collecting data of the apparent luminosity of the different satellites along their orbit (Figures 1 & 2). These data are instrumental to understand the reflection behavior of the satellites and to calibrate the predictive model of the expected luminosity by future constellations. Some of these data have been requested by some constellations' operators.
- An open repository of research and images (for download & upload) is being built, in addition to the observing network to collect the images.
- CPS is working with satellite operators to set target brightness levels and other mitigation parameters and with regulators to consider aggregate (cumulative) impacts.

- Technological studies on different materials have been initiated by some companies in the attempt to reduce the bi-directional reflectivity of the satellites. The results of these studies are made publicly available to the world space industry.
- The state-of-the-art position data of the satellites is being used to predict satellite in such a way that the satellite's trails might be avoided during astronomical observations.
- CPS is developing software for processing and analyzing data.
- Discussions with operators are ongoing to implement mitigation measures to protect radio astronomy sites, especially radio quiet zones.
- CPS is building international collaborations.
- CPS is providing input to regulators developing frameworks for regulations.
- CPS is providing input to the discussion on how to apply environmental laws to low-Earth orbit mitigation of harm to astronomy as a requirement of licensing.
- The lessons so far learned and the best practices to be proposed to future constellation companies are being collected to be made publicly available.

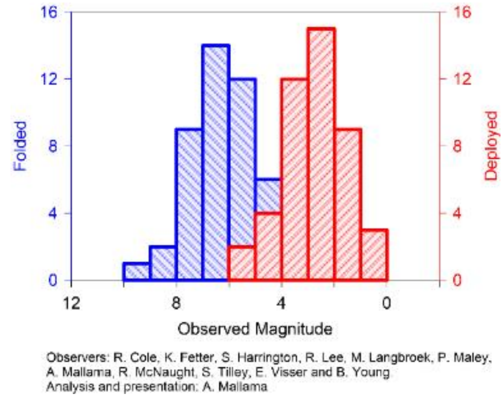

Fig. 2: Visual Observations of AST Spacemobile BlueWalker3 in December 2022. Observers were R. Cole, K. Fetter, S. Harrington, R. Lee, M. Langbroek, P. Maley, A. Mallama, R. McNaught, S. Tilley, E. Visser, and B. Young. Analysis by A. Mallama. Note the 4 magnitude increase in brightness after the antennae were deployed.

These are the effort of the members of the four hubs or groups that comprise the IAU CPS: SatHub, the Industry and Technology Hub, the Policy Hub and Community Engagement Hub. SatHub focuses on new tools and resources to track and remove trails in data as well as manage other interference (e.g., data repository; software). The Industry Hub is developing guidelines for best practices, especially for mitigation measures in designing next generation satellites. The Policy Hub is in discussions with US and other governments about national and international issues, including environmental law/policy. The Community Engagement Hub aims to establish a fair-minded forum for the conscious and respectful discussion of the constellations with all stakeholders involved and communities affected.

The poster will focus on the status of the IAU CPS, its membership, the activities of each one of the four hubs and other recent developments. For more information, visit cps.iau.org.

9.6% Rise in Light Pollution between 2011-2022 Observed by Citizen Scientists

Theme: Measurement and Modeling

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Introduction

Astronomers are inherently concerned with light pollution affecting their research as well as the environment, excess energy consumption and human health. The artificial glow of the night sky is a form of light pollution; its global change over time is not well known. Developments in lighting technology complicate any measurement because of changes in lighting practice and emission spectra. The authors investigated the change in global sky brightness from 2011 to 2022 using 51,351 citizen scientist observations of naked-eye stellar visibility from an international citizen science campaign called Globe at Night.

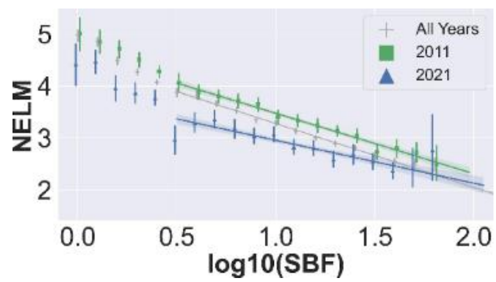

Fig. 1: Relationship between naked eye limiting magnitude estimated by Globe at Night participants and the modelled artificial brightness of the night sky in 2014. "Sky brightness factor" is the ratio of total radiance to natural sky radiance, so a factor of 1 here means the sky is 10 times brighter than starlight. The relationship is shown for two separate years (green, blue), and all years together (gray). Smaller NELM values mean a brighter sky. The fit lines are calculated only for $\log_{10}$SBF>0.5, which corresponds to about 3 times brighter than starlight.

NSFs NOIRLab, the US national center for ground-based, nighttime optical astronomy, hosted Globe at Night for the last 17 years. Globe at Night invites people from around the world to compare the constellation of the monthly campaign with the charts shown in the app. The charts represent different limiting stellar magnitudes. Hence charts with fainter magnitudes represent less light polluted skies.

Methods

In a recent paper by Kyba et al. (2023), the authors investigated the change in global sky brightness from 2011 to 2022 using 51,351 of the Globe at Night citizen scientist observations of naked-eye stellar visibility (Fig. 1). The number of visible stars decreased by an amount that can be explained by an increase in sky brightness of 9.6% worldwide per year (10.4% in North America) in the human visible band (Fig. 2). This is equivalent to doubling the sky brightness every 8 years. This increase is faster than emissions changes indicated by satellite observations (2%). This is mainly because the satellites are not sensitive to the wavelengths (short of 500 nm) at which white LEDs (primarily from cities) peak, or to light emitted horizontally. In addition, blue light is more effectively scattered in the atmosphere than other colors. These two effects give a possible reason for the lower estimate from orbital-based light pollution measures versus the ground-based estimates studied by Kyba et al 2023.

Conclusions

The authors draw two conclusions from these results. First, the naked-eye visibility of stars is deteriorating rapidly, despite (or perhaps because of) the introduction of LEDs in outdoor lighting applications. Existing lighting policies are not preventing increases in skyglow, at least on continental and global scales. Second, the use of naked-eye observations by citizen scientists provides complementary information to the satellite datasets.

Sky glow from light pollution can be reduced. The strategies for cutting light pollution are straightforward: use outdoor lighting only when, where, and how it is needed; minimize blue light content, and use fully shielded fixtures (https://www.darksky.org/our-work/lighting/lighting-for-citizens/lighting-basics/). As results from the Kyba et al. study indicate, more effort is needed to put these recommendations into ordinances, bylaws and other regulations to slow down and hopefully reverse the degradation of our shared night sky.

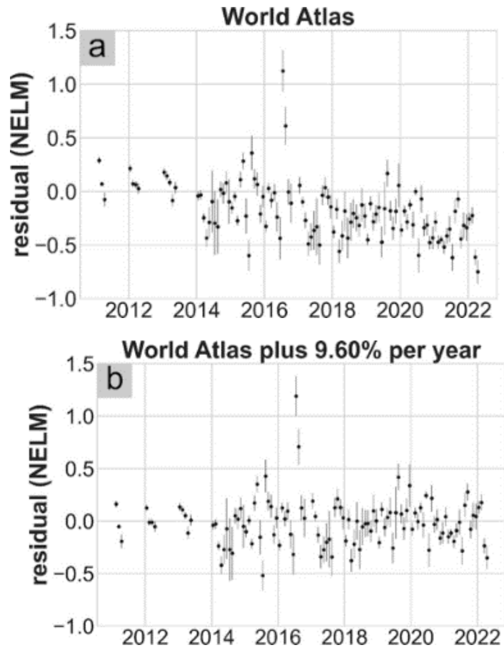

Fig. 2: The fit residuals (observed minus expected) for naked eye limiting magnitude are shown with the standard World Atlas prediction (a) or with the Atlas adjusted for an annual exponential growth of 9.6% per year. Larger values mean observers reported more stars than expected. Note that data points before 2014 include a larger numbers of observations than those afterwards. Error bars show the standard error.

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Taking the atmosphere into account:
Finding a stronger link between air and light pollution and how to treat it in the future

Theme: Measurement and Modeling

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Introduction

Measurements of artificial light at night represent an incredible challenge as the optical state of the atmosphere is highly unstable thus making both long-term trend analysis and inter-comparison of multiple observations difficult. Variations of atmospheric parameters, caused by either natural or anthropogenic processes, can massively influence the level of resulting night sky brightness caused by light pollution. By this are meant continuously variable influences caused by the volatile atmosphere, actually responsible for causing light scattering and, consequently, light pollution over a large territory (e.g., Cinzano & Falchi 2012). It is the state of atmospheric layers, chiefly lower ones, where these effects are occurring, and more fundamentally the impact of individual fluctuating parameters determining the dimension of resulting night sky brightness (NSB) and level of pollution for both air and light (Bará et al. 2022, Edensor 2015). Besides of natural appearing seasonal changes of those atmospheric elements, mainly meteorological and anthropogenic processes define scales in time and size variations of alterableness. As a consequence, the impact of ALAN to NSB potentially fluctuates from night to night, enabling long-term analyses possible solely if this is taken into account for obtained observations. Our aims are therefore defined as: i) identify aerosol and atmospheric parameters more or less important for shaping NSB; ii) find new ways in measuring the atmospheric state and its impact on resulting NSB; iii) quantify the role of particles smaller than aerosols, i.e., molecules.

Methods

Two different methods are used in order to answer our research goals:

i) Making use of theoretical modelling, computing a specific light emission source and furthermore its impact to NSB. However, here we concentrate on the same exact build-up at varying atmospheric conditions and changes in emission function. More precisely, the central focus lies on six parameters underlying theoretical variations: aerosol optical depth, asymmetry parameter, single scattering albedo, emission function including the surface reflectance and direct uplight ratio, and aerosol scale height. All these elements present essential input parameters for skyglow modelling. The goal being aimed at in this work is to

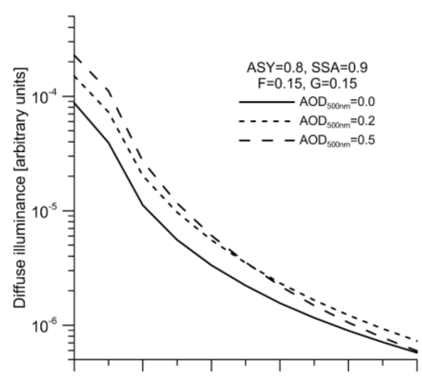

Fig. 1: Results of computations analyzing the diffuse illuminance at the ground caused by the light emitting source at a range of distances and three specified AOD values.

distinguish, how each of those individual key figures influences the NSB, situated either inside, near or farther away from a light emitting source.

ii) It is very hard to characterize local atmospheric layers during in-situ measurements. However, there could be new approaches in the usage of currently used instruments, like Sky Quality Meter or various cameras, in order to retrieve information about atmospheric impacts. Our plan is to use air-bound vehicles like helicopters, drones or even small airplanes to do so. The manner how this is achieved is by mounting measurement devices on those vehicles and, together with location coordinates and altitude values, being able to characterize the impact of light domes and scattering of light waves by cities of various distance.

Furthermore, we want to introduce a new measurement network, consisting of not only NSB but also ceilometer stations in order to accurately quantify atmospheric impacts in the future. In addition, we want to highlight final results from a comparison analysis of long-term air quality (PM_{10}, $PM_{2.5}$, CO, O_3, SO_2, H_2S, NO, NO_2 and relative humidity) and NSB monitoring data.

Conclusions

It cannot be neglected that air quality and light pollution do have a strong relation. Taking care of atmospheric conditions means to also influence the level of environmental impact caused by artificial light at night (see also Kocifaj & Barentine 2022). Especially in times of environmental management growing in importance or in need of energy savings, urban development and civil engineering processes must take this into account in order to create or protect habitable areas for humans, wildlife and nature. Results obtained from computations simulating varying atmospheric parameters explicitly identify those having a significant impact forming the night sky brightness at a site suffering from artificial light at night. The six elements analyzed have shown influences being differently pronounced depending on their relation to absorption, scattering or extinction efficiencies in the atmosphere. In-situ measurements of calibrated drones are ongoing and still a matter of detailed analysis.

Acknowledgments

This work is part of the project for which the financial means was funded by the European Union's Horizon 2020 Research and Innovation Programme on the basis of the Grant Agreement under the Marie Skłodowska-Curie funding mechanism No. 945478 - SASPRO 2. This work was supported by the Slovak Research and Development Agency under Project No. APVV-18-0014.

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Identifying Sources of Sky Glow Through Triangulation with a

Distributed All-Sky Camera Survey

Theme: Measurement and Modeling

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**Presenting author*

ALAN impacts the nighttime environment on multiple scales - from direct light exposure to skyglow affecting nighttime brightness on a regional scale. Skyglow, though indirect, can contribute more light into an environment than all natural sources combined while obscuring the night sky - even in areas that emit no ALAN themselves. Sources of skyglow are often identified by examining nighttime images and visually defining the "light domes" they create along the horizon. At its simplest, the quantity of skyglow observed at a location is a function of the distance from the source and the source's intensity. In many instances, multiple sources can aggregate into a conglomerated skyglow, particularly near crowded urban environments. In this study, we demonstrate a method of identifying and disentangling sources of skyglow which can help quantify their individual impact as well as help address their mitigation.

This method involves simultaneously collecting images of the night sky with multiple, all-sky cameras distributed across a region of interest. This experiment uses GONet cameras - a compact, inexpensive, automated all sky imaging device designed for light pollution observations. Multiple GONet cameras are distributed across the Palos Preserves, a 6,700-acre International Dark-sky Association designated Urban Night Sky Place, 25 km southwest of Chicago. This area contains virtually no sources of ALAN but is affected by skyglow both near and far beyond its boundaries. Light domes in each image are identified using a standard methodology, their extents are defined, and the images are then geolocated using GIS software. Given the offset baseline between each camera, we can calculate the direction and distance to each source of skyglow observed from within the preserves. We then confirm these distances by projecting the azimuthal angles of each light dome within view of each camera outward over a map of the region with remotely sensed data from the VIIRS DNB and ISS.

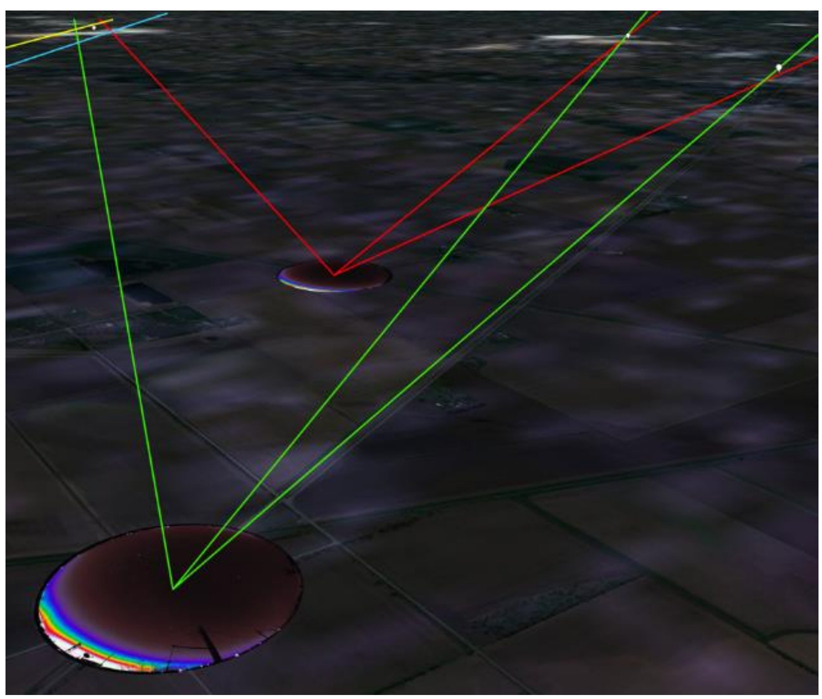

Fig. 1: Test identification of light dome sources via triangulation method. Map Image: Google, Landsat/Copernicus

These results can aide in determining the most efficient mitigation strategies to help reduce light pollution at the Palos Preserves. We believe this method can be used to identify and even quantify the impact of skyglow sources in a variety of night environments. A notable aspect of this experiment is the active inclusion of teens in the research process. We hope it can be used as a model of engaging young people with the scientific process and the light pollution research community.

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NASA Collection 2 Black Marble Nighttime Light Product Suite

Theme: Measurement and Modeling

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NASA's standard global Black Marble nighttime light (NTL) product suite is produced from Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB) onboard the Suomi National Polar-orbiting Partnership (Suomi-NPP), NOAA-20, and NOAA-21 satellites launched in 2011, 2017, and 2022 respectively at the spatial resolution of 15 arc second (Román et al., 2018). Black Marble NTL has been increasingly used for the quantitative analysis of human activity and human behavior dynamics with reduced noise uncertainties to support the United Nations Sustainable Development Goals (SDGs).

The Collection V001 (C1) Black Marble product suite includes (1) daily Top-of-Atmosphere (TOA) DNB NTL radiance (VNP46A1); (2) daily atmospheric- and lunar-BRDF-corrected NTL radiance (VNP46A2); and (3) monthly and annual NTL composites (VNP46A3/A4) (Román et al., 2018;Wang et al., 2022). A novel "Turning off the Moon" approach is applied to derive the daily atmospheric- and lunar-BRDF-corrected NTL radiance product. This approach combines cloud-free, atmospheric-, terrain-, snow-, lunar-, and stray light-corrected nighttime VIIRS DNB radiances, daytime DNB surface reflectance, Bidirectional Reflectance Distribution Function (BRDF)/Albedo, and Lunar irradiance values to minimize the influence of extraneous artifacts and biases (Wang et al., 2021). The lunar contribution to the DNB radiance is estimated and removed by integrating a lunar irradiance model with surface DNB BRDF/albedo. The removal of surface-reflected lunar radiance enables the generation of temporally-consistent daily NTL products. The monthly and annual NTL composites are generated from the daily VNP46A2 NTL radiance (Wang et al., 2022). The Collection V002 (C2) reprocessing, scheduled for 2023, refines the VNP46A1/A2/A3/A4 products and includes a new NTL change metrics product (VNP46A5). The C2 Black Marble products are generated not only from Suomi-NPP but also from NOAA-20 and NOAA-21 DNB observations.

Cross-calibration was conducted to evaluate the effect of the different spectral response functions of Suomi-NPP, NOAA-20, and NOAA-21 DNB. The aurora is identified using a machine learning method (Kalb et al., 2023) and the aurora mask is added to the daily TOA DNB NTL product (A1). The C1 Black Marble A2/A3/A4 are land products only. The C2 reprocessing expands these products to have NTL over the water. Viewing Zenith Angle (VZA) stratified COntinuous monitoring of Land Disturbance (COLD) algorithm (VZA-COLD) was developed to continuously detect global NTL changes (A5) with daily updating capability. Specifically, the NTL observations are divided into four VZA intervals (0-20°, 20°-40°, 40°-60°, and 0-60°) to mitigate the impacts of viewing geometry and surface conditions (e.g., building heights, vegetation canopy covers, etc.). NTL changes were detected based on the actual observations and model predictions of each VZA interval. The final NTL change maps were generated by assembling the changes detected from the four VZA intervals and excluding consistent dark pixels. Results indicated that the VZA-COLD algorithm reduced the DNB data temporal variations caused by disparities among different viewing angles and surface conditions (Fig 1). The NTL changes can be detected with an overall accuracy of 99.71%, a user's accuracy of 87.18%, and a producer's accuracy of 68.88% at six globally distributed test sites.

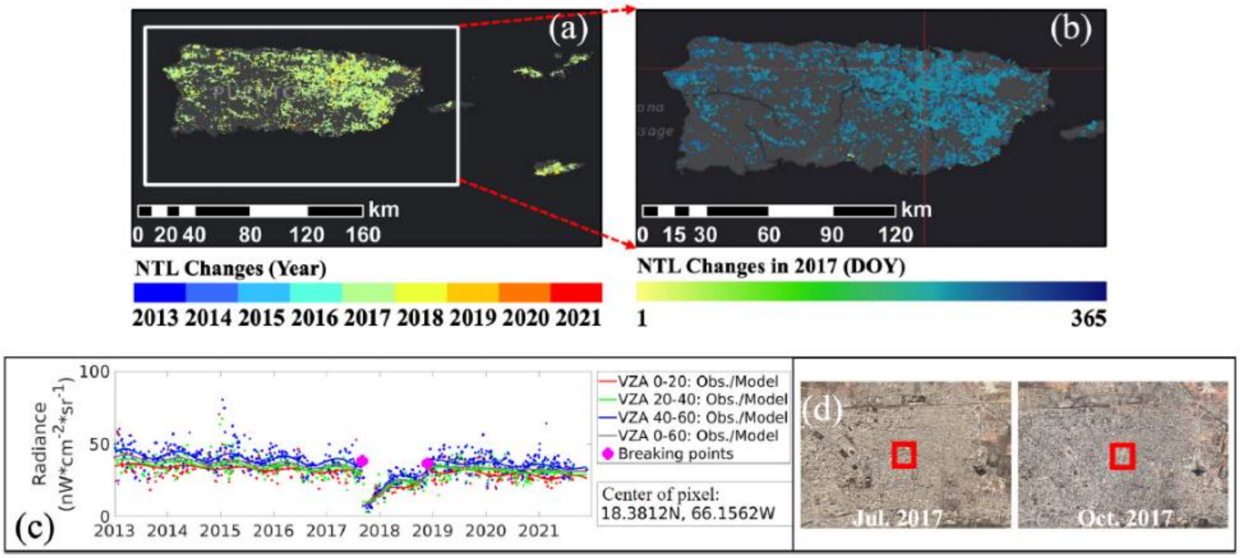

Fig. 1: The VZA-COLD detection for Puerto Rico. (a) The accumulated annual NTL change maps from 2013 to 2021 with the latest detected change year presented. (b) The day-of-day NTL change map in 2017 over the region enlarged from the white rectangle from Fig. 1a. (c) The time series plot of a selected pixel (red cross in Fig. 1b) and the corresponding VZA-COLD detection results, in which the red, green, blue, and grey colors indicate the different VZA intervals, the lines represent the estimated models, the small dots are the DNB observations, and the large magenta dots are the detected changes. (d) The high-resolution Google Earth image in July 2017 and October 2017. The red squares represent the location and size of the selected pixel in Fig. 1c.(Li et al., 2022).

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Solar Global Radiation and night sky brightness

Theme: Measurement & Modeling

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Introduction

"The new world atlas of artificial night sky brightness" was published in 2016 (Falchi et al., 2016). The atlas shows the intensity that illuminates the nights and states that 83% of the world's population live under light-polluted skies. In this scientific publication a new upward emission function is described, which was modelled with images in a clear atmosphere. In the publication the assumed state of the atmosphere is seen as a possible modelling error.

In April 2020 the new study "Light over Vienna VII, light content of the night from 2009 - 2019" was published(Wuchterl & Reithofer, 2020). In the study, the authors describe the environmental impact of light pollution in Vienna and the energy expended with the associated CO2 equivalents. And they can investigate correlations with measured values of air humidity and other air quality data. It is absolutely necessary to indicate local atmospheric indicators or different weather conditions with the measured sky brightness. This is the only way that short-term trends can be placed more quickly diagonally and measures to reduce artificial light can be made possible in a short time.

These studies show that it has become necessary to take a meteorological view of the atmosphere at night. One possibility is to compare the knowledge about global radiation with the night sky brightness or apply the knowledge, even if it is a great challenge that the magnitudes are extremely different.

Methods

A new method is presented where comparisons are made with night sky brightness, humidity, wind speed and temperature on cloud-free nights with those during the day. The moon being the sun of the night. It is completely equivalent to the sun except for the intensity and therefore enables a direct comparison to global radiation during the day. The place of this research is the Kanzelhöhe Observatory for Solar and Environmental Research of the University of Graz in Austria. For the night sky brightness a LIGHTMETER (Müller et al., 2011) and for the global radiation the ARAD(Olefs et al., 2016) monitoring network are used.

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The light of Vienna – an aerial and decadal view

Theme: Measurement and Modeling

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Introduction

The light of Vienna is measured by long-term, all-weather monitoring of ground based illuminance and irradiance and helicopter-based, area and direction complete measurements of luminance and illuminance.

Fig. 1: The city-centre of Vienna as seen by the high sensitivity channel of the imaging system. Note the scattered light of St. Stephen's cathedral's monument lights. Image by the author.

The flight-campaign, in 2016 documented the city-lights before the beginning of the exchange of the approximately 164 000 public street-lights of the city of Vienna. The second campaign the half-way status, with the first flight accomplished in summer 2022. The next flight – with flight readiness and the weather waiting period ongoing at the time of this submission – will add information after 100 000 new lights. We present the first direction-complete measurements of city lights, including luminance for the brightest sources and an evaluation of the effective directional efficiency of new-generation public street lighting as well as the first look at the environmental-impact relevant distribution of light-imissions of a city. Finally we show the in-situ measured light-emission directional characteristic of the city of Vienna.

Fig. 2: Vienna from the S at medium height angle. Note the blink of one of St. Stephen's monument lights (center). Image by M. Reithofer.

Methods

The monitoring (2009 to the present) is done with Mark 2.3l Ligtmeters at 1 Hz cadence on a network of stations covering distances from the city-centre from 0 to 110 km.

The aerial measurements are done with 3 Lightmeters at 10 Hz mounted in Nadir and port/starboard directions and a high dynamic range (1:10^{10}), meter-resolution imaging system on a 6 x 36 direction grid on a top-flattened hemi-sphere of 12 km radius, around the city center.

Instruments are calibrated on natural light sources and validated with highest accuracy radiation measurement instruments. The imaging photometry is done with astronomical standard methods on an 18 image stack for every direction of the altitude-azimuth direction-grid for the light emission angles, that were covered with the helicopter.

Conclusions

The luminances of the brightest city light-sources are comparable to the one of the most powerful lighthouses, i.e. in the Mcd domain.

Distributions of Vienna's city-light sources are "top heavy" with a significant contribution of immission by the brightest sources.

The decadal growth of light levels above Vienna ranges from an average of 3 to 20% per year, depending on the distance from the centre with a first hint of "peak light" in 2019 for the central districts of Vienna.

Fig. 3: Vienna at night during the 2016 Helicopter-campaign – obtained from a NE, near nadir perspective of one of 9 exposure levels in the low-sensitivity channel of the imaging system. Image by the M.Reithofer.

Contiguous U.S. (2012-2019): Spatial Variations, Temporal Trends and Environmental Justice Analyses

Theme: Measurement & Models

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Artficial light at night (ALAN) is a growing environmental exposure with economic, ecological and public health implications. Moreover, previous studies suggested a higher burden of light pollution and related adverse effects in disadvantaged communities. It is critical to characterize the geographic distribution and temporal trend of ALAN and identify associated demographic and socioeconomic factors at the population level to lay the foundation for environmental and public health monitoring and policy making. We used satellite data from the Black Marble suite to characterize ALAN in all counties in contiguous US and reported considerable variations in ALAN spatiotemporal patterns between 2012 and 2019. As expected, ALAN levels were generally higher in metropolitan and coastal areas; however, several rural counties in Texas experienced remarkable increase in ALAN since 2012, while population exposure to ALAN also increased substantially in many metropolitan areas. Importantly, we found that during this period, although the overall ALAN levels in the US declined modestly, the temporal trend of ALAN varied across areas with different racial/ethnic compositions: counties with a higher percentage of racial/ethnic minority groups, particularly Hispanic populations, exhibited signicantly less decline. As a result, the disparities in ALAN across racial/ethnic groups exacerbated between 2012 and 2019. In conclusion, our study documented variations in ALAN spatiotemporal patterns across America and identifed multiple population correlates of ALAN patterns that warrant future investigations.

Regulatory Approaches to Dark Sky Protection

Theme: Governance & Regulation

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Due to the broad economic, social and environmental adverse impacts of increased artificial light at night (ALAN), the last decade has marked a regulatory recognition of light pollution as an environmental problem and, as a consequence, the development of legal and policy approaches towards its mitigation. This was evidenced at the international level, e.g., The Convention on the Conservation of Migratory Species of Wild Animals[4], at the European Union level, e.g. the Brno Appeal to reduce light pollution in Europe[5], as well as at the national and local levels, e.g. Light Pollution Protection Act (Croatia)[6] 2019 and Outdoor Lighting Ordinance (City of Presidio, Texas, USA)[7] 2021.

This paper provides a broad overview of this regulatory trend, indicating how different jurisdictions address the growing environmental challenge. It proposes a classification of the approaches based on the regulatory levels, namely, international, the EU, national and local, and areas of implementation, such as energy efficiency, urban planning and development, dark sky protection and environmental protection. This article specifically emphasizes the need for the distinction between policy and law, as well as binding and non-binding instruments for a better understanding of the effectiveness of the regulatory approaches. In addition, based on the classification, the paper includes a list of examples of legal and policy documents adopted to address light pollution. Finally, conclusions and recommendations are drawn in order to facilitate the improvement of the existing regulatory framework for dark sky protection and the adoption of the new regulatory instruments on this matter. The paper is intended to contribute to filling a gap in legal and policy research related to the reduction of light pollution and protection of the dark sky.

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Empirical Measurement of Lighting Technology Changeover in New York City

Theme: Measurement and Modeling

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In an effort to reduce electricity consumption from artificial lighting (Montoya et al., 2017), policies at the national, state, and local level in the United States have recently been implemented to support the upgrading of lighting technologies. For example, the federal policy to phase-out incandescent lightbulbs was designed to promote the diffusion of energy-efficient lighting nationally (Energy Conservation Program: Energy Conservation Standards for General Service Incandescent Lamps, 2019; Eilperin and Steven, 2019), while locally, US cities have developed further policies of their own (Gerdes, 2013). For example, in 2013, the Bloomberg administration in New York City (NYC) announced that 250,000 streetlights were to be replaced by LEDs by 2017 (Mayor Bloomberg Announces All Street Lights in NYC Will Be Replaced With Energy-efficient LEDs, 2013). Both qualitative and quantitative methods have been used to review and assess the efficacy of these policies. Qualitatively, for example, Guo and Pachauri (2017) found the spread of millions of energy efficient lighting products in China is due to strong and sustained government commitment, mandatory national standards on quality control, and various incentive schemes. Quantitively, measurements of lighting technology use via the study of Artificial Light at Night (ALAN) has focused heavily on the use of satellite remote sensing. These studies typically require both high spatial resolution and multiple spectral bands to determine lighting type. For instance, in 2018 the Jilin1-03B satellite with spatial resolution <1 m and wavelength range from 430-720nm was able to distinguish high-pressure sodium (HPS) versus white LED bulbs (Zheng et al., 2018) in an urban environment with roughly 80% accuracy. However, a detailed study of policy-induced lighting changeover requires not only high spatial and spectral resolution, but also long temporal baselines, and there is currently no overhead platform that uniquely combines all three. Recently, Dobler et al. (2021) deployed an "Urban Observatory" (UO) in NYC, that uses proximal remote sensing with very high-resolution hyperspectral imaging at Visible Near-Infrared (VNIR HSI) wavelengths to determine lighting technology use from a side-facing vantage point. With observations covering the time range of 2013 to present, this longer temporal baseline and spatial resolution that captures individual light sources enable studies of the changeover from energy-inefficient to energy-efficient lighting, the proliferation of LEDs, and the effectiveness of the 2017 LED retrofit policy in NYC via time-dependent images of the Manhattan skyline.

In this work we identified light sources and the associated lighting technology type in two UO hyperspectral image scans of the NYC skyline, one from 2013 and the other from 2018, to empirically measure the performance of the 2017 NYC LED retrofit policy. The HSI scans required multiple pre-processing steps including field-of-view registration, detector artifact removal, and source versus background separation. Once lighting sources pixels were identified we used two methods to determine their lighting type from their associated spectra which covered a wavelength range of 0.4-1.0 micron in roughly 850 spectral bands. First, we used a maximum positive correlation method with spectral templates collected from online lighting databases from NOAA and the Light Spectral Power Distribution Database (LSPDD) (Roby & Aubé, 2015) after interpolation onto our instruments' wavelengths. Second, we trained a 1-D Conventional Neural Network (CNN) using 1329 hand-labeled source spectra from our HSI scans as a training/testing set, and find an average (across all lighting types) model accuracy of roughly 98%. In addition to individual pixels, we also correlated the NOAA and LSPDD spectral templates with aggregated spectra across all pixels in each individual scan, using Markov Chain Monte Carlo sampling of the likelihood surface to determine the coefficient amplitudes (and associated fully covariant uncertainties) in 2013 and 2018 for each spectral type.

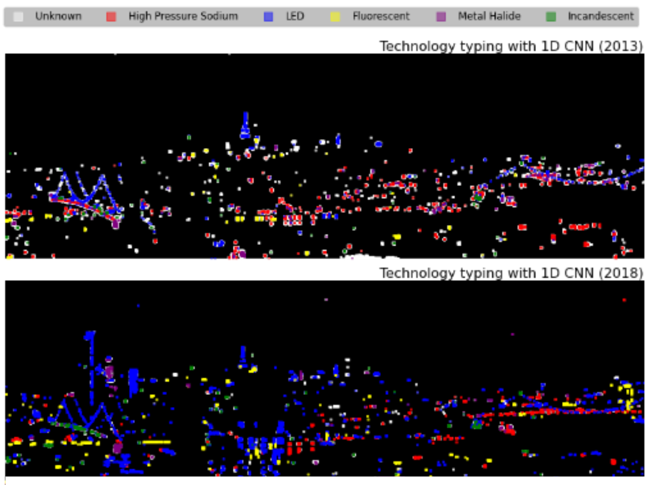

Fig. 1 Lighting Technology Typing with 1D-CNN

When comparing the 2013 and 2018 results from the above methodologies, we find several important indicators of lighting technology changeover. First, new sources in 2018 compared to 2013 are dominated by LEDs. For example, buildings from new construction primarily use LED bulbs and given the rate of construction these dominate parts of the scene (see Figure 1). Second, the ratio of HPS to LED light has strongly shifted towards LEDs between 2013 and 2018. In 2013 the HPS/LED luminosity ratio is 0.89 compared to 0.20 for our scene in 2018. Finally, we demonstrate that it is also possible to directly identify individual light sources that have changed lighting technology over this 5-year baseline, especially for street lighting which was the focus of the NYC LED changeover policy implementation. However, we note that in some cases, including the lights along the Manhattan Bridge in our scene, specific design features meant to minimize skyglow such as downward beaming render some LED lights non-observable, even from our side-facing vantage point.

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Key role of attenuated vasopressin rhythmicity in negative effects of light pollution

Theme: Health

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Artificial light at night (ALAN) is increasing during the last decades and can interfere with the circadian control of physiology and behaviour. Numerous recent studies indicate that increasing light pollution has negative consequences on biodiversity and human health. Exact mechanisms of how ALAN exerts its effects are not well understood. Most hypotheses are centred on the suppression of melatonin, which is known as a direct output of the master circadian clock localized in the suprachiasmatic nuclei (SCN) of the hypothalamus. In our recent studies, we also focused on new neuroendocrine pathways, which can mediate the effects of ALAN on physiology and behaviour of animals and humans.

In our experiments, we explored the effects of low-intensity ALAN (~2 lux during the whole night) on rat molecular clockwork in the SCN and downstream brain structures, which control hormonal axes, regulating different physiological processes and behaviours. Expression of clock and clock-controlled genes in the brain was measured using in situ hybridization and daily rhythms of gene expression in peripheral organs by real-time PCR. Circulating hormones were determined by immunoassays. Daily rhythms of behavioural parameters (rest/activity, food and water intake, energy balance) were evaluated in behavioural phenotyping cages, and cardiovascular rhythms were measured by telemetry. We evaluated 24 h rhythms to reveal rhythm characteristics, such as amplitude and acrophase, which are insufficiently quantified in literature.

We found compromised timekeeping function of the central clocks after exposure of rats to dim ALAN, indicated by suppressed rhythm amplitude of dominant clock gene *Per1* and eliminated rhythmicity of *Per2* in the SCN (Okuliarova et al., 2022). The gene expression rhythm of the important output signal, *Reverbα*, which controls many downstream genes, was suppressed. Importantly, we found the suppressed rhythm of arginine vasopressin (*Avp*) expression in the SCN. Vasopressinergic neurons mediate the circadian output from the SCN to different brain structures and play a supportive role in the coupling of SCN neurons via V1a receptors, which are abundantly expressed in the SCN. Interestingly, the receptors are under circadian control and are 180° out of the phase with AVP levels. Thus, circadian oscillations in AVPergic neurons may be required for high-amplitude circadian output of the SCN. The supressed *Avp* rhythm found in our study indicates 1) a compromised output and 2) coupling among clusters of neurones controlling behavioural rhythms (such as drinking and feeding, sleep/wake and locomotor activity).

Further, we showed the eliminated rhythm of circulating melatonin levels and decreased amplitude of the cardiovascular parameters after ALAN exposure (Molcan et al., 2019) and provided the first evidence that ALAN eliminates daily rhythmicity of dominant androgen testosterone (Okuliarova et al., 2022). Limited data exist on effects of ALAN on circadian control of reproduction, which can be desynchronized in relation to environmental conditions, especially at the behavioural level. Moreover, we found the suppressed and phase-advanced rhythm of plasma corticosterone, which can have serious consequences because glucocorticoids control the transcription of many genes. The phase-advanced corticosterone rhythm can interfere with sleep quality and partially explain early waking up observed in stressed people at the end of the resting period. Animal studies exploring underlying mechanisms are lacking and are in progress in our lab.

In addition to the SCN, AVP, produced in the paraventricular (PVN) and supraoptic nucleus of the hypothalamus, is transported by axonal transport to the posterior pituitary and released into the systemic circulation in response to changes in osmotic pressure and/or body fluid volume. Expression of *Avp* in the PVN was arhythmic, but the low-amplitude rhythm of circulating AVP was found in control animals and was eliminated after ALAN exposure. Importantly, ALAN-exposed rats showed a marked reduction in feeding and drinking at the beginning of the active phase compared to controls and the eliminated peak of water intake occurring at the end of the dark phase (Okuliarova et al., 2022). Since this peak protects against dehydration during sleep in nocturnal rodents and is controlled by the central clock (Gizowski et al., 2016), our study reveals a way how ALAN can interfere with water and osmotic homeostasis. Besides regulation of osmotic and water balance, blood pressure, body temperature, corticotropin release, memory and sociosexual behaviour, AVP can also be implicated in metabolism control (Yoshimura et al., 2021), which is strongly affected by ALAN (Okuliarova et al., 2020, Rumanova et al., 2022). Moreover, our recent unpublished data showed a blunted rhythm of V1a receptor gene expression in the liver after ALAN exposure, indicating that disturbed AVP signalling can also participate in the negative metabolic effects of ALAN.

In conclusion, our results highlight multiple pathways how the disturbed AVP rhythmicity can mediate negative effects of light pollution on essential physiological and behavioural processes. The interference with the stress response and water/osmotic balance can be critical for biodiversity and human health, especially in combination with modern lifestyle and climate changes

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An Analysis of Anthropogenic Light for Optical Quantum Communication and Optical Quantum Ground Station Deployment

Theme: Measurement and Modeling.

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Introduction

As quantum communication advances to the point where larger networks are required it is clear that in order to expand quantum networks to international, and indeed global scales, satellites will need to be used as a communication intermediary. A Quantum ground station (QGS), used in conjunction with a trusted satellite, is an important step in extending the global reach of quantum communication networks.

Fig. 1: The optical quantum ground station located at the University of Calgary. This computer controlled 280 mm telescope is one of the primary instruments used to collect data for the analysis of anthropogenic light pollution in the Calgary metropolitan area. Photo: Mathew Yastremski

Part of quantum communication involves encoding information in quantum states, or qubits, as opposed to classical communication's use of bits. One method of generating a qubit is by using the polarization of a photon (Nielson 2010). As this form quantum information is relayed using photons one source of interference may come from anthropogenic light. If the amount of light pollution in an area is too great, it may result in lower quality of photon transmission between satellite and QGS or QGS and satellite.

Consider that from 1990 to 2014 urban sprawl increased by over 95%. This corresponds to a yearly average increase of almost 4% (Behnisch 2022). As urban centers grow, the measurable light pollution in a region increases (Li 2017). From 1992 to 2013 a study by Li et al found an increase of global light at a rate of 3.5% per year. These values of light pollution vary from 2.3% to 3.5% per year depending on the instruments used for measuring light pollution. Regardless of the variations, a clear trend of increasing light pollution has been observed globally with the largest increase in urban areas (Li 2017, Cinzano 2001, Aubé 2012, Kyba 2013).

It is therefore necessary to consider how anthropogenic light interacts with free-space quantum communication, both satellites and quantum ground stations (QGS). A study is being undertaken by the University of Calgary, along with the University of Waterloo to establish what effect light pollution has on free-space quantum communication. In this study several wavelengths of light pollution are examined using photon counts gathered using a QGS (Calgary) and a bare multimode fiber with a filter (Waterloo). The wavelengths of interest were chosen to more directly compare the wavelengths currently used in free-space quantum communication. Additionally, measurements were taken in broadband to compare our methods with the Visible Infrared Imaging Radiometer Suite (VIIRS) dataset provided through the NASA Black Marble

Data Product (NASA 2023). The goal of the study is to assist in determining appropriate locations for quantum ground stations in the future and if current locations are affected by the increase in urban light pollution.

Methods

By using an existing Optical Quantum ground station (Figure 1) The University of Calgary recorded down-link light pollution measurements. A 280mm computer-controlled telescope was used to measure eight distinct azimuthal directions with three different elevations from the horizon: 30, 45, and 60 degrees. Four measurements were taken at the maximum elevation (85 degrees) for the telescope in each cardinal direction. The directions were chosen to simulate elevations and positions of a passing satellite. Each measurement set used a narrowband filter allowing one of four predetermined wavelengths to be measured. The wavelengths, 750 nm, 800 nm, 850 nm, and 905 nm were chosen due to their use in optical quantum communication (Bourgoin 2014).

To estimate the light pollution that would be seen by an optical quantum ground station during a downlink measurement, the University of Waterloo used a 0.22 numerical aperture multimode fiber, coupled directly into an Excelitas SPCM-AQRH series single photon detector (SPD), allowing for the direct measurement of photon flux in a given solid angle. Optical filters were placed at the fiber input to take measurements within specific wavelength ranges.

Conclusions

By considering both measurement methods, the QOGS at the University of Calgary, and the open fiber cage system used by the University of Waterloo, we will be able to construct an appropriate profile on light pollution that can be used when considering locations for future optical quantum ground stations. Additionally, by using the NASA Black Marble Data Product we can further examine the light pollution a satellite would see when receiving uplink communications from an optical quantum ground station.

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