ALAN 2016

4th International Conference on Artificial Light at Night

September 26-28, Cluj-Napoca, Romania

Conference Handbook

Edited by
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ALAN 2016 is the final conference of the "Loss of the Night Network"

COST Action ES1204 (2012-2016)

LoNNe
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- The conference volunteer team, especially the students from Building Services Department who contributed in many ways.
- The International Dark-Sky Association, for hosting the steering committee conference calls

Dear ALAN Participants,

The ALAN conferences started in Berlin, Germany in 2013, moved to Leicester, UK in 2014, crossed the Atlantic to Sherbrooke, Canada in 2015, and is now back in Europe at the Technical University of Cluj-Napoca, Romania for ALAN 2016. The launch of ALAN as a conference series would not be possible without the help of EU Cost programme ES1204 Loss of Night Network LoNNe. During the last four years, our group of specialists from Technology and Design, Biology and Ecology, Modelling and Measures, Society and Health has met twice a year. As a lighting engineer, I have learned a lot from my colleagues, as I had to change from lighting exclusively for human vision, to both human health and vision, and now to consider the many animals, birds, fish and insects that are influenced by electric lighting produced by humans for their own need. Lighting designers nowadays need to be very careful in choosing the light class as low as possible, in order to avoid unnecessary over sizing, in using Constant Light Output for luminaires, avoiding cold temperature of LEDs and, above all, seizing the importance of using lighting control systems. The good thing about LEDs is that you can dim and switch on/off easily, and this raises the importance of sensors. In order to change lighting codes we need threshold values, which will be scientifically proven, and this is why I believe the ALAN conference is so important. In the years to come, I am afraid of the possibility of increasingly huge advertising panels, commercial signage of different colours and so on.

But there are also sociological aspects. In order to prepare the general public for this conference, we had invited Ian Cheney, film director of the documentary "The City Dark" to present his movie in a series of cities around Romania, including Cluj-Napoca. During the Q&A a very typical question was: "You want to go back in time to the darkness of communist period?" After 1990, many people from former communist countries expected more light during nigh time, and thought that this will reduce levels of crime. It is therefore necessary to clearly explain the importance of ALAN avoidance, so that we can have the next step in Romania - to create dark-sky parks.

Transylvania is a mixture of old and new. You can see villages where nothing has changed much in the last 100 years, but also booming city like Cluj-Napoca, where IT it's the new industry, replacing traditional ones. Cluj-Napoca, a former Roman city, is one of the fastest growing cities in Romania. With seven universities, an airport connected directly to many European cities, a film festival – TIFF and two music festivals – Untold and Electric Castel and the fact that in 2016 Transylvania was declared #1 in Top Region by LonelyPlanet, Cluj-Napoca is becoming a touristic destination.

I want to thank you all the members of Organizing Committee for the many hours spent in sending/responding e-mails and for the Internet calls, which were essentials for ALAN 2016!

Raising awareness about the importance of darkness is very important and the moment is now, so all participants to ALAN 2016 will have to play a key role in changing the paradigm of light at night.

Re-connect with night!

Sincerely,

Dorin BEU

Coordinator, ALAN 2016

Dear ALAN participants,

The Artificial Light at Night conference series has now began its fourth edition, and so far, no two ALANs have been alike. On behalf of the steering committee, I'd like to explain how we got here, and fill you in on some changes for the future.

Attendees have told us after each ALAN that they wished they could have seen more of the talks. As a result, this year we decided to try to experiment with an all-plenary format, together with stronger poster sessions. However, when your abstracts arrived in such great quantities, we found that sticking to the all-plenary format would not allow us to accept even half of the submissions for oral presentations! We therefore decided to add some parallel sessions, but despite this, the acceptance rate remained only 57%. I hope that you'll recognize that our poster sessions this year therefore contain a great deal of excellent results, many of which would certainly have been accepted for oral presentations at previous ALAN conferences.

Another challenge for the series has been the varying length between conferences, and the (excellent) problem of having "too many light pollution conferences". To solve both of these, we are switching to a 2-year schedule, alternating with LPTMM. The next LPTMM will take place in Spain in 2017, and the next ALAN in 2018, outside of Europe.

This year, most sessions end with a short period for "discussion and conclusion". We hope that this might allow for panel session-like discussion, while ensuring the full breadth of ALAN topics have a chance to be discussed.

In its fourth year, ALAN is still a young, developing series. We hope that after the conference you will take part in a survey to help us in planning the format of future ALAN conferences. We would especially welcome your help in identifying extraordinary researchers and practitioners who's work deserves greater attention, especially those from outside of Europe and North America or from traditionally disadvantaged groups, people with disabilities, and rising stars still at the start of their careers. To ensure that you receive the survey, please be sure that you've signed up for the conference mailing list at http://tinyurl.com/alan-signup.

Thank you for attending ALAN! The series couldn't exist without your participation.

Sincerely,

Christopher Kyba
Chair of ALAN steering committee

ALAN 2016 preliminary schedule

Note that only presenters are listed here, complete author lists are available in the conference abstract booklet. Invited speakers are listed in bold. The numbers next to the titles indicate the abstract number. This number will be displayed on the poster boards.

Monday, September 26

8:30-10:20 registration open, poster setup & coffee
9:50-10:05 session chair meeting

Session 1
Opening Session (OPEN TO THE PUBLIC)

Chair : Dorin Beu

10:20-10:40	TBA	Welcome to Cluj-Napoca Welcome to ALAN
10:40-11:05	**Franz Hölker**	(1) Keynote opening
11:05-11:30	**George Brainard**	(2) Exploring the Power of Light and Darkness: From the International Space Station to Cancer Risk
11:30-11:55	**Alexandru Florin Sirca**	(3) Human adaptive artificial lighting for public spaces
11:55-12:15	Eva Knop	(4) The impact of artificial lighting on pollination success
12:15-12:25	Oscar Corcho	(5) STARS4ALL – A collective Awareness Platform for Promoting Dark Skies

PUBLIC PORTION ENDS

12:25 – 13:30 lunch

Session 2
Health

Chair : Sibylle Schroer

13:30-13:35	Gold sponsor elevator pitches	
13:35-13:50	Poster session 3 elevator pitches	Titles in session 3, below
13:50-14:15	**Michal Zeman**	(6) Physiological mechanisms mediating negative effects of ALAN on human health
14:15-14:35	Abraham Haim	(7) Energy efficient short wavelength illumination – can this come on the account of our health risk?
14:35-14:55	Paul Marchant	(8) Does increasing road lighting increase road injuries?
14:55-15:05	Discussion & conclusion	

Poster Session 3: Technology & Design and Measurements & Models

15:05 – 16:30 (including coffee break)

Technology & Design	Dimitra Anagnostopoulou	(45) Comparative Analysis of Artificial Lighting for the Facades of Byzantine Temples in Greece
	William Beauchesne	(46) A Lamp Spectral Power Distribution Web Access Database for research applications
	Catalin Galatanu	(47) Public Lighting: The paradigm Change
	Hyojoo Kong	(48) Measurement Method of Light Pollution for Decorative and Advertising Lighting in South Korea
	Timothy Shotbolt	(49) Developing Light Spill Criteria Considering the Environment Not Just Mankind
	Stelios Zerefos	(50) Creating a methodology for presenting lighting designs
Measurements & Models	Chistopher Baddiley (Martin Morgan Taylor)	(51) Light pollution modelling and measurements of the effects of county rollout of blue rich LED lighting on an Area of Outstanding-Natural-Beauty.
	Roland Dechesne	(52) Integrated study of Sky Glow, Calgary, Alberta, Canada
	Anita Dömény	(53) Night sky quality monitoring in existing and planned dark sky parks by digital cameras
	Brian Espey	(54) The growth in lighting in Ireland pre- and post-Celtic Tiger: population and economics
	Andreas Hänel	(55) SQMDroid – A universal SQM measurement device
	Andreas Jechow	(56) Using fisheye-lens imagery to track the reach of skyglow under clear and partly cloudy conditions near Montsec Astronomical Park in Spain
	Andreas Jechow	(57) Measuring the night sky brightness in a coastal environment: fisheye lens imagery from a boat
	Gon Kim	(58) Real survey measurement and process for the determination of lighting environment management zone in South Korea
	Kornél Kolláth	(59) Estimating the height of low-level stratiform clouds at night by photometric measurements
	Jongmin Lim	(60) An Installation Guideline of Preventing Light Pollution in Residential Area's Street Lighting in South Korea
	Henryka Netzel	(61) Updated high-resolution map of light pollution
	NataliyaRybnikova	(62) Identifying Geographic Location of Research and Educational Activities Using Spectral Properties of Light Emitted During Nighttime
	Alejandro Sánchez de Miguel	(63) STARS4ALL night sky brightness photometer
	Nur Shariff	(64) Light Pollution and its Impact towards Islamic New Moon (hilal) Observation

Measurements & Models (cont)	Alexandre Simoneau	(65) Potential impact of a transition to white LED on the sky of Hawaii
	Leena Tähkämö	(66) Developing an environmental impact category of light pollution for life cycle assessment

Session 4
Technology & Design

Chair: Andreas Jechow

16:30-16:55	**Maurice Donners**	(9) Preserving the night using outdoor lighting intelligently
16:55-17:15	Johanne Roby	(10) An Innovative Lighting System with Adjustable Spectrum that Mimics Natural Light in Intensity and Color
17:15-17:35	Parisa Khademagha	(11) Directionality: an important light parameter for human health to consider in lighting design
17:35-17:45	Discussion & conclusion	

17:45-18:30 open discussion in poster room

Social event from 19:30 at the Urban Culture Center - Casino
Also planned: STARS4ALL observation of stars and/or app flashmob

Tuesday, September 27

Session 5
The human side of light

Chair : Josiane Meier

9:00-9:15	Poster session 7 elevator pitches	Titles in session 7, below
9:15-9:40	**Anna Steidle**	(12) Light and darkness and its impact on human behavior
9:40-10:05	**Siegrun Appelt**	(13) Touched by light
10:05-10:30	**Gregory Dobler**	(14) The Pulse of the City Lights
10:30-10:50	Thomas Kantermann	(15) Comparing Circadian Questionnaires with the Dim Light Melatonin Onset
10:50-11:00	Discussion & conclusion	

11:00-11:20 coffee break

Session 6	6a Remote Sensing	6b Birds
	Chair: Constance Walker	Chair: Marcel Visser
11:20-11:40	Alejandro Sanchez de Miguel	Airam Rodriguez
	(16) Are LEDs reducing light pollution?: Dealing with light pollution in a colour changing world	(20) GPS tracking for mapping seabird mortality induced by light pollution
11:40-12:00	Geza Gyuk	Roland Dechesne
	(17) NITESat: A High Resolution, Full-Color, Light Pollution Imaging Satellite Mission	(21) Nocturnal seabirds: light pollution's impact on their global ecological niche
12:00-12:20	James Carr	Arnaud Da Silva
	(18) Observing Nightlights from Space with TEMPO	(22) Effect of intelligent experimental lighting on bird singing and foraging behaviours
12:20-12:40	Christopher Kyba	Barbara Helm
	(19) Are relationships between artificial light emission and land use dependent on community size?	(23) Extensive whole-body effects of experimentally applied artificial light at night on birds
12:40-12:50	Discussion and conclusion	Discussion and conclusion
12:50-13:50	lunch	

13:50-15:15 **Poster Session 7: Health, Society, and Biology & Ecology**
(coffee available from 15:00)

Health	Amit Green	(67) The effects of screen illumination on: sleep efficiency and architecture, physiology, emotion and behavior- possible effect on human health
	Christopher Kyba	(68) Evidence for the waking effect of sunlight during winter in social media data
	Katharina Stebelová	(69) Different intensities of light exposure during the sleep and its impact on concentration of melatonin and sleep quality
Society	John Barentine	(70) Going for The Gold: Quantifying and Ranking Visual Night Sky Quality in International Dark Sky Places
	Andrea Giacomelli	(71) Participatory Dark Sky Quality Monitoring from Italy: interactions between awareness raising and research
	Emanuele Giordano	(72) Outdoor lighting design as a tool for tourism development. The case of Valladolid.
	Jeong Tai Kim	(73) Light Pollution Prevention Act in Korea
	Efthalia Velegraki	(74) Lighting and the Urban Space – Illuminating the collective memory
	Constance Walker	(75) Societal Contributions to Globe at Night Observations in the Last 10 Years
	Constance Walker	(76) The Quality Lighting Teaching Kit: Inspiring our Society to be Part of the Solution to Light Pollution

Biology & Ecology	Yael Ballon	(77) The effects of different lightning regimes on activity rhythms of the eastern spadefoot (Pelobates syriacus)
	Anika Brüning	(78) Spotlight on fish: The impacts of artificial light at night on biological rhythms of European perch and roach
	Roy van Grunsven	(79) The response of migrating toads to artificial lights.
	István Gyarmathy	(80) Hortobágy National Park – an island of undisturbed nighttime environment
	James Hale	(81) Baseline lighting data for landscape biodiversity conservation
	Julia Hoffmann	(82) Effects of different types of artificial light at night on a small mammal
	Tzlil Labin	(83) Influences of exposure to different LED illumination wavelengths on activity patterns in common spiny mice (Acomys dimidiatus)
	Sohyun Lee	(84) The First Dark Sky Park in Asia: Yeongyang Firefly Eco Park in South Korea
	Julie Pauwels	(85) Dark corridors: accounting for light pollution in connectivity modelling for urban bats
	Thomas Raap	(86) Light pollution affects body mass and oxidative status in free-living nestling songbirds: an experimental study
	Marcel Visser	(87) Long-term population effects of experimental artificial illumination of a forest edge ecosystem

Session 8	**8a The nighttime environment**	**8b Ecological field experiments**
	Chair: Dietrich Henckel	Chair: Eva Knop
15:15-15:35	Antonella Radicchi & Josiane Meier (24) Urban Planning Challenges: Toward integrated approaches to sustainable lightscape and soundscape planning	Andreas Jechow (29) Design and modeling of an illumination light source for a large scale freshwater experiment at LakeLab on lake Stechlin, Germany
15:35-15:55	Katharina Gabriel (25) Levels of night sky quality in Germany	Maja Grubisic (30) Artificial light at night affects biomass and community composition of freshwater primary producers
15:55-16:15	Andrej Mohar (26) Correlated Color Temperature (CCT) of Natural and Light-polluted Sky	Jonathan Bennie (31) Trophic effects of artificial light on plant and invertebrate populations in a five-year ecological experiment

16:15-16:35	Dimitris Nikolaou	Thomas Davies
	(27) Technical and economical assessment of the containment of light pollution through the use of luminous intensity restrictive measures	(32) Comparing the impacts of multiple nighttime LED lighting strategies in a grassland ecosystem
16:35-16:55	Axel Stockmar	Kamiel Spoelstra
	(28) Lighting of railway premises – Minimizing obtrusive lighting according to current regulations	(33) Effects of artificial light on mammals: gain and loss of habitat, behavioural changes and cascading effects
16:55-17:05	Discussion and conclusion	Discussion and conclusion

Time TBA: Conference Dinner Klausenburger Restaurant www.klausenburger.ro

Wednesday, September 28

Session 9
Ecology

Chair: Barbara Helm

10:00-10:25	**Sharon Wise**	(34) Intrusion of artificial light at night into leaf-litter habitats: Implications for activity in a nocturnal salamander
10:25-10:45	**Alessandro Manfrin**	(35) Artificial light at night affects biotic linkages between aquatic and riparian ecosystems
10:45-11:15	**Clémentine Azam**	(36) Considering light pollution at different spatial scales: How can we mitigate the impacts of artificial lighting on bats in urban landscapes?
11:15-11:25	Discussion & conclusion	

11:25-11:45 coffee break

Session 10
Ecophysiology

Chair: Jonathan Bennie

11:45-12:05	Joanna Durrant	(37) Dim light at night reduces cricket immune function
12:05-12:25	Davide Dominoni	(38) The effects of light pollution on stress, energy expenditure and personality in free living songbirds: results from an experimental illumination of forest edges
12:25-12:45	Kylie Robert	(39) Artificial light at night desynchronizes strictly seasonal reproduction in a wild mammal
12:45-12:55	Discussion & conclusion	

12:55 – 14:00 lunch & take down posters

Session 11
Concluding Session

Chair: Johanne Roby

14:00-14:25	**Martin Aubé**	(40) The LED outdoor lighting revolution: Opportunities, threats and mitigation
14:25-14:45	Kellie Pendoley	(41) Transcontinental Australia, Dark Sky Quality Survey; Perth to Brisbane, one road, 5500km, 9 days
14:45-15:05	Salvador Ribas	(42) How clouds are amplifying (or not) the effects of ALAN
15:05-15:25	Taylor Stone	(43) The ethics of artificial nighttime lighting: creating a taxonomy of darkness as a moral value
15:25-15:30	Discussion	
15:30-15:50	**Sibylle Schroer**	(44) The Loss of the Night Network (LoNNe) Conference wrap up and announcement of ALAN 2018

ALAN 2016 abstracts

Artificial Light at Night (ALAN): not always a bright idea
Theme: Opening

Franz Hölker*,[1]
on behalf of the COST Action ES1204 *Loss of the Night Network* (LoNNe)

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Technology rarely fulfils only its intended function, but instead often shows unexpected impacts on natural and social systems. The invention and widespread use of artificial light is one of the most important human technological advances, but the fundamental transformation of nightscapes (Hölker et al. 2010a, Bennie et al. 2014, Falchi et al. 2016) is increasingly recognised as having adverse effects on humans and nature (Rich & Longcore 2006, Hölker et al. 2010a, Gaston et al. 2015). Humans often illuminate their environment uncritically, with no regard for the manifold impacts of artificial light. Since the biological world is organised to a large extent by natural cycles of variation in light and darkness, artificial light at night (ALAN) can influence a wide range of processes, from gene expression to ecosystem function (Rich & Longcore 2006, Hölker et al. 2010b, Gaston et al. 2015). Natural light cycles, at least as perceived by many organisms, have been fundamentally disrupted by the introduction of ALAN into the nighttime environment. As a result, ALAN threatens biodiversity through changed night habits and is changing the rhythm of human life (Rich & Longcore 2006, Gaston et al. 2013, Meier et al. 2015, Schroer & Hölker 2016). Furthermore, it is considered an important driver behind the erosion of provisioning, regulating, and cultural ecosystem services and may reshape entire social-natural systems (Hölker et al. 2010b, Lyytimäki 2013).

Fig. 1: Photograph of the Iberian Peninsula at night from the International Space Station showing Spain and Portugal. Image courtesy of the Earth Science and Remote Sensing Unit, NASA Johnson Space Center.

The EU identified lighting as a source for energy saving to meet the 2020 Energy Strategy in accelerating investment into efficient lighting technology. Unfortunately, policy-driven improvements in efficiency alone are unlikely to reduce energy use, because they leave users free to use more light with possibly higher energy consumption and a wider loss of natural nightscapes as a consequence. Technological innovations should, therefore, not only save consumers money, but also consider human health, ecological, and socioeconomic aspects (Hölker et al. 2010a, Kyba et al. 2014).

Such a transdisciplinary approach requires (1) an understanding of the broader impacts of artificial lighting on the natural environment, human health and society, (2) innovations in technology and lighting concept to address these impacts of artificial lighting and to identify potential corrective measures, and (3) lighting policies to regulate the use of light for any given task while minimizing both the energy use and negative environmental side effects. This needs enrolling multiple disciplines, including ecology, physiology, chronobiology, sociology, economics, landscape architecture, remote sensing, astronomy, and illuminating engineering. Thus, the aim of the European COST Action ES1204 *Loss of the Night Network* (LoNNe, http://www.cost-lonne.eu/) was to improve knowledge of the multiple effects of increasing artificial illumination. LoNNe invited stakeholders from any field of research, with the explicit goals of influencing the development path of modern lighting technology, and creating guidelines for sustainable lighting concepts. Within the network, researchers and policy makers in diverse fields were able to share their relevant experience, and move towards development of innovative policy measures and sustainable technological innovations to improve our use of light.

In this talk, several ways will be identified, in which practical steps can be taken to reduce environmental concerns, with the explicit goal of influencing the development path of modern lighting technology, and creating guidelines for lighting concepts and policies that are ecologically, socially, and economically sustainable.

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Exploring the Power of Light and Darkness: From the International Space Station to Cancer Risk

Theme: Health

George Brainard[1], Robert Dauchy[2], John Hanifin[1], Benjamin Warfield[1], Steven Hill[2], Melissa Wren-Dail[2], Shulin Xiang[2], Lin Yuan[2], David Blask[2]

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Light is a potent stimulus for regulating human circadian, neuroendocrine and neurobehavioral responses (1,2). In addition, light has the capacity to restore human health in clinical applications such as treating winter depression and selected sleep disorders. Light therapy also has been evaluated for healthy individuals who experience problems associated with intercontinental jet travel, shift work and space flight (1-4). Any agent that has the capacity to heal, however, also has the capacity to harm.

In 1987, it was hypothesized that the increased risk of breast cancer in industrialized countries is due, in part, to increased exposure to electrical light at night (5). That hypothesis was based on the idea that exposure to light at night would result in melatonin suppression that would, in turn, increase breast cancer risk. Since then, a series of epidemiological studies, have supported that original hypothesis including observations that: night shift working women are at higher risk; blind women are at lower risk; risk has an inverse association with sleep duration; and across societies, incidence of breast and prostate cancer and nighttime ambient illumination as measured by satellite imagery are correlated. In general, the collected epidemiological studies support the "light, melatonin, breast cancer hypothesis" (5-7). Empirical evidence from both *in vivo* and *in vitro* animal studies also support this hypothesis (7,8). Most importantly, it has been demonstrated that human breast cancer xenografts perfused *in situ* with nocturnal, physiologically melatonin-rich blood collected from premenopausal female volunteers during the night exhibited suppressed breast cancer proliferative and metabolic activity. This finding identifies a definitive nexus between the exposure of healthy premenopausal female human subjects to light at night and the enhancement of human breast cancer growth progression via disruption of the circadian melatonin signal (8). In 2010, the International Agency for Research on Cancer that provides assessments of cancer risks of potential carcinogens for the World Health Organization (WHO), published an extensive monograph concluding that shiftwork "that involves circadian disruption is probably carcinogenic to humans" (9). Shiftwork nearly always involves exposures of workers to light during the nighttime hours. In the WHO monograph, the strongest evidence behind their conclusion came from both epidemiological studies and controlled human and animal studies on breast cancer (9). Subsequently, in 2012, the American Medical Association (AMA) published a policy statement on potential health hazards of light at night (10).

An analogy exists between breast cancer in women and prostate cancer in men since both are primarily hormone-driven cancers. Recent epidemiological studies are addressing the potential of exposure to light at night as a risk factor for prostate cancer in males (7). Preliminary empirical studies on light exposure fostering human prostate tumorigenesis will be presented (11,12).

Given the emergent scientific evidence on the potential benefits and detriments of light and darkness, it is valuable to deepen our understanding of these salient forces.

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Human adaptive artificial lighting for public spaces

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Energy efficiency is one of the most important concern of 21th century.

The annual energy consumption for public street lighting in the 25 countries member of EU, in 2005 was 35TWh, representing 1.3% of all the energy consumption in those countries.

In terms of energy savings, the share of public street lighting is symbolic; nevertheless its importance is bigger if we consider that it is a public service and it is financed by taxes.

The need to adapt the lighting solutions to national and international standards is unanimously recognized and it assumes, as the main purpose of public street lighting, to provide safety for users of the traffic routes.

The fulfilment of essential objectives for public street lighting must be, every time, related both with the necessity of saving energy (not only for minimizing operational costs), but also to assure the best compatibility with the environment.

For several years now, on the market we found complex telemanagement systems that offer the control of the lighting for outdoor public spaces, solutions which provide cost reduction regarding maintenance and energy consumptions, according to some predefined running programs.

But now, the challenge for telemanagement systems is to dynamically adapt the lighting to the public spaces functionalities by integration of sensors in these telemanagement systems.

Title: The impact of artificial lighting on pollination success

Theme: Biology and Ecology

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Artificial lighting is rapidly increasing yet the consequences for biodiversity and ecosystem functioning are barely known. Although we know that organisms do respond to artificial lighting with changes in behaviour and physiology, there is very little known about the impact on biological diversity and ecosystem functioning. Here, for the first time, we experimentally tested how plant-pollinator interactions are altered due to artificial lighting (LED-street lamps), and what consequences it has for the reproduction success of a model plant. To do so, we experimentally illuminated seven independent field sites in the Bernese Oberland, Switzerland, using mobile LED-street lamps. All sites were in a generally dark area and had previously no artificial lighting sources within at least 100 m. At these sites and seven dark control sites we observed the plant-pollinator interactions on the model plant (*Cirsium oleraceum*) which is frequently visited by pollinators during day as well as during night. We further determined the reproductive success of *C. oleraceum*. Number of plant-pollinator interactions and mean seed mass was significantly reduced under the light treatment. This suggests that artificial lighting reduces the number of pollinators and the plant fitness. It further shows that nocturnal pollination matters also when plant species are not specialized on nocturnal pollinators. Our results suggest, that artificial lighting is not only a threat to biodiversity but also to ecosystem functioning and hence will most likely worsen the worldwide pollinator crisis.

STARS4ALL - A collective Awareness Platform for Promoting Dark Skies

Theme: Society

Oscar Corcho[1] and the STARS4ALL consortium

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Introduction

People who live in or near cities have lost much of their view of the universe due to light pollution. Most urbanites have never seen the Milky Way and they get astonished when they watch it in a dark spot. This everyday-increasing excess of light in the sky has an adverse impact on the environment and seriously threatens to remove forever one of humanity's natural wonders, the view of our universe. However light pollution does not only have a negative impact on Astronomy, but also in Energy, Biodiversity and Human Health.

Artificial light at night in combination with insufficient daylight, can lead to disorganization of our circadian rhythm or chronodisruption, which is associated with an increased incidence of widespread disease, linked to decreased immune response and metabolism (Bonmati-Carrion et al. 2014).

About one third of today's estimated vertebrate species and more than half of all known invertebrate species are night active(Hölker et al. 2010). The senses of nocturnal wildlife have adapted to their niche of rather low light levels. Some species are highly sensitive to light and avoid habitats, which are under the influence of artificial light. Other species are attracted to light and become easy prey, when disoriented by light sources. The habitats of light sensitive species are decreasing with increasing night-time lighting and the impact on sensitive species is cascading in ecosystems, disrupting ecological communities and food webs and consequently the loss of biodiversity (Bennie et al. 2015).

Although there are many professional and amateur scientists concerned about this problem and fighting against it, it is necessary to create more social awareness about the importance of preserving the darkness of our cities and environment. Citizens may transfer this awareness to the main actors responsible for light pollution; such as consumers, local authorities, government, retail, industry, etc.

STARS4ALL

The project STARS4ALL (www.stars4all.eu) is funded by the European H2020 framework, within the initiative "Collective Awareness Platforms for Sustainability and Social Innovation" (CAPS). STARS4ALL aims at deploying a Collective Awareness Platform for fighting against Light Pollution, so as to provide citizens the tools and support required to incubate and create local or global working groups (Light Pollution Initiatives - LPIs), with different domain-specific purposes (e.g. preserving clean skies for Astronomy, reducing Energy consumption, ensuring Biodiversity, improving Human Health).

The project also aims at extending the legislation on sky protection that is currently applicable to the Canary Islands to the European Union, by promoting a European Citizens' Initiative for preserving the darkness of European skies. The platform provides access to running activities, i.e. to become involved in a photometer network; it offers the broadcasting of astronomical phenomena, such as eclipses and Aurelia Borealis, and various tools for education and campaigning.

Finally, the STARS4ALL platform will integrate a crowdfunding tool to fund the LPIs; it will consider incentives that motivate citizens to participate in LPIs, as well as policies to handle those incentives; and it will provide innovations in data acquisition from sensors deployed by citizens and in games with a purpose.

Networking for the benefit of the stars – a common property

The EU initiative CAPS aims at the awareness of sustainability problems to offer collaborative solutions based on networks. The "Loss of the Night Network" (COST Action ES1204, LoNNe) enhanced in its four years working progress (2012-2016) mobility between different actors in light pollution from science, health care, public authorities and industry. LoNNe functions as an external activist team within the STARS4ALL project (2016-2020), in order to cooperate, disseminate standard operating procedures, and to influence the development path of modern lighting technology. The platform STARS4ALL will further motivate and support light pollution grassroot organizations, to derive power from the people, in engaging citizens in actions and science and enhancing participatory democracy on creating guidelines for lighting concepts that are ecologically, socially, and economically sustainable.

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Title: Physiological mechanisms mediating negative effects of ALAN on human health

Theme: Health

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Introduction

Light contamination is a ubiquitous phenomenon in modern society and it is expected to affect negatively human health. Underlying mechanisms are still not known and are frequently only at the hypothetical level. Their identification and explanation is important for setting the critical limits of light contamination and possible ways of protection. Generally, artificial light at night (ALAN) is expected to disturb circadian organization, which is involved in coordinated action of regulatory systems, such as nervous, endocrine and immune systems. Disturbances of these control mechanisms can result in cardio-metabolic and neurological diseases, as well as cancer.

The circadian system consists of the master oscillator localized in the suprachiasmatic nucleus (SCN) of the hypothalamus and peripheral oscillators localized in every cell of the body. The molecular mechanism of circadian rhythm generation is based on the transcriptional/translational feedback loop of clock genes. Two basic helix-loop-helix transcription factors, CLOCK and BMAL1, form heterodimers that bind to E-box enhancer elements in promoters of target genes driving the transcription of *Per1, Per2, Per3, Cry1, Cry2*. After the PER and CRY proteins have been translated in the cytoplasm, they form heterodimeric complexes that translocate to the nucleus and inhibit their own transcription by the formation of a negative complex which prevents CLOCK/BMAL1 to bind to E-box. In addition to these canonical clock genes, recently several other genes were suggested to contribute to robustness and stability of circadian oscillations. Molecular clockwork of peripheral oscillators is very similar to the central circadian clock localized in the SCN. Their mutual communications occur via different control systems, such as the autonomous nervous system, endocrine and immune systems.

Recently, synchronisation effects of physiological, metabolic and behavioural rhythms on peripheral oscillators have been recognized. Periodic food intake seems to be the most powerful entraining agent for the peripheral oscillators while the environmental light:dark cycle is the dominant synchronizer for the central circadian pacemaker. Food availability may even uncouple central and peripheral circadian rhythms, which may be protective against short-term disruptions such as jet lag. However, in long-term, such uncoupling of central and peripheral oscillators may lead to internal desynchronization, with negative effects on health. Melatonin is a one of the most frequently studied internal synchronizer between the central and peripheral oscillators and is considered as a marker of circadian disruption. Suppressed melatonin biosynthesis by ALAN has been suggested as a potential risk factor for increased breast cancer incidence in women from developed countries (Stevens, 2009, Kloog et al., 2008).

Our studies revealed lower amplitude of the circadian melatonin rhythm in hypertensive patients exhibiting non-dipping blood pressure profile in comparison with hypertensive patients with normal 10-20 % dipping profile during the nighttime (Zeman et al., 2005). Melatonin receptors (MT) were identified in structures of the central nervous system governing blood pressure (Campos et al., 2013) and also in the vessels (Dubocovich and Markowska, 2005). In addition to endothelial cells melatonin receptors were localised in the smooth muscle cells and more surprisingly also in the adventitia of blood vessels (Schepelmann et al., 2011). The presence of melatonin receptors in the adventitia suggests a new way of action for this highly pleiotropic compound. At this side melatonin can be involved in the control of extravascular inflammation, which is recently considered as one of the serious risk factors for development of cardiovascular diseases. Moreover, we detected high expression of MT_1 receptors in the perivascular fat (Molcan et al., in preparation) and hypothesise that melatonin via its anti-oxidative and anti-inflammatory effects can protect blood vessels from the perivascular space. Perivascular fat can be a source of reactive oxygen species. High density of MT_1 receptors in this tissue and in the adventitia can protect conduit arteries against vascular inflammation induced by leucocyte infiltration in the perivascular space. On the other hand, melatonin receptors in the endothelial cells of resistant arteries can protect vessels from insults from circulation and atherosclerosis development. These our conclusions are supported also by *in vitro* studies with human endothelial cells, in which melatonin suppressed activated reactive oxygen species production and deposition of extracellular matrix proteins, such as fibronectin.

All the data suggest the protective role of melatonin in the cardiovascular system, which can be diminished after exposure to ALAN with negative effects on the cardiovascular health.

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Energy efficient short wavelength illumination - can this come on the account of our health risk?

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The introduction of energy efficient illumination was aimed as an environmental friendly illumination due to the reduction in electrical energy from power stations followed by a reduction in CO_2 emission. With the accumulated knowledge over the last two decays it's time to assess the environmental benefits *versus* the health risks in regards to exposure to such an illumination. The environmental signals that entrain our temporal organization are light/dark cycles accompanied by changes in light intensities an in addition to these changes they are accompanied by different spectral composition where in the morning, noon and early afternoon the short wavelength (SWL) parts are dominant while in the late afternoon and early evening into the night they disappear and replaced by the long wavelength parts of the spectrum. In regards to Artificial Light at Night (ALAN) if we try to imitate natural conditions the part of spectrum we use at night should not include dominant SWL under 500nm.

A great advance took place in our understanding of the circadian system in the human body and the way it is entrained by environmental signals. If the light/dark cycles are the signal for entrainment of our biological clock (Master oscillator) located in the Supra-chiasmatic Nuclei (SCN) of the hypothalamus we can ask how does it operate?. The biological clock is connected to the Non image forming photoreceptors (NIFP) of the retina by a special nerve pathway known as the Retinal-hypothalamic tract (RHT). The SCN however, is also connected by a nerve network to the pineal gland, where the signal is picked and transformed from a neural signal to a neuro-hormone, melatonin which is produced under dark conditions, and secreted to the blood stream. In the NIFP a new pigment named melanopsin was discover some 15 years ago and this pigment was found to be sensitive to the blue part of the spectrum under 500nm. At day time when these parts of the spectrum are dominant no signal is transferred to the SCN and from it to the pineal gland and melatonin production is suppressed. At night-time when the SWL part of the spectrum is not dominant, or not included in the spectrum the signal is transferred and the pineal gland produces melatonin. Interestingly, the SCN cells contain melatonin receptors.

Photoperiod is the bases for seasonality where the relative duration between the environmental light and dark hours in a 24h cycle are expressed by the levels and duration of melatonin produced and secreted by the pineal gland. Under short days high plasma levels of melatonin are for a longer period while under long days they decrease. The levels of melatonin and the duration of secretion are the signal for the body cell in regards to seasonality. So basically the same mechanism used for the clock is used for the calendar. Bearing in mind that the human evolution as that of other mammals and organism took place under environmental illumination conditions where during day time apart of the high light intensity SWL parts of the spectrum were dominant while at night time the low light intensity was accompanied by long wavelength parts of the spectrum. No doubt that ALAN changed our lifestyle and enabled human to be active in many ways after sunset or before sunrise. ALAN which emerged from incandescent bulbs was characterized by long wavelength illumination. The main problem of this type of illumination is that much of the electrical energy is converted into heat rather than into light. The high production of heat decreases the efficiency of the bulb consuming more electrical energy but also produces heat to closed environments that need to be cooled by air condition. So what is the problem with ALAN emerging from SWL-illumination with a dominant wavelength between 450-500nm?

The problem is suppression of melatonin production by the pineal during the dark hours, when it needs to be produced, resulting in a disruption of various biological rhythms including that of sleep. Moreover, melatonin is considered a "Jack of traits" hormone which is involved in the regulation of many physiological systems including the metabolic system, it also regulates the immune system function. It's an effective antioxidant and anti-oncogenic agent against breast and prostate cancers. Results of studies from our research center and from other laboratories in the world reveal that melatonin is involved in epigenetically modification the changes in Global DNA Modifications GDM-levels in breast cancer cells of mice and pancreatic cells in rats exposed to SWL-illumination disturbances at night. GDM levels decreased in mice and rats exposed to SWL-illumination, melatonin treatment given at the dark period reversed the process and GDM-levels increased. Therefore, the benefit of energy saving from SWL-illuminations should be assessed in relation to health risk resulting in increase of breast and prostate cancers, obesity and diabetes as well as decrease in immune function. Can energy saving come on the account of risking human health? The answer should be no. We can defiantly show today that obesity on a worldwide scale is connected to high levels of light pollution. In countries with high levels of light pollution obesity is significantly higher than in countries with low levels. Under laboratory condition using animal models we can show it has to do with SWL-ALAN.

The American Medical Association in Jun 2012 passed a resolution that light at night is a source of pollution as it suppresses melatonin secretion and disrupts biological rhythms including sleep. They call upon looking for new illumination technologies, such technologies should involve energy saving but not on the account of health risk. Therefore, the SWL dominant parts of the spectrum below 500nm should not be included in such illumination. As the changes among others are epigenetic, the period between constant exposure and the stage where the disease appears can be long. Bearing this in mind opens new opportunities in preventing health risks however, much research needs to be carried out in such a direction. At this stage to be on the safe side, illumination with a dominant SWL-pick should be limited, as it cannot come on the account of risking our health as a result of disrupting our temporal organization.

Title: Does increasing road lighting increase road injuries?

Theme: Society

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Abstract

The work presented examines the effect of increasing road lighting on reported personal injury road traffic accidents, in one large city. The increase in lighting occurs by brightening and whitening road lamps. Other work suggests that new lighting has not reduced crime by the 20% that was claimed it would. This presentation examines the impact on road traffic accidents when tens of thousands of lamps have been changed and tens of thousands of road injuries have occurred, within the whole city area, during the 9-year time period of the study.

A multilevel analysis of the time series of the road traffic accident data is presented. The analysis, done at the small area level, utilises the times of lighting change and the times of occurrence of the accidents. The analysis recognises that the underlying accident rate is simultaneously changing (generally decreasing) over time, in the absence of any change in the lighting level. The analysis follows its protocol with some small variations, which will be discussed.

The results are interesting in that they suggest a modest but detectable increase in the accident rate as the lighting increases. This effect remains despite considerable checking and discussion of the methods and analysis!

Other large, comprehensive datasets need to be examined to see if this harmful effect occurs in other places where major road lighting increases are made.

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Preserving the night using outdoor lighting intelligently

Theme: Technology

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The enormous proliferation of outdoor lighting over the last century clearly demonstrates that lighting is a basic human need. Without lighting, the world would be a more dangerous and less pleasant place. There are however a number of clear downsides. Ever since its introduction, installation cost and energy use are a major issue. The latter became even more relevant when people saw the effects of global warming. Recently, concerns have grown over possible negative effects of public lighting on wildlife and even on human health. So although we need lighting for safety and comfort, we need to use it in a cautionary way.

Ever since the introduction of road lighting, a number of strategies have been used to save cost and energy. There is the initial decision whether to install lighting at all – which is still a valid option in current lighting standards. Then the times to switch the lighting on and off have to be fixed. From the 1980s it became possible to dim public lighting, either using a local sensor or via a central system. Nowadays, LEDs in combination with all the available digital technology allow a lighting system to adapt to any situation using data from both local sensors and other sources, using various combinations of local intelligence and central management.

This presentation will give an overview of how lighting has been controlled up to now, what we can expect in the near future and how this can help to preserve the night.

Title: An Innovative Lighting System with Adjustable Spectrum that Mimics Natural Light in Intensity and Color.

Theme: Technology and Design

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For billions of years, living organisms have evolved under natural light, and have developed sensitive photoreceptors to its different spectral color variations and intensity. But in the last hundred years, artificial light has emerged in our societies and has interfered with the cycles of natural light. As a result, our lifestyle has been affected; we are over-exposed to artificial light both by day and night along with its beneficial and harmful side-effects.

Outdoor artificial lighting has grown steadily by way of incandescent-bulbs (orange-yellow color) to the high pressure sodium varieties (HPS, orange color), metal halide (MH, cool white color), and more recently, light emitting diodes (LEDs, blue enriched spectrum). Similarly, indoor artificial lighting has gradually evolved through incandescent and halogen bulbs, then to fluorescent tubes (FL, blue enriched spectrum) and LEDs for private areas, and by cool-white fluorescent lighting (FL, blue enriched spectrum) and LEDs for public areas with a large span of Correlated Color Temperature (~2200K to more than 6500K). The use of artificial full spectrum daylight for human activities is uncommon; however, it is used in light therapy, greenhouse lighting and in pet shops. This type of artificial light is reputed to mimic natural sunlight, but that is not totally accurate. The spectral distribution curves of all these artificial lightings are very different from one another and from natural light as illustrated in Figure 1. Moreover, artificial light has a static spectrum while natural light modulates over days and seasons. To mimic natural light and its cycles, we must develop lighting systems that are similar to natural light.

In this presentation, we will introduce a prototype of lighting system that mimics natural light, adjustable in color and intensity that our research team has developed. We will also present its possible applications for private and public areas.

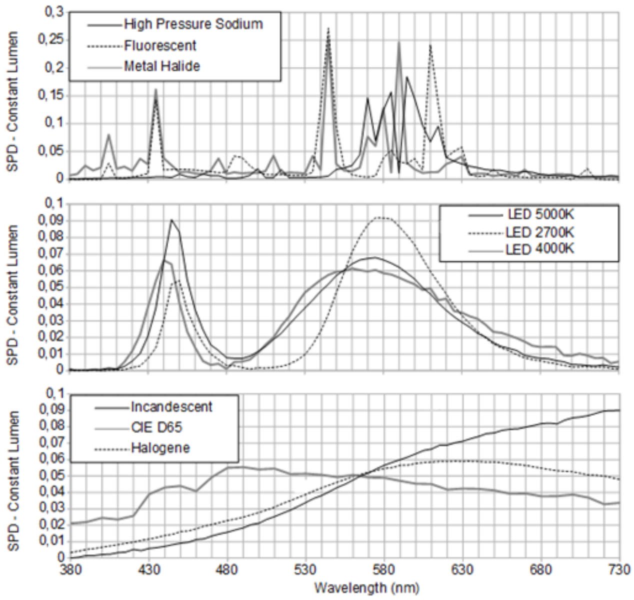

Figure 1. Constant lumen spectral power distributions of differents outdoor and indoor lighting devices. CIE D65 is a reference illuminant from the Commission Internationale de l'Éclairage (CIE). D65 corresponds to a midday Sun in Western/Northern Europe with CCT~6500 K. (Modified figure from Aube and al (2013) *Evaluating Potential Spectral Impacts of Various Artificial Lights on Melatonin Suppression, Photosynthesis, and Star Visibility.* PLoS ONE 8(7).)

Directionality: an important light parameter for human health to consider in lighting design

Theme: Technology and Design (Architectural lighting)

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Introduction

Ocular light exposure is not only important for its image-forming effects enabling humans to perform their visual tasks, but also for its non-image-forming effects influencing human health and well-being through regulation of biological rhythms. The direction in which light enters the human eye plays an important role in the magnitude of the non-image-forming effects (Visser et al., 1999; Lasko et al., 1999; Glickman et al., 2003; Ruger et al., 2005). In this paper, relevant literature on light directionality was studied to determine it can be optimally incorporated in building lighting design.

Directionality and human health

A non-rod, non-cone photoreceptor in the human eye called “intrinsically photosensitive Retinal Ganglion Cells” (ipRGC) is primarily responsible for stimulation of the non-image-forming effects. Two distinct approaches were used in laboratory experiments to investigate the spatial distribution of ipRGCs in the retina: 1) *in situ* experiments with human subjects, 2) *in vitro* experiments using isolated animal retina. Four different areas in the retina have been studied: inferior, superior, nasal, and temporal areas.

In experiments with human subjects, suppression of the hormone melatonin (the hormone that regulates the sleep-awake cycle) is often chosen as a biomarker for non-image-forming effects of light. Different research groups have studied the effect of directionality of light exposure on human melatonin suppression (Visser et al., 1999; Lasko et al., 1999; Glickman et al., 2003; Rüger et al., 2005). The method, light source, and experimental conditions varied in every study. For instance, while Lasko et al. used an illuminance of 500 lx on the superior and inferior retina and disregarded the full retinal light exposure, Glickman et al. chose to work with full retinal exposure of 100 lx and 200 lx with similar retinal photon flux in addition to superior and inferior retinal exposure of 200 lx. Moreover, in the Glickman-study retinal exposures were fully controlled with the help of a helmet with shields whereas in the Lasko-study retinal exposures were distinguished simply by moving the location of the light source from the upper to the lower part of the view gaze. In both the Visser and Rüger-study a helmet was designed for controlling only the nasal and temporal retinal exposure. For the inferior and superior light exposure, they relied on the lens properties of the cornea.

Aside from methodological differences in aforementioned studies, melatonin suppression was higher when the inferior retina was illuminated compared to the superior retina (Visser et al., 1999; Lasko et al., 1999; Glickman et al., 2003). The difference has reached statistical significance in the Glickman and Lasko studies ($p < 0.05$). In addition, a significant effectiveness of illuminating the nasal retina compared to temporal retina ($p < 0.05$) in melatonin suppression was observed (Ruger et al., 2005; Visser et al., 1999). These results suggest that the inferior and nasal retinal area are to be either (i) more sensitive toward light stimuli when the non-image forming effects of light are concerned, or (ii) contain a higher density of the ipRGCs.

In animal studies, the exact special distribution of the ipRGCs was investigated *in vitro* using different cell-marking methods. A cell-tracer was injected into different retino-receipant structures in order to identify the ipRGCs. The choice of retino-receipant structure depends on the type of animal. In the most recent study, Galindo-Romero et al. (2012) have presented an automated method to quantify the number of ipRGCs in adult albino rats. They have found that the ipRGCs are denser in the superior-temporal area which is in agreement with previous studies on adult rats (Hannibal and Fahrenkrug, 2002; Hattar et al., 2002; Decay at al., 2005).

Implementation of light directionality in lighting design for buildings

Literature on the influence of light directionality, especially on human subjects, is rather limited. Human studies show that inferior and nasal retinal areas are significantly more effective in stimulation of non-image-forming effects using melatonin as biomarker. Animal studies show that ipRGCs are more densely packed in the superior-temporal retinal area. Although these two types of studies suggest different spatial distributions for ipRGCs in the retina, both reveal a non-homogenous distribution and thus highlight the importance of light directionality on human health. For the design of lighting in buildings this translates into the fact that one can positively influence the occupant's health by choosing the right position for luminaires and daylight openings depending on the magnitude of the influence one is looking for. In addition, it enables different stakeholders in the (day)lighting industry to design lighting that supports both human vision and health.

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Light and darkness and its impact on human behavior

Theme: Society

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Light and darkness determine what and how much individuals can see of their environment and hence shape human behavior. This experience of light and darkness has been so fundamental for humans that it has served as a scaffolding for our representation of different concepts and mental actions. Metaphors of light, darkness and vision help to describe abstract concepts such as knowledge (e.g. “to be let in the dark”, “a bright person”), morality (e.g. “the bright innocent bridal dress“ vs. the “a dark immoral character”) and for mental process of understanding (e.g. “to gain insight”). Due to these metaphorical meanings, light and darkness can influence thoughts, feelings and behavior above and beyond its direct experience. Taking a psychological perspective, this talk will provide an overview of how light and darkness – experienced directly and activated associatively – affect basic mechanisms, such as information processing and self-regulation, which in turn impacts cooperation and creativity. Differences of light and darkness at day and night will be discussed.

Touched by light

Society / Technology & Design

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With the introduction of the LED as illuminant a new era of dealing with lighting has dawned. Digitalisation, light guidance and light quality take on greater significance. Physical and emotional impacts of light on the human being have become common topics in the everyday life of a modern society.

Our visual perception has adapted and assimilated to an increasing amount of artificial light over the years, decades and centuries. What was once perceived as bright today isn't much more than a dusky light which can't either be used in a functional way or even less meet current standardization regulations. The amount of light which determines the character of spaces is steadily increasing. Artificial light and daylight are constantly gaining importance inside buildings and in intensively built-up urban areas.

The project *Langsames Licht / Slow Light* searches for ways to practically implement theoretical insights and experience from the subjects of art, science and design, allowing a targeted use of light.

64 kW, bei: Updating Germany ,11. Architekturbiennale Venedig
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Title: The Pulse of the City Lights

Theme: Measurement & Modeling

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Introduction

With millions of interacting people and hundreds of governing agencies, urban environments are the largest, most dynamic, and most complex macroscopic systems on Earth. I will describe the newly created Urban Observatory (UO) at the Center for Urban Science and Progress (CUSP), a facility designed to use persistent, synoptic imaging of the New York City skyline to better understand the complex urban system. By combining techniques from the domains of astronomy, physics, computer vision, remote sensing, and machine learning to analyze nighttime CUSP-UO imaging data, I will present the detection of an underlying pulse to the pattern of city light variability. These patterns can be used in studies of circadian rhythm disruptions, proxy measures for energy consumption, and public health impacts of light and/or noise pollution. I will also demonstrate the efficacy of side-facing hyperspectral imaging for lighting technology determination and a methodology for combining this imaging data with the wealth of correlative data available in New York City.

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Title: Comparing Circadian Questionnaires with the Dim Light Melatonin Onset

Theme: Measurement & Modeling

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Introduction: The dim light melatonin onset (DLMO) is considered the gold standard marker to assess circadian timing in humans. Often DLMO is used to time bright light exposure or exogenous melatonin for circadian treatments. However, the assessment of DLMO is laborious, costly and hardly available to clinicians. As surrogate measures of circadian timing, the Morningness-Eveningness Questionnaire (MEQ) and the Munich ChronoType Questionnaire (MCTQ) are regularly used to estimate diurnal preference and chronotype, respectively. In the largest sample to date, we analyzed the correlations between DLMO, MEQ score and MSF_{sc} (midpoint of sleep on work-free days corrected for sleep debt on workdays, derived from MCTQ).

Methods: In 60 participants (18-62 years; 36 healthy controls and 24 people with delayed sleep phase disorder, who all slept freely at times of their choosing prior the study) we collected MCTQ and MEQ information, together with their DLMOs under controlled laboratory conditions.

Results: We found that the DLMOs ranged between 18:30h and 02:38h, and that the DLMOs significantly correlated both with the MEQ score ($r=-0.70$, $p<0.001$; explaining 49% of the DLMO variance) and MSF_{sc} ($r=0.68$, $p<0.001$; explaining 47% of the DLMO variance). There was a range of about 4-hours in DLMO at each given MEQ score and MSF_{sc}.

Discussion: Diurnal preference (MEQ score) and chronotype (MSF_{sc}) correlated significantly with DLMO. However, the DLMO range around a given MEQ score and MSF_{sc} suggests some imprecision. Hence, neither of the two questionnaires tested here should be used exclusively to time circadian treatments. Both questionnaires are compared on the specific behaviors they assess, additional outcomes (e.g. social jetlag from MCTQ), completion time, burden to the subject, calculation difficulties, and whether the use of an alarm clock confounds chronotype assessment.

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Are LEDs reducing light pollution?: Dealing with light pollution in a colour changing world

Theme: Measurement & Modeling + Biology & Ecology

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Introduction

Light pollution is drastically changing our environment. So much so that it has become a threat to the wellbeing of humans, other animals and plants (Gaston et al. 2013). It is impacting our culture as well as our lifestyle. In order to create awareness concerning these changes, and to determine how to respond to them most effectively we need to measure light pollution around the world.

Currently, most researchers are using single band (DMSP, VIIRS, SQM)(Bennie et al. 2014, Estrada-García et al. 2015, Kyba et al.2015) measurement systems. Although these systems are unable to estimate the spectra of the light sources, they were considered to perform sufficiently at a time when streetlights such as Mercury Vapor lamps were popular. When Mercury Vapor lamps were replaced by High pressure sodium lamps (HPS) the inability to consider the spectra of the source was of little relevance since the change was from a more polluting light source to a less polluting one for the same photopic emission. However, since the LED revolution we are dealing with a reversal to this situation in which we have replaced a less polluting light source with a more polluting source (Aubé et al. 2013). Therefore, it has now become a priority that we start using measurement systems that can take into consideration the spectra of the sources.

We will be presenting the following new systems that are able to measure the real environmental impact if applied in the proper way: ISS imagery (Sánchez de Miguel 2015), the new multi spectral photometer TESS (Zamorano et al. 2015), and DSLR/CCD photography (Sánchez de Miguel 2015).

Also, there will be future platforms for remote sensing in several bands, for example in the case of the ORISON balloons (Ortiz 2016).

Only with these new instruments, will we be able to make correct estimation of Melatonin Suppression, Stars visibility and other indicators when it comes to the effects of light pollution.

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NITESat: A High Resolution, Full-Color, Light Pollution Imaging Satellite Mission

Theme: Measurement and Modeling

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Mission Concept

NITESat (the Night Imaging and Tracking Experiment Satellite) is a small yet capable nanosatellite inspired by the 2007 Nightsat mission concept (Elvidge et al. 2007). NITESat is a pilot mission testing the potential for a simple and inexpensive (<$500,000 including development costs) satellite to deliver high-resolution three-color data on artificial light at night in a 1000x1000km region (see Fig 1). In addition to providing unprecedented resolution and color data for light pollution research, the NITESat mission will develop an extensive ground-based education/outreach array of all-sky monitors covering the same region with ~20 full sky light pollution stations. These citizen-operated stations will provide data synchronized with the orbital mission overpasses as well as providing near continuous light pollution monitoring. If the initial mission is a success, the potential exists to expand the program to a low cost constellation of satellites capable of delivering global coverage. NITESat is being designed, built and will be operated by the Far Horizons CubeSat program at the Adler Planetarium in Chicago, Illinois.

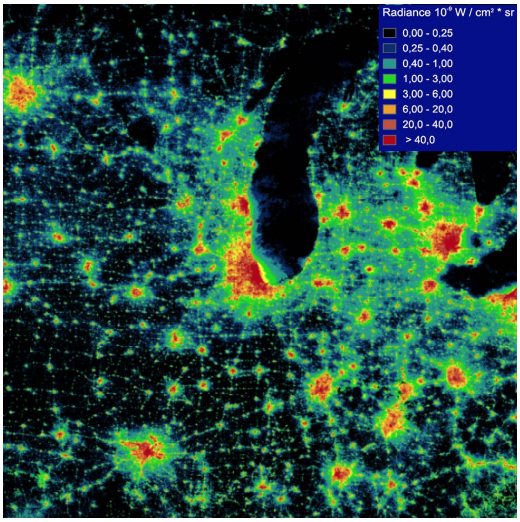

Fig 1: VIIRS data for the 1000x1000km NITESat imaging area centered on Chicago. This region covers 4 orders of magnitude in population density from rural areas to one of the world's most light-polluted cities. The Great Lakes provide areas of contrasting zero population. Image and Data credit: NOAA's National Geophysical Data Center

Technical Details

NITESat will be a 2U (10x10x20cm) CubeSat, based on a commercially available (GOMSpace) bus. It will include Commercial Off The Shelf (COTS) power, communications, attitude control and flight computer modules. The main payload will be a low-light imager based on the three color PCO Edge 3.1 sCMOS camera and a fast (FL=1.4) 25mm Lensation lens. During each night-time overpass, multiple rapid (0.02s exposure, 0.1s cadence) images will be taken and stacked by an on-board processor. Stacked images will be stored and downlinked in losslessly compressed form. The target performance is given in Table 1.

Table 1: NITESat Imager Parameters

Resolution	Bands	Sensitivity	FOV	Dynamic Range
200 m/px	0.4-0.5, 0.5-0.6, 0.6-0.7μm	$<10^{-8}$ W/cm^2/sr/μm	30°	15 bits

An extensive qualifying program is currently underway using high-altitude balloon missions and laboratory tests to ensure the main payload is space-ready and both the hardware and software is fully integrated with the spacecraft bus.

Data Details

NITESat will orbit at approximately 500km at an inclination of 50°. Taking into account cloud cover averages, our target region will be fully imaged multiple times in a year. In our reference orbit, 9pm-midnight passes occur in clusters lasting approximately 1 month separated by a 1 month period without imaging opportunities. This cadence allows the downlink of stored data during lulls in the imaging portion of the mission. The expected orbital lifetime of 1-2 years will allow tracing seasonal variations of the emission of artificial light at night.

Due to data downlink constraints on our single ground station, we limited the target region to a 1000x1000km area centered on Chicago. As can be seen in Figure 1 this region represents a diverse set of urban and rural populations of widely varying densities. Figure 2 shows details of a simulated comparison between VIIRS and NITESat data for the Chicago metropolitan area.

The Far Horizon team will make its data publically available in reduced form. We are also interested in collaboration with the light pollution community to help optimize our mission design and provide the most valuable data to best serve the community's research goals. Partnerships with groups interested in providing downlink services may allow additional imaging opportunities.

Fig 2: Simulated NITESat (left) and actual VIIRS (right) images of the Chicago region. NITESat will provide a 3-fold increase in resolution over VIIRS as well as invaluable broad-band color data. NITESat simulation is a down-sampled image from the ISS. Image credits: Earth Science and Remote Sensing Unit, NASA Johnson Space Center and VIIRS Image and Data by NOAA's National Geophysical Data

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Observing Nightlights from Space with TEMPO

Theme: Measurement & Modeling

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Abstract

TEMPO ("Tropospheric Emissions: Monitoring of Pollution") is an Earth Venture Instrument funded by NASA to be launched as a hosted payload on a geostationary satellite in the 2018-2021 timeframe. Its spatial coverage extends from Mexico to Canada and from the east coast to the west coast of the continental United States. The primary mission of TEMPO is the study of air pollution, the diurnal cycle of its emission and its chemistry. TEMPO operates with a scan mirror, telescope, and an Offner-type spectrometer. TEMPO can cover its field of regard in an hour with nominally 1282 scan-steps. Each step comprises a line of 2038 spatial pixels, roughly aligned north-to-south and perpendicular to the direction of scan. TEMPO will also be able to perform partial scans of its full field of regard to make regional observations with a time resolution of 10 minutes or less. Light from each spatial pixel is dispersed into two spectral channels (wavelengths 290-490 nm and 540-740 nm) with a spectral resolution of ~0.6 nm FWHM sampled every 0.2 nm. The spatial extent of a pixel at the center of the field of regard is about 2.1 km (north-to-south) by 4.4 km (east-to-west). TEMPO will be joined by similar instruments in geostationary orbits over Asia and Europe, respectively the GEMS ("Geostationary Environment Monitoring Spectrometer") and the Sentinel-4/UVN ("Ultraviolet/Visible/Near-infrared"). Together with Sentinel-5p/TROPOMI ("Tropospheric Monitoring Instrument") and Sentinel-5/UVNS (UVN/Shortwave-IR) in low Earth orbits, TEMPO, GEMS, and Sentinel-4/UVN will comprise a near-global constellation to observe air quality and transport of pollution.

TEMPO observing is optimized for its primary air quality mission, which uses the spectral signatures of trace gases observed in reflected sunlight to measure their concentrations in the atmosphere. When night falls across the field of regard, the only tasks for TEMPO are a short solar calibration performed using a diffuser when the sun is 30° off axis and dark current calibrations. To take advantage of what would otherwise be down time and expand the mission's scientific return, we are developing a nighttime observing plan that offers a new and interesting capability to spectrally characterize nightlights. Our paper presents the capabilities of TEMPO to collect light at night from artificial sources at useful signal-to-noise ratios and therefore characterize these sources by type. We show that TEMPO will be able to spectrally discriminate between common lighting types using an integration time of about 10 s at each dwell step with the dark current of our flight detectors. Lighting types with sharp spectral features (*e.g.*, low-pressure Na vapor lamps that are in common use in outdoor lighting for reasons of light pollution mitigation and energy efficiency) are especially well suited to observation by TEMPO. We show that other common lighting types will also be observable given the spectrally integrated radiance levels that are seen in VIIRS Day-Night-Band (DNB) nighttime imagery. Observations from spectrometers, such as TEMPO, coupled with broad-band observations from VIIRS-DNB, will provide new and interesting data for those interested in light pollution and energy efficiency as it relates to artificial lighting.

Are relationships between artificial light emission and land use dependent on community size?

Theme: Measurement and Modeling

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Introduction

Large cities and rural settlements have differing needs for artificial light at night, and therefore likely have different types of light use. Urban areas also tend to have taller buildings and less vegetation. Therefore, the light from major cities and smaller communities therefore surely differs in terms of spectra, temporal changes, and angular emission properties (Kyba et al. 2015). Yet, to the best of our knowledge, these potential systematic difference has never been evaluated or considered in any of the many analyses using space based observations of artificial light emissions (see Huang et al. 2014 for an overview of the types of analyses that use night lights data).

Here we use of two types of night lights datasets to examine the relationship between land use and light for communities of differing size, ranging from major European cities to rural municipalities with populations in the hundreds. The first dataset are 1 meter resolution mosaic images based on aerial photography of portions of the city of Berlin, Germany, and the state of Upper Austria, including the cities of Linz and Wels, Austria. The second dataset are photographs of more than a dozen large European cities taken from the International Space Station (ISS).

Methods

a) Mosaics from aerial photography

Aerial photography (Fig 1) allows the upward light emissions to be measured at very high spatial resolution from a relatively large area (max ~1000 km^2). Typically, thousands of photographs are taken during several aircraft passes over the target area, over a period of 2-3 hours. These photographs are later automatically georeferenced using information about the aircraft's position and the camera orientation (see Kuechly et al. 2012 for details). The individual photographs are then overlayed to create a mosaic of the complete study area.

Fig 1: Aerial photograph of a bridge over the Danube River and other lit surroundings in Linz, Austria. Individual cars and streetlamps can be resolved.

Color aerial photographs were acquired on the nights of 18 October 2013 (Berlin) and 26 October 2014 (Upper Austria), using a Nikon D3 50mm 1.8G (Berlin) and Nikon D4S with a Nikkor 50mm AF-S f1.4 lens (Upper Austria). Georeferenced images were produced using the algorithms described in Kuechly et al. (2012), with the additional modification of including a digital elevation model, which was required due to the topography of Upper Austria. Mosaic images were compared to maps of land use: for Berlin the Berlin Digital Environmental Atlas (Berlin Senate Department for Urban Development & the Environment, 2011), for Upper Austria "*Bundesamt Eich- und Vermessungswesen, Wien: Digitale Katastralmappe*".

b) Photographs from the International Space Station

Photographs of specific European cities from the International Space Station (e.g. Fig 2) were obtained from the Cities at Night gallery (Sánchez de Miguel et al. 2014). All available images from each target city were visually inspected, and the image judged to have the best spatial resolution and atmospheric clarity over the full city area was selected. Images were radiometrically calibrated following the procedure Sánchez de Miguel (2015). Georeferencing was performed semi-automatically in ArcGIS: first the image was rotated by hand, and 2-3 ground control points (GCP) were manually added. Then, ArcGIS automatically selected new GCP, using Open Street Maps data as a base map. Following this procedure, additional GCP were added by hand if the spatial coverage of the GCP was considered not sufficient. The radiometrically calibrated images were warped in GDAL based on the GCP using thin spline interpolation and nearest neighbor. The resulting images were saved as geotiffs.

Fig 2: Crop of an ISS photograph of Berlin. ISS047-E-29989 courtesy of the Earth Science and Remote Sensing Unit, NASA Johnson Space Center.

Each geotiff was compared to data from the Urban Atlas of the European Environment Agency (EEA) in order to determine the relationships between land use type and light emission. The Urban Atlas maps are not as detailed as those used in the aerial photography analysis, but allow apples-to-apples comparisons of the cities, and importantly the amount of light associated with their street networks. The city of Madrid, Spain, was selected to examine the systematic uncertainty associated with the method. Here, 13 images with taken on different dates, ISS overpass times, spatial resolutions, and view directions are compared.

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GPS tracking for mapping seabird mortality induced by light pollution

Biology & Ecology

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Introduction

Seabirds, mainly burrow-nesting petrel species (Order Procellariiformes) suffer from mass mortality episodes caused by artificial lights. Petrel fledglings are disorientated by artificial lights when they are leaving their nests for first time and fly towards the sea. Every fledging season, thousands of fledglings of different species are grounded by light pollution, being exposed to injuries, fatal collisions, road-kills or predation. To mitigate light-induced mortality, rescue campaigns are organized to pick up grounded birds, releasing into the ocean a high proportion (usually > 90%, although these rates could be underestimated and 60% might be a more accurate estimate). Why petrels get disorientated by lights is far from being fully understood. The majority of our knowledge comes from observational data from rescue campaigns, and it mainly consists in the reporting of species identification, individual numbers, date and location. The highest numbers of grounded birds have not been reached in the most light-polluted areas, probably because interaction with other factors, such as distribution of the breeding colonies and distance to artificial lights, plays a crucial role. Unfortunately, rescue campaigns can not identify the colony of origin of birds grounded by artificial lights, and an important information gap arises around how far birds are attracted to lights and which are the thresholds of light intensity to have a considerable effect.

Here, we used miniaturized GPS data loggers to track the flights of fledglings from their nest sites to ground and high resolution nocturnal satellite imagery to assess light pollution levels. We describe flight characteristics to assess extent and intensity of impact by light pollution on the pathway of birds to the sea. Furthermore, using recovery rates of fledglings banded at colonies, we built generalized linear models to explain the contribution of geographical variables on the light pollution impact on the colonies.

Results

All rescued birds were found at lower elevations than their nesting colonies (or releasing site in the case of second fliers) and at locations less than 16 km from their colonies, with half of the birds being rescued within a radius of 3 km. According to the VIIRS satellite imagery, birds were rescued in more light-polluted areas than their colonies, excepting one individual. The majority of birds were grounded in areas showing light pollution levels greater than 18 $nW/sr*cm^2$, and both straight length and cumulative length from nests to grounding locations and length of flights were positively related to light pollution levels.

Birds left nesting burrows 161.2 ± 153.8 (mean ± SD, n = 18) minutes after sunset on average. After grounding, 13 of 18 GPS-tracked birds were rescued within 24 hours, two were rescued 24-48 hours after grounding, one was rescued four days after grounding and two birds were rescued five days after grounding. The proportion of recovered birds in relation to marked birds was positively related to the distance to sea and elevation of breeding colonies. Models including explanatory variables of light pollution explained lower proportions of deviance.

Discussion

Information provided by our study has important implications for conservation and management because if only birds flying over or near to light-polluted areas are susceptible to disorientation by lights, then light pollution would have a local effect. However, if birds from distant areas were grounded by lights, the consequences of light pollution would worsen by increasing its extent and impact, affecting a higher proportion of the island population.

Our data indicates that stranded birds are typically naïve birds which get locally disorientated in their maiden flight. The contribution of fledglings attracted by lights back to the land from the ocean does not seem to be substantial to total number of grounded birds. First, we did not recover any birds from dark sky colonies. Second, all recovered birds were grounded at locations close to their breeding colonies, i.e. < 16 km. Third, birds were grounded the same night when they left their burrows, i.e. no birds reached the sea and were grounded by lights on subsequent nights. GPSs also provided interesting information on the timing of rescue of birds, some of them being rescued five days after getting stranded. A key factor determining the mortality of fledglings grounded by light pollution is rescue date, with late rescued fledglings having a higher probability of death. Thus, an enhancement in the rescue campaign design should be done to avoid death by exhaustion and release the birds as soon as possible, or provide them with veterinary care, if required.

Our models indicate 'distance to sea' and 'elevation' are more important than light pollution level variables to explain the vulnerability of colonies to artificial lights. Thus, coastal breeding colonies have the lower levels of light pollution affection, while artificial lights act as a barrier for the movement of fledglings from inland colonies. Because of the high philopatry exhibited by petrels and the light-induced mortality of fledglings, one would expect a low recruitment rate at inland colonies which may lead to their extinction in combination with other non natural threats.

An effort should be done to reduce light pollution to levels as low as possible at natural protected areas, but also at adjacent areas in order to avoid attraction of birds born at dark-sky colonies. This action, i.e. reduction of radiance levels < 10 $nW/sr*cm^2$ within 3 km from colonies, could reduce by 50% the attraction of shearwaters raised in protected areas. However, the positive relationships between flight distances and light pollution levels suggest that radius of light attraction of birds is dependent on light intensity; greater light pollution intensities indicate larger attraction radii. Therefore, a 3-km buffer may not be enough to reduce attraction especially in areas with high-polluted areas. Furthermore, a majority of fledglings leave their nests during the first three hours after sunset, coinciding with greatest usage of lights at night and consequently greatest light pollution levels. To minimize conflict with the general public an effort should be to inform residents and tourists about ecological and economic consequences of light pollution on native seabirds in order to reduce the light emitted into the sky, especially during the fledging period.

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Nocturnal Seabirds: light pollution's impact on their global ecological niche

Theme: Biology & Ecology

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Light pollution has negative consequences for a number of species of birds from many diverse groups. Much research and outreach attention has been directed towards a wide range of nocturnally-migrating songbirds and collisions with lit structures, as well as a few seabird species of threatened status (for example, Shearwaters in Hawai'i and Malta, Storm Petrels in Hawai'i, Puffins in Atlantic Canada) which have the dual problems of collision risk and fledgling misorientation away from the sea due to nocturnal lighting.

In the present synthesis, we review why these seabirds, and many others not closely related to these, choose to operate nocturnally. One suggestion, made by Lack (1966), Cody (1973), Ainley *et al.* (1975), Nelson (1989) and Gaston and Dechesne (1996) is that the nocturnal nesting behaviour of some seabirds arises due to pressure from aerial piracy or kleptoparasitism, perhaps by Frigate birds, Skuas , Gulls or Terns. As we develop this idea further, it appears that any seabird, regardless of genus or family, within the smaller size range that puts them at risk of kleptoparasitism, has a strong preference to nocturnal, or at least crepuscular, behavior.

From this, we argue that light pollution is not just a potential issue for certain specific species of seabirds, but rather, a problem that possibly impacts an entire ecological niche, filled globally by a wide range of unrelated families and genera of smaller seabirds. A partial list of the birds involved includes several Prions, Swallow-tailed Gull, Least Tern, many Alcids (including Atlantic Puffin; Crested Auklet; Marbled, Cassin’s, and Xantus Murrelets), Western Grebe, Little Penguin, Shearwaters, Storm Petrels, and Red-footed Booby.

The broad use of the crepuscular or nocturnal environment by birds of this size is not restricted to seabirds. Similar-sized land-based species that are at least partially crepuscular or nocturnal include Common Nighthawk, Owlet-Nightjar, Chimney Swift, American Woodcock, Spotted Crake, some Sandpipers, Red Knot, American Robin and the Common or Eurasian Blackbird. Light pollution’s impacts on some of these species are well documented (Miller 2006, Dominoni *et al.* 2013).

Furthermore, since animal population sizes and densities commonly scale in inverse relation to the size of the organism (White et al. 2007), the fact that this ecological niche is occupied by smaller seabird species signifies that this ecological niche may be expected to have, in an undisturbed environment, a relatively high number of individuals. A large expected population in any ecological niche is no guarantee that individual species within that niche should also be common or even widespread, since other factors can control seabird colony sizes (Jovani *et al.* 2015). However, the fact that so many of these smaller seabird species are classified as threatened (Marbled Murrelet, Atlantic Puffin, Yelkouan and Newell's Shearwaters, Hawaiian Petrel, Band-Rumped Storm Petrel, for example) indicates that we may be underestimating light pollution’s and other environmental challenges faced by these nocturnal birds. Globally, it is the northern hemisphere populations that primarily appear to be in decline, with exclusively southern-hemisphere species remaining abundant. This may reflect the northern hemisphere's greater prevalence of light pollution in combination with over-fishing of the seabirds' food resources and nest predation by rats and feral cats.

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Title: Effects of intermittent experimental night lighting on bird singing and foraging behaviours

Theme: Biology & Ecology

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Introduction

Recent studies showed that light pollution can alter the natural timing of activities in many animal taxa, including fish, amphibians, birds, and mammals. In passerines, we previously demonstrated that ALAN alters the daily timing and the seasonal development of the dawn and the dusk choruses in some species (Da Silva et al. 2014, 2015). Other studies found that those same species can use streetlights to extend foraging into the night either in winter or, to a lesser extent, in spring (Byrkjedal et al. 2012; Russ et al. 2014). However, these light effects on timing of singing and foraging may have been confounded by other anthropogenic agents correlated with the presence of ALAN. Manipulating the presence of ALAN in previously dark habitats is therefore imperative in order to confirm these findings. Using experimental lighting in the field may also help elucidate the mechanisms underlying these temporal shifts. In general, four non-mutually exclusive mechanisms can explain the differences in timing of behaviour observed between birds living in urban environments affected by ALAN and those living in dark places (Partecke, 2014). (1) Phenotypic plasticity in the form of behavioural flexibility: this implies an immediate adjustment of behaviour. It is the most likely mechanism, because the initiation of dawn song and foraging is strongly linked to natural light levels, as suggested by the delayed starts on cloudy mornings, and the advanced starts on nights with bright moonlight. (2) Phenotypic plasticity in the form of developmental effects: parental phenotype or environmental conditions early in life may influence behavioural development. For instance, individual birds that have been exposed in the nest to artificial light may show early activity after fledging. (3) Phenotypic-based habitat choice: individuals with early chronotypes may preferentially settle in territories exposed to ALAN. (4) Genetic effects: micro-evolution (via natural or sexual selection) may have changed the timing of activity for urban birds living in lighted areas. Finding the mechanisms underlying the shift in timing of singing and foraging is essential to understand whether ALAN can alter evolutionary trajectories in songbirds.

For this reason, we experimentally manipulated the presence of ALAN in a cyclic fashion, in several naturally undisturbed forest patches, during the early springs of 2014 and 2015, and during the early winter of 2015. During the two consecutive spring seasons, we investigated how male songbirds responded to the day-to-day variation in the presence of ALAN in terms of the timing of dawn song. The singing males had already established territories, and the experiment was conducted on a short temporal scale; thus, any changes in timing of dawn song would reflect behavioural plasticity rather than differential settlement or developmental/genetic effects. We recorded dawn song on a daily basis in four passerine species that have already been shown to be affected by ALAN, i.e., the European robin *Erithacus rubecula*, the common blackbird *Turdus merula*, the great tit *Parus major*, and the Eurasian blue tit *Cyanistes caeruleus*. In contrast, during the winter season, we tested whether resident songbirds were able to exploit the artificial "night light niche" in order to extend foraging at automated feeders placed inside each forest patch. These feeders were providing food around dawn and dusk only, and feeding visits were video-taped. This time, the study species were the most common species visiting the feeders during the experimental period, i.e., the common blackbird, the great tit, and the Eurasian blue tit, as well as the Eurasian jay *Garrulus glandarius*, the Eurasian nuthatch *Sitta europaea*, and the marsh/willow tit *Poecile sp.*

For the spring experiment on singing behaviour, we show that males of all four species can immediately and reversibly adjust start of dawn song in response to ALAN. This effect was strongest in the robin, which was singing nocturnally on most lighted nights, and increasingly earlier from one lighted day to another. In contrast, plasticity was small in the blue tit, the great tit, and the blackbird, which may indicate that longer-term effects of ALAN on timing of singing may also occur in urban lighted habitats, or that those species use compensatory behaviours such as light avoidance. For the winter experiment on foraging behaviour, we find that the most regular feeder visitors, i.e., the blue tit and the great tit, started to forage earlier during the mornings with ALAN. In the great tit, this effect was stronger during snowy and windy mornings. At dusk, we did not find any effects of the light treatment on cessation of foraging in any of the six species. We discuss the implications of our findings in the context of the ALAN impact on the evolution of behavioural timing. We also propose alternative experiments that could be used in order to test for light avoidance and light exploitation behaviours in songbirds.

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Extensive whole-body effects of experimentally applied artificial light at night on birds

Theme: Biology & Ecology

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Introduction

Since the work by Rich and Longcore (2006), evidence for advanced daily song and activity patterns of birds exposed to artificial light at night has accumulated. In our earlier studies on free-living Blackbirds (*Turdus merula*) we had used individually-based light loggers to record the light intensities encountered by birds (Dominoni et al. 2013b). This work has shown that in the wild, birds may experience artificial light at night intensities of up to on average 1.5 lux. The Blackbirds altered activity patterns in the wild and, in a subsequent study, also in captivity (Dominoni et al. 2013a). Under experimental conditions, the Blackbirds also depressed melatonin levels when exposed to equivalent light at night (Dominoni et al. 2013a).

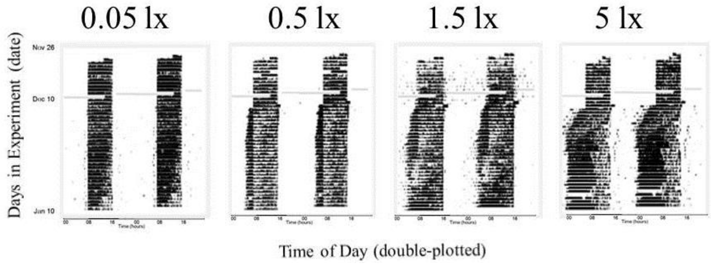

Fig 1: Activity of representative 4 individual Great Tits exposed to different levels of light at night. Data show activity (in black) for a given hour of day; each line represents a day; see De Jong et al. 2016.

Current studies

To investigate how such empirically determined light levels might affect whole-body processes of birds, we subjected male captive Great Tits (*Parus major*) to a range of nocturnal illumination intensities between 0.05 and 5 lx. A first, published study (De Jong et al. 2016) has reported dose-dependent effects of these different nocturnal illuminations (Fig. 1). The birds were altering their activity rhythm under these conditions, with a strong advance of activity onset which progressively increased with higher intensity of light at night (Fig. 1). The study also documented alterations in the birds' melatonin profiles (De Jong et al. 2016).

We then carried out a follow-up study on Great Tits to evaluate whether these light levels were sufficient to affect whole-body processes, such as rhythmic gene expression and metabolism. We quantified day-night differences in physiology of birds subjected to the light conditions shown in Figure 1 in the following ways: we measured expression of key genes in several tissues (liver, spleen, testes, brain) using RT qPCR, and we used LC/MS to derive plasma metabolomic profiles. We found strong signals of modulated day-night differences in gene expression and metabolites across the tissues we examined, and an overall down- and up-regulation at day and night in specific pathways. These pathways included, for example, stress receptors, reproductive activation and physiological systems linked to learning and memory. Metabolomic profiling in particular proved a powerful tool to identify putative pathways, which can then be studied in more detailed follow-up experiments. These strong effects were unexpected considering the low intensity of light at night, and should alert researchers and the public to the possibly extensive consequences of low levels of light at night for wild species and humans alike.

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Urban Planning Challenges: Toward integrated approaches to sustainable lightscape and soundscape planning

Theme: Society

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There are substantial similarities between the effects of artificial light and noise in the outdoor environment. Light and sound are both powerful sensory stimuli that can heavily impact the natural environment as well as human well-being, quality of life and – for noise certainly, for light very likely – health. These effects are particularly concentrated in dense urban areas: they are the epicenters of the light and noise pollution in which large portions of the population are constantly immersed. The mitigation of the negative effects of artificial light and noise is thus a matter of public concern and demands responses from policy-making and planning, all the more as natural darkness and quietness are becoming ever scarcer goods in cities.

The development of approaches that are capable of adequately addressing the issues at hand is, however, no easy task. The impact of artificial light and noise can be measured and quantified, but their perception is ambivalent because it is subjective and context-dependent, making it difficult to identify general planning guidelines which refer to and deal with both quantitative and qualitative effects of light and noise.

As a necessary part of sustainable urban development, an integrated perspective is therefore needed that steps beyond the largely technical and quantitative approaches that have thus far dominated policies and planning related to light and noise issues.

The search for alternative approaches to the issue of noise pollution has a considerably longer history than the still fairly new insight that artificial lighting is not necessarily benign. Accordingly, the debate relating to noise abatement, corresponding citizens' movements and the associated development of policies and planning tools is considerably further advanced than the search for adequate responses that address artificial lighting. The soundscape approach is of particular interest as it offers rich potential for informing the discussion related to artificial lighting: It has been developed over the past decades as a planning tool for the sonic environment in order to compensate for the dominant technical perspective: it proposes the notion of sound(scape) in extension of that one of noise(scape); it focuses on the relationship between people and the sonic environment rather than on only the sources; and it is based on both qualitative and quantitative methods of inquiry and representation.

This presentation asks which lessons could be learned from best practices in planning and policy approaches related to noise(scape) and sound(scape) issues – extending the perspective from a domination by mere technical approaches to more integrated ones – for artificial lighting – and (at least prospectively) vice versa?

To this end, the presentation will first highlight key similarities and differences between the effects of outdoor artificial lighting and noise pollution by providing a structured comparison. Against this background, it will outline an experimental methodology that is currently under development by one of the authors (Radicchi) to achieve quietness by advancing the soundscape approach, and make initial proposals regarding potentials of developing a similar approach aimed at contributing to the development of sustainable lightscapes.

Levels of Night Sky Quality in Germany

Theme: Society

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Introduction

Artificial light at night (ALAN) is disrupting the natural rhythm of brightness and darkness, causing various negative effects, e.g. on human health. However, the degree of skyglow in Germany caused by light pollution as well as the percentage of population living under these conditions have not been described in their spatial dimensions, yet.

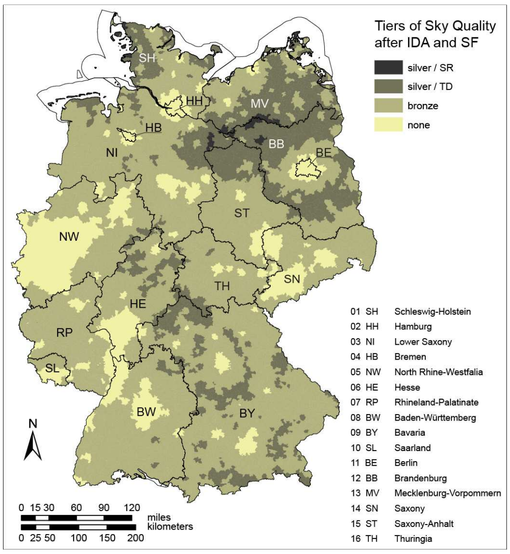

Fig 1: Tiers of Sky Quality after International Dark Sky Association (IDA) and Starlight Foundation (SF) in Germany.

Data & Methods

Data of the 'First World Atlas on the artificial night sky brightness'(1) was analyzed on national level as well as on level of federal states and on community level. The aggregated data were evaluated after thresholds stated by International Dark Sky Association (IDA) (2, 3) and by Starlight Foundation (SF) (4, 5) and combined with population data on community level for 12/2011 (6).

Results

Every single bit of the sky above Germany's territory is affected by artificial light at night. There is neither a community whose mean value provides sky conditions of 'gold' quality nor a single pixel which would fit into this category. The sky above the majority of the country's area (66.46%) provides a quality of 'bronze'. Matching areas seem to be the background, in which spots of the other classes are embedded (see Fig 1). Above 14.26% of Germany's national territory the night sky is not worth being labelled for quality, while in just less than 20% of it the sky is dark enough to see the Milky Way: individual communities providing the quality of 'silver' form a band spreading northwest to southeast. Continuous areas of 'silver' can be found in the north-eastern part of Germany. Here as well as on islands in the North Sea and in the Baltic Sea, communities fulfilling the tight requirements for Starlight Reserves can be found (0,63% of the territory).

The majority of the population (55.17%) is living under a night sky not worth being labelled for quality (see Fig 2a). In the city states of Berlin, Bremen, and Hamburg this accounts for 100% while in Brandenburg (surrounding Berlin!) only one quarter of the population is affected.

A total of 41.25% of the population is living und a sky worth being labelled as 'bronze', with a range from 17,1% (in North Rhine-Westphalia) to 70,4% (in Thuringia) (see Fig 2b). In the respective communities worth being labelled for 'silver' a portion of 3.58% of the population is living (see Fig 2c+d), but reaching a percentage of more than 20% in Brandenburg and Mecklenburg-Vorpommern.

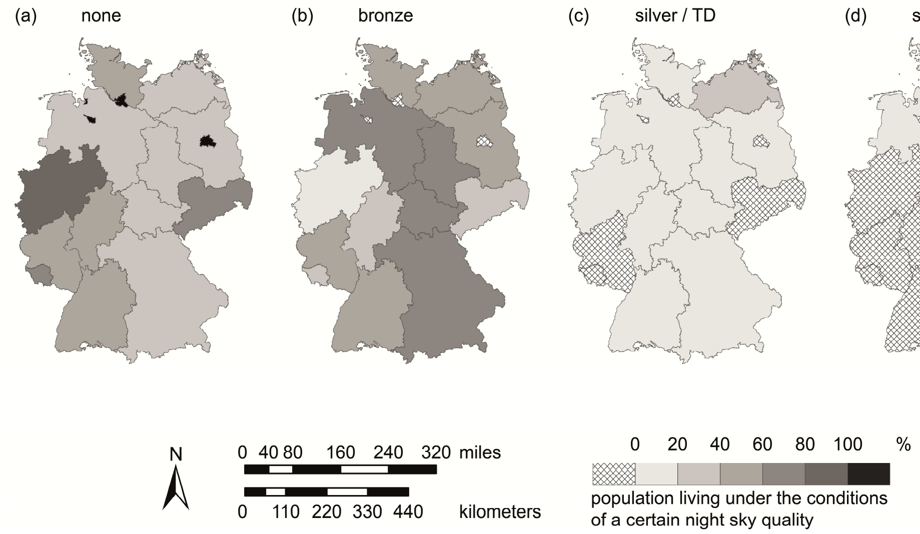

Fig 2: Percentage of population living under the conditions of a certain night sky quality
(a) quality not worth being labelled after IDA or SF;
(b) quality worth being labelled as bronze tier after IDA;
(c) quality worth being labelled as silver tier after IDA and as Tourist Destination (TD) after SF;
(d) quality worth being labelled as silver tier after IDA and as Starlight Reserve (SR) after SF.

Discussion

The sky above Germany is affected by artificial light nationwide. The assigned tiers of quality are related inversely to the population density.

96.42% of the German population is living in areas where they are not able to observe nocturnal sky phenomena such as the Milky Way as these are hidden by artificial light and sky-glow. This is not only a loss of beauty but also a loss of cultural context.

Though the quality class of 'none' comprises only a small fraction of the country's area it is inhabited by more than half of the population in Germany. This is thought-provoking as there is growing evidence that the disruption of the diurnal signal of light and dark is involved in the development of certain diseases.

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Correlated Color Temperature (CCT) of Natural and Light-polluted Sky

Measurement and Modeling

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Introduction

In the last 30 years a dominant light source in outdoor lighting worldwide has been a high pressure sodium bulb (HPS) with a warm, yellow-orange color. The CCT (Correlated Color Temperature) of the HPS bulb is around 2100K. At lighting exhibitions in last few years and also in many new lighting installations across the EU, a transition to LED lamps with a high CCT is clearly visible. It is an unwritten "law" of the lighting industry nowadays to push LED luminaires with a CCT of around 4000K. LED lamps are also not uncommon, with an even higher CCT of up to 5000K. The introduction of luminaires with high blue content will not only cause increased light pollution because of more intense scattering of blue light in the atmosphere, but it will also change the color of the night sky. Professional and casual night sky observers were lucky in the past era of HPS bulbs. Most of the HPS emissions were in a spectral region far from the most sensitive part of human's scotopic sensitivity curve.

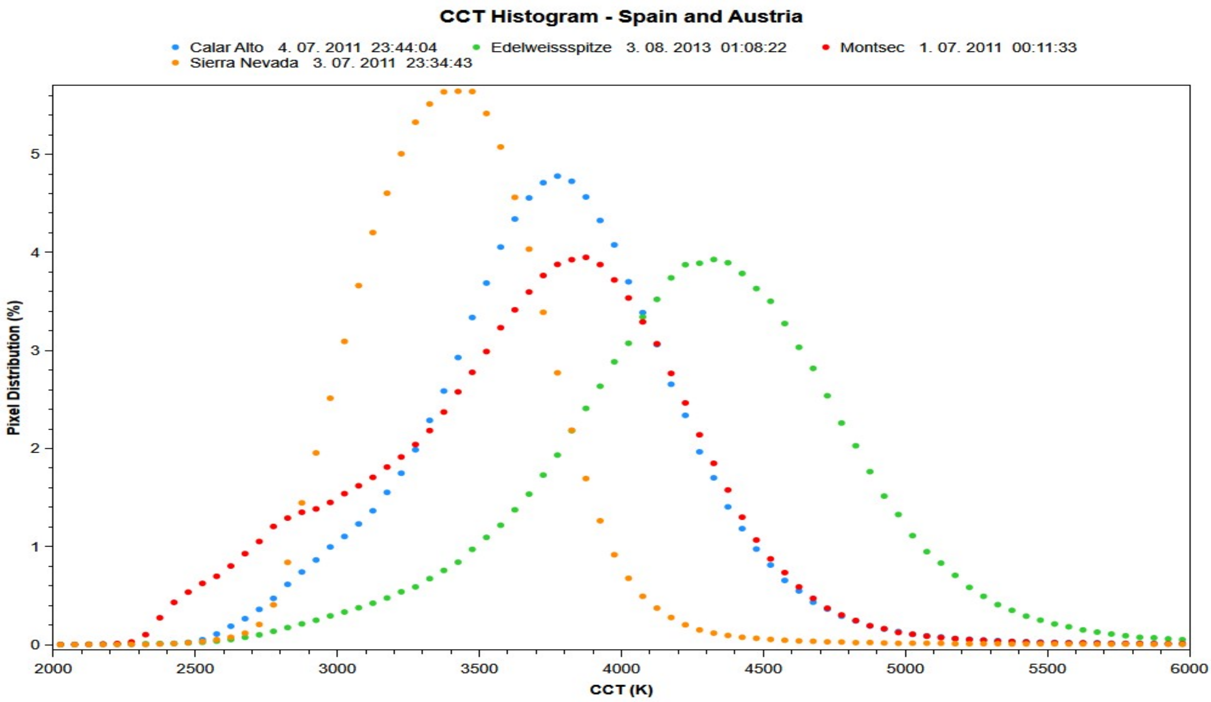

Fig 1: Histogram of CCT for the whole sky above Calar Alto, Montsec and Sierra Nevada in Spain and Edelweissspitze in Austria. Pixel distribution presents the area of sky in percentages.

Because of the transition of lighting technology from yellow–orange to white color light sources with high blue content, monitoring the CCT of night sky is more important than at any time in history. We will present the latest measurements of night sky CCT based on DSLR cameras. The night sky color temperature at several locations and different levels of light pollution will be compared and evaluated. A whole sky histogram of CCT will be introduced and proposed as a measure of the quality or degradation of the night sky.

Technical and economical assessment of the containment of light pollution through the use of luminous intensity restrictive measures

Theme: Technology & Design

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Abstract

Road lighting and outdoor lighting in general, is considered a very important public and social asset. Its existence serves a number of beneficial purposes. Visual comfort, perception of security and road safety are some of its positive impacts on the daily human activity. On the other hand, there are serious problems that come with the extensive use of street lights. Light pollution, is a visible sign of a bad lighting installation resulting in non-cost effectiveness, waste of energy and in negative consequences for the environment, including sky glow, CO2 emissions, wildlife and vegetation disturbances. It is of an outmost importance, that a balance needs to be found between the positive and the negative results of lighting in the environment.

The street lighting network in EU25 (data of the year 2005), is comprised of 56 million of luminaires according to the "Preparatory Study for Eco-design Requirements of EuPs: Public street lighting, Contract TREN/D1/40-2005/LOT9/S07.56457". The size of the network in conjunction with the outdated type of the luminaires, and their conventional high intensity discharge lamps, that is comprised of, is an indication of the energy waste and the alleged lighting pollution that it inflicts in the environment.

The European Norm EN 13201-2:2015 categorizes the street luminaires in 6 luminous intensity classes (G1 to G6) depending on their intensity in certain gamma angles, and specifically 70°, 80°, 90° and above 95°. The classes G4, G5, G6 are the most stringent, forbidding any upward light but restricting on the other hand, the intensities in lower angles. The G1 to G3 classes are more easy and luring to be achieved by the luminaire manufactures, as there are no limitations in the critical lower gamma angles and furthermore no limitations in the Upward Light Ratio (ULOR). Despite the above fact, most of the high end LED street luminaires comply with the ULOR=0% regardless of their G class classification.

An investigation was performed on whether the G-classification restrictions in LED luminaires could help the problem of sky glow to be addressed. Several indicative road and street scenarios were taken into account, in which simulations were made, to determine what would the impact of imposing further limits be in the G ratings to the environment and to the installations' efficiency. The various geometric parameters of the typical infrastructures were examined in combination with the road lighting classes of the EN 13201-1:2014 to study whether, how and how much, the overall power density is going to be affected in the typical and indicative road and street scenarios. The impact of luminaires' inclination to the light pollution was also examined.

The sky glow is connected with both the direct light leaving to the atmosphere, as much as to the indirect part reflected from the area to be lit and the surroundings. CIE has introduced two parameters that help control the spilled light. Upward Light Ratio (ULR), which is the proportion of the luminous flux emitted at and above the horizontal to the total luminous flux of the installation, with the luminaire's tilt taken into account. ULR though, does not take into account the effect of the reflected light from the illuminated surfaces, making it more a luminaire related index rather than an installation's one. LED luminaires with higher G classes had relatively the same ULR values compared to the lower G class luminaires in installation inclinations up to 15^o. The maximum ULR value didn't exceed 1.4% at 15^o in all street LED luminaires that were included in the tests.

The Upper Flux Ratio (UFR), which also takes into account the light reflected upwards from the installation was evaluated in all cases. Although most of the attention is focused on the light leaving directly to the sky, the simulations showed that in many cases ULR=0 installations, end up having more sky glow than other installations with less restrictive ULR policies, because the optics that were used were less efficient as far as the road lighting is concerned. It is very important to underline that the results showed an increase in the reflectance of the area to be lit, has a positive impact on the minimization of the sky glow as it leads to lower installed luminous flux levels.

According to the assessment that was conducted in commercially available luminaires, there is no clear indication that enforcing stricter rules in G classification, would lead to a reduction in the sky glow effect. The results showed that the more efficiently a lighting distribution is chosen, the less the spilled light will be, regardless of the G class of the optic having been used. The practice of currently available (G4-G6) optics led to higher power density in the simulations due to being less efficient in critical angles. The above fact, resulted in higher sky glow since the pole distance needed to be smaller or in some cases luminous flux to be greater for the same lighting requirements. The tilt of the luminaire, provided that is used efficiently, can help minimize the light pollution in an LED installation.

In overall, the economic impact of imposing G class restrictions in currently available LED street lighting products would be great. It would lead also to an overall increase in the spilled to the sky light making installations less efficient. There are a number of restrictive measures introduced to road lighting practice to tackle light pollution which are ULR and UFR among others. The assessment showed that the carefull planning of an installation, leads to the minimization of its light pollution as well as its energy footprint.

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Lighting of railway premises - Minimizing obtrusive lighting according to current regulations

Theme: Society

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Summary

There are more than 5000 small, medium or large passenger stations and a similar number of freight track areas in Germany usually lit during the hours of darkness. These railway areas are located in different environmental zones as classified in CIE Publication 150:2003 'Guide on the Limitations of the Effects of Obtrusive Light from Outdoor Lighting Installations', i.e. in natural, rural, suburban, or urban surroundings. Lighting requirements for the lighting of open or covered platforms as well as of freight track areas are specified in the European Standard EN 12464-2:2014 'Light and Lighting - Lighting of work places - Part 2: Outdoor work places', and in addition in regulations published by the Deutsche Bahn AG dealing with specific aspects (e.g. the lighting of platform edges, or the limitation of glare for vehicle drivers) not considered elsewhere. Depending on the illuminance levels required for safety and comfort for passengers and personal and on the reflection properties of platforms and track systems, some light will be spread into the environment. The effects are evaluated not only using the methods described in the European Standard, but also using the procedures given in the German LAI regulation 'Hinweise zur Messung, Beurteilung und Minderung von Lichtimmissionen' (2014). According to this document stricter limits apply to the light on properties and a special method for the evaluation of glare is to be used instead of limiting the luminous intensities of the potential glare sources (which is not distance dependent).

To minimize light pollution in general a number of measures are taken, in particular:

- Use of luminaires with flat glass cover in horizontal mounting position wherever possible, i.e. the upward light ratio is virtually zero; this will also reduce glare for vehicle drivers
- Reduction of illuminance levels on platforms depending on the number of passengers, reduction of illuminance levels on freight track areas depending on activities, i.e. making use of adaptive lighting systems (now possible according to the revised European Standard)
- Switching off during hours of guaranteed non-operation of trains
- Reduction of luminaire mounting height and additional shielding of luminaires to protect flora and fauna in nearby national parks or protected areas
- Avoidance of high mast lighting installations wherever possible; this reduces usually also the maintenance costs

- Use of light sources of high efficacy and of luminaires of high efficiency with suitable light intensity distributions installed in appropriate positions to provide adequate platform utilization factors (and not to light the track) and/or to limit light on properties, e.g. alongside freight track areas, and to limit the disability glare for users of nearby transport systems

- Reduction of light levels on roads leading to stations or to freight track areas as well as on parking lots dependent on traffic volume (adaptive lighting according to revised European Standard EN 13201-2:2015 ‘Road lighting - Part 2: Performance requirements)

For the pre-selection of appropriate luminaires ‘tables platform lighting’ and ‘tables railyard lighting’ have been developed which allow to consider the impact on the environment at an early design stage.

All the measures play an important role in the Deutsche Bahn AG approach to minimize light pollution, obtrusive light, and sky glow. The negligible number of complaints over recent years has proven the success of this integral approach.

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EN 13201-2:2015 ‘Road lighting - Part 2: Performance requirements’

Design and modelling of an illumination light source for a large-scale freshwater experiment at LakeLab on lake Stechlin, Germany

Theme: Technology and Design

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Introduction

Recent studies show significant evidence that light pollution (LP) can have an impact on ecosystems [1,2]. While the majority of experiments investigating the effects of LP on the environment focused on terrestrial animals [3,4], there is growing concern that aquatic life might be affected by LP as well [5]. However, only few studies in the context of aquatic systems exist [6,7]. To study its ecological impact, it is necessary to mimic LP scenarios as realistically as possible, at best in an outdoor setting, and with maximum control over several parameters. Several such experimental field sites have been developed so far, mainly with a land-based street lighting architecture investigating “direct” LP [3,4,8]. Here, we report on the design and implementation of an illumination source that aims to mimic “skyglow” (or indirect LP), at a large-scale mesocosm experiment in a freshwater lake. To our knowledge, no such light source has been developed, yet.

Experimental field site

The experimental field site is a freshwater mesocosm facility, the LakeLab, located 80 km north of Berlin, Germany. The LakeLab consists of 24 cylindrical mesocosms (Fig. 1) each with a diameter of 9 m and a depth of about 20 m installed in a freshwater lake. The test cylinders consist of swimming aluminum pontoons and insulating foil. A recent study of the night sky brightness at this site showed that LakeLab is well suited for LP studies, as the background can reach zenith brightnesses darker than 21.6 mag_{SQM}/arcsec [9].

Fig 1: View of a mesocosm of LakeLab in Lake Stechlin, Germany, Pic. by A. Jechow.

Experimental design and setup

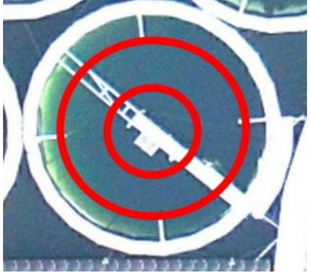
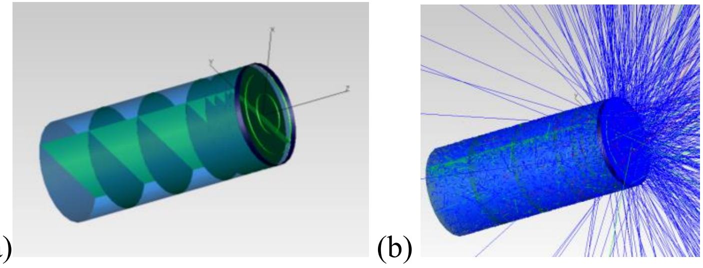


Fig 2: Top view of a mesocosm and sketch of ring shaped emitters.

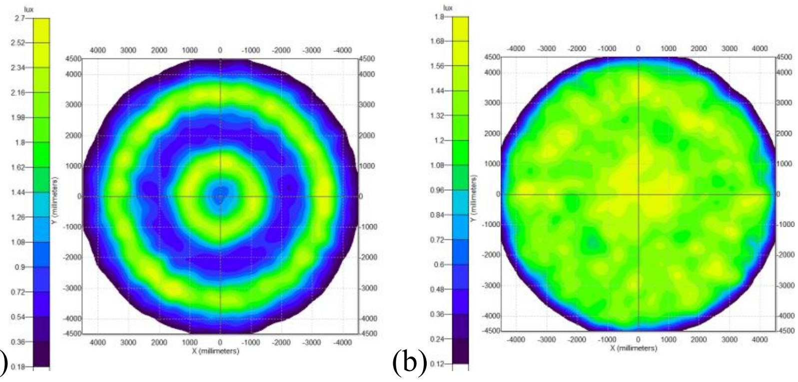
The aim of this work is to illuminate the mesocosms uniformly with a faint light source emulating skyglow. LED strips with diffusors (VarioLED NIKE SV, LEDlinear, Germany, www.ledlinear.de) with an almost Lambertian spatial emission pattern and a broadband spectrum (“warm white 2300 K”) were selected as luminaires. As the water body to be illuminated is cylindrical, a circular arrangement of the luminaires was chosen (Fig. 2). The light propagation was modeled with a commercial 3-dimensional ray-tracing software (TracePro, Lambda Research corp., USA www.lambdares.com) that includes refraction, absorption and scattering in the water body.

Wavelength resolved scattering and absorption coefficients have been measured under solar illumination, and can be implemented in the raytracing model. However, for simplicity a single wavelength approach was used; as this is sufficient to compare different luminaire arrangements with each other. Figure 3a shows the CAD model of the water body (blue cylinder) with a double ring emitter structure just above the water surface (green rings) and the detector planes (green areas). Fig. 3b shows 10 percent of the traced rays. The luminaires were defined to be 10 mm wide, and two rings with diameters of 6.75 m and 2.25 m have been modeled with a distance of 0.4 m above the water surface with the light emitted downwards. The output was set to 1W/m at a wavelength of 500 nm. Figure 4 shows the illuminance at the water surface (a) and at 1 m depth (b) in lux. While the ring structure can be seen at the surface, the pattern is almost washed out at 1 m depth due to scattering in the water and the Lambertian emission pattern of the LED strips. The design achieves a homogeneous illumination at a specific depth, with a very low amount of shading of daylight. Further modeling results, details of the mechanical construction, and surface and irradiance measurements of the prototype will be presented.



(a) (b)

Fig 3: (a) CAD model of the raytracing model, (b) raytracing including backscattering.



(a) (b)

Fig 4: Illuminance at the water surface (a) and at 1 m depth (b).

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Artificial light at night affects biomass and community composition of freshwater primary producers

Theme: Biology & Ecology

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Introduction

Artificial light at night is recognized as a contributor to environmental change at the global scale (Cinzano et al. 2001) and a biodiversity threat (Hölker et al. 2010). Increasing research efforts have demonstrated numerous adverse effects on aquatic and terrestrial animals (e.g. Moore et al. 2000, Perkin et al. 2014), microorganisms (Poulin et al. 2013, Hölker et al. 2015), and plants (Bennie et al. 2015). Aquatic primary producers, however, have rarely been studied and the impacts on benthic autotrophs are poorly understood.

Benthic autotrophs, such as diatoms, green algae and cyanobacteria, grow attached to underwater surfaces and form the basis of the food web in many streams and clear, shallow waters (Stevenson 1996). They use light both as a source of energy for photosynthesis and growth, and as an information cue for the regulation of physiological processes, especially those that display a circadian rhythm (Kianianmomeni & Hallmann 2014). Further, the major autotroph groups differ in their preferences for light conditions (Richardson et al. 1983), therefore the alteration in light regimes may cause changes in community composition.

Fig 1. Outdoor flume system fed by a pristine sub-alpine stream

We conducted experiments in two different freshwater systems: an outdoor flume system mimicking a sub-alpine stream (Bruno et al. 2016, Fig.1) and a low-land agricultural drainage ditch, the Westhavelland experimental site (Holzhauer et al. 2015, Fig.2). We simulated the night-time light conditions of a waterbody in a light-polluted area (approx. 20 lux at the water surface), and compared the biomass and community composition with those grown under natural nights. The experiments were performed in different seasons in both ecosystems in order to account for seasonal differences in community composition. Two light sources, warm-white LEDs and high-pressure sodium (HPS) lamps, were used in the experiments in the Westhavelland site while only warm-white LEDs were used in the sub-alpine stream.

Fig 2. Low-land agricultural drainage ditch

The LED-based nighttime illumination over three to six weeks resulted in a decrease of autotroph biomass in both aquatic systems. Community composition was also affected by LED, but the effect varied between the systems, seasons and developmental stage of the community. Primary producers did not respond to HPS-based illumination, likely a result of different spectral composition. Our results show that artificial light can have profound effects on the primary producers of aquatic ecosystems. By negatively affecting the biomass and altering community composition, artificial light at night may hinder primary production as a vital ecosystem function and therefore negatively impact the resilience of aquatic ecosystems. This effect is likely to increase with the current shift from sodium lights to white LED.

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Trophic effects of artificial light on plant and invertebrate populations in a five-year ecological experiment

Theme: Biology and Ecology

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Introduction

Fig 1: Night-time view of the experiment at Exeter University

Direct biological effects of artificial light at night have been recorded across a wide range of plant and animal species. However, understanding the effects on biotic interactions, such as relationships between predators and prey, or herbivores and plants has proven more difficult. We present results from a five-year mesocosm experiment designed to investigate whether artificial light at night has top-down (predation controlled) and/or bottom-up (resource controlled) impacts in grassland communities. Experimental mesocosms were illuminated at night to simulate conditions under different common forms of street lighting – both cool white light-emitting diode (LED) lighting and simulated low pressure sodium (LPS) lighting. The impacts on invertebrate herbivore abundance were dependent on the lighting technology and apparently mediated via other trophic levels, with both top-down and bottom-up effects occurring. We conclude that (i) exposure to artificial light at night can trigger trophic cascades, (ii) the nature of such impacts depends on the wavelengths emitted by the lighting technology employed, and (iii) given the increasing ubiquity of artificial light at night, these impacts may be widespread, although generally unnoticed, in the environment.

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Comparing the impacts of multiple nighttime LED lighting strategies in a grassland ecosystem

Theme: Biology and Ecology

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Introduction

White Light-Emitting Diodes (LEDs) are rapidly replacing conventional lighting technologies around the world. Despite concerns over their impact on the environment and human health, the flexibility of LEDs has been advocated as a means of mitigating the ecological impacts of outdoor night-time lighting through spectral manipulation, dimming and switching lights off during periods of low demand. These strategies have been widely adopted to cut local government expenditure in the fall out from the 2008 financial crisis, but with limited investigation of whether they have had such ecological benefits. We present results from the first three years of an ongoing field experiment (ECOLIGHT) in which the impacts of each of these lighting strategies on plants and invertebrates were compared in a previously artificial light naïve grassland ecosystem. White LEDs had profound impacts on the structure and composition of adult spider and beetle assemblages. Dimming LEDs by 50% or manipulating their spectra to reduce ecologically damaging wavelengths partially reduced the number of species affected, while a combination of dimming by 50% and switching lights off between midnight and 04:00 am showed the most promise for reducing the ecological costs of LEDs. These results suggest that some management strategies will be effective at reducing the number of taxa affected by LEDs, although averting the ecological impacts of nighttime lighting may ultimately require avoiding its use altogether.

Effects of artificial light on mammals: gain and loss of habitat, behavioural changes and cascading effects.

Theme: Biology & Ecology

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Introduction

Species have evolved on a rotating planet, with a strong modulation of light intensity: high light levels during daytime, and very low light levels during the night. The vast, ongoing increase in artificial light now thwarts this pattern on a large scale. In order to prevent biodiversity loss by limiting impact on species and species groups, it has become ever more important to know the effects of artificial light on our ecosystem. Many examples of fast responses to light have been reported, but for many – especially less conspicuous – species even direct effects are still unclear. For all species, subtle and latent effects may only be detected by long-term measurements. Knowing these is essential as lights are virtually never installed for a short period of time. Here we show consequences of artificial light on common and less common bat species, mice, and large mammals, in a large-scale study in which we experimentally illuminate natural habitat – with commonly used light levels for countryside roads – for a longer period of time.

Fig 1: Three colors of light at one of the eight experimental sites. Images by Kamiel Spoelstra / NIOO-KNAW.

At the start of the experiment, we observed an increase in activity of common bat species by light. This was related to spectrum and insect density. Now, after several years, we are able to show that sparsely distributed, forest dwelling bats respond with a clear decrease in activity. This response implies loss of foraging habitat, and is dependent on the spectral composition as well.

Since the start of the experiment, experimental light in the forest has suppressed activity of wood mice in a relatively large area underneath the light posts. A consequent assessment of murine activity under existing lights in rural areas indicates a wide-scale effect. Further measurements suggest cascading (bottom-up) effects between trophic levels.

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Intrusion of artificial light at night into leaf-litter habitats: Implications for activity in a nocturnal salamander

Theme: Biology and Ecology

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Abstract

Light pollution from artificial light at night (ALAN) is increasingly common and can intrude into habitats occupied by wildlife as a result of sky glow, glare (light directly from sources, such as streetlamps), and automobile headlights. ALAN may be disruptive to the behavior of nocturnally-active species, such as salamanders, that have evolved under naturally-dark nocturnal conditions. Many species of salamanders are fossorial or are found under the leaf litter or under cover objects during the day. Typically, they emerge above ground at night when the humidity is high and carry out behaviors associated with foraging and mating. It is unknown whether or not there is sufficient light present in the leaf litter to allow these salamanders to detect changes in light conditions from diurnal to nocturnal periods and for light pollution to impact this detection. Therefore, we carried out a series of field and laboratory experiments to determine if natural or artificial light is detectable below the leaf litter and whether a salamander, the eastern red-backed salamander (*Plethodon cinereus*), is likely to be impacted by artificial light at night.

First, we measured illuminations under the leaf litter in a forest habitat, but concluded that such measurements could not be made confidently without altering the microhabitat and light levels being measured. So, we evaluated the effect of leaf litter depth (2, 4, and 6 cm), ambient (above-litter) illuminations (10^{-3}, 10^{-1}, and 1 lx), and litter moisture content (moist, dry) on illuminations below the leaf litter in the laboratory. We hypothesized that light penetration would be limited by litter depth. We constructed a box where ambient above-litter light levels, litter moisture, and litter depth were varied, and measured illuminations below the leaf litter. Depth of leaf litter and above-litter illuminations, but not moisture content, affected the amount of visible light that passed through the litter. The illuminations below the leaf litter at 2 cm and 4 cm depths at all above-litter illuminations would be detectable by salamanders (light needed for salamander vision is approximately 10^{-4} lx). The deepest litter depth (6 cm) allowed sufficient light to enter to allow vision at higher levels (1 lx) levels of above-litter illumination. These data suggest that litter-dwelling organisms such as *P. cinereus* may be able to detect differences in light levels that trigger emergence from the leaf litter and that artificial light at night may alter the light levels below the leaf litter.

We also examined the effect of ALAN at ecologically-relevant levels on the activity of *P. cinereus*. We hypothesized that emergence times would be delayed and above-litter surface activity would be reduced with ecologically-relevant increases in ambient light at night. In a field study, we made a single-night observation of salamanders exposed to white artificial lights at night strung across 12 16-m transects (2 m wide) at 10^{-2} lx and 10^{-4} lx (dark control). We searched transects in random order using a headlamp 1-2 hr after dark. Significantly fewer salamanders were active in the lighted transects than in the unlighted transects.

To more specifically examine the impact of ALAN on the nocturnal behavior of *P. cinereus*, in a laboratory experiment we exposed salamanders to a 12L:12D photoperiod for 5 days with varying nocturnal illuminations of 10^{-3} lx (control, natural dark illumination, moonlight); 10^{-1} lx

(moderate amount of light pollution); 1 lx (substantial light pollution; dawn/dusk); or 100 lx (dim, overcast daylight) with a diurnal illumination of 100 lx in all treatments. We monitored and recorded the activity of these salamanders (time to emerge from under a cover object and time spent outside the cover object) during the night using infrared cameras. Salamanders showed delayed emergence and less time active outside cover objects with increasing nocturnal illumination and compared to the dark control. In another laboratory experiment using illuminations of 10^{-4}, 10^{-2}, and 1 lx during scotophase, and where salamanders were not given a cover object as a refuge, activity was increased with increased nocturnal illumination (a result that was predicted based on the negative phototaxis exhibited by these salamanders in past studies).

The results of these experiments provide evidence that short-term exposure to ALAN alters the nocturnal behavior of these forest salamanders. Because salamanders primarily forage above the litter on the forest floor at night under moist conditions, artificial light at night may reduce foraging time by delaying emergence due to the natural behavior of avoidance of light at night. Chronic exposure to ALAN may thus affect energy budgets by reducing time spent foraging and may impact social behaviors such as courtship and territorial behavior. Thus, ALAN may have both short and long-term impacts on nocturnally-active salamanders; although the impact of chronic exposure is currently untested.

Title: Artificial light at night affects biotic linkages between aquatic and riparian ecosystems

Theme: Biology & Ecology

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Abstract

Among the most prominent consequences of artificial light at night (ALAN) are alterations of animal behavior and movement. This can lead to large-scale changes in migratory patterns and to small-scale redistributions on the landscape (Longcore and Rich 2004, Perkin et al. 2011, Gaston et al., 2015). Many organisms move from freshwater systems to the adjacent riparian areas (Polis et al. 1997, Nakano and Murakami 2001) and constitute important trophic subsidies for consumers in recipient ecosystems (Marczak and Richardson 2007, Bartels et al. 2012). However, the natural dynamics of these subsidy fluxes are increasingly threatened by anthropogenic alterations of both aquatic and terrestrial areas (Greenwood and McIntosh 2010, Paetzold et al. 2011). The extent to which these fluxes are affected by ALAN is currently unknown. In a two-year field experiment in an agricultural drainage ditch system in Northern Germany, a previously ALAN-naïve area was illuminated with commercial streetlights, and the response of local aquatic and terrestrial arthropod communities was assessed (Holzhauer et al., 2015). We observed an increase in the number of emerging aquatic insects under ALAN, increasing the subsidy biomass for riparian consumers. The streetlights attracted both freshwater and terrestrial flying insects into the riparian area. The community composition of riparian arthropods was affected by artificial illumination resulting in a selection for specific predatory and scavenging taxa.

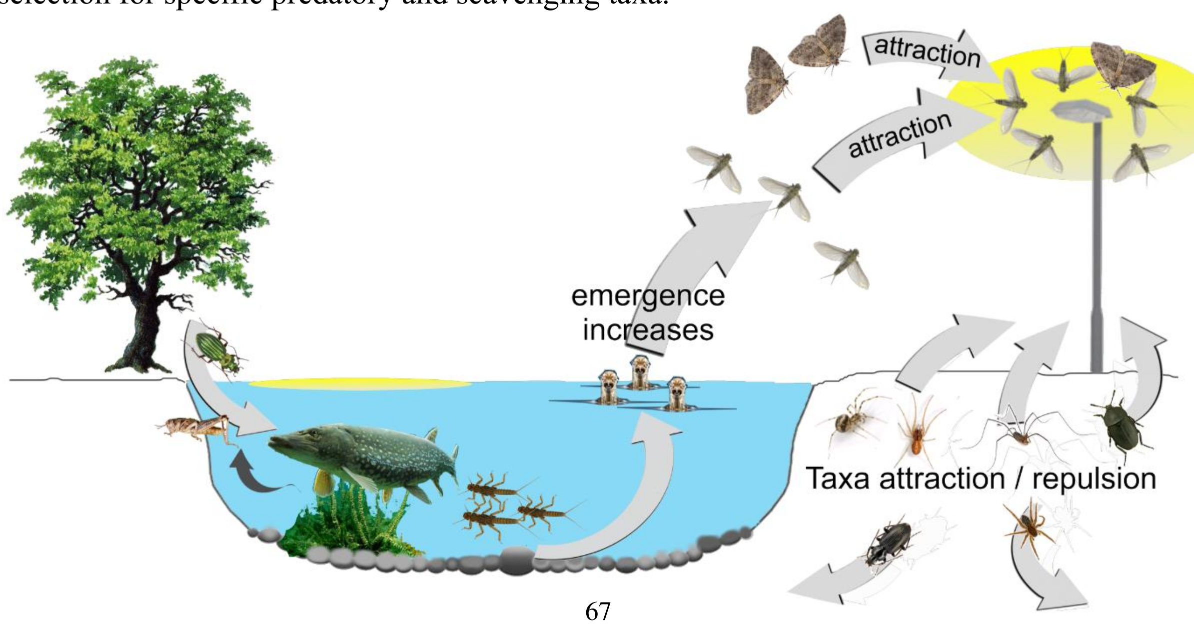

Fig. 1: A schematic representation of a coupled aquatic-riparian system under the influence of artificial light. Light increases the number of emerging aquatic insects, attracting both aquatic and terrestrial flying insects and affecting the composition of riparian predatory and scavenging communities.

These results suggest that ALAN disrupts the subsidy fluxes between aquatic and riparian zones with apparent cascading effects on the composition of terrestrial arthropod consumers. This experiment is the first to document how artificial lights in previously dark areas can promote important ecological effects across ecosystem boundaries.

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Title: Considering light pollution at different spatial scales: How can we mitigate the impacts of artificial lighting on bats in urban landscapes?

Theme: Biology & Ecology

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Abstract

Light pollution is a global change affecting a substantial part of the world and a wide range of ecosystems. As nocturnal mammals, bats are particularly sensitive to this anthropogenic disturbance. Here, we aimed at characterizing the landscape-scale impacts of light pollution on 4 common European bat species and at determining how to efficiently limit light pollution along ecological corridors to allow the persistence of light-sensitive species in human-impacted landscapes.

Using a French national-scale acoustic monitoring program (n=3996 transects), we characterized and compared the extent of impacts of light pollution, impervious surface and intensive agriculture at 4 different landscape scales. In complement, we did an *in situ* paired experiment (n=270 sites) to measure the distance of impact and the light intensity threshold of streetlights on bat activity.

The landscape-scale effects of light pollution was significantly negative for 3 of the 4 species studied, and was always stronger than the effect of impervious surface, but weaker than the effect of intensive agriculture for all species. With our experiment, we estimated that urban ecological corridors and linear elements such as trees and hedgerows should be separated from streetlights by 10 to 25 m and be illuminated by less than 1 lux to allow light-sensitive species movements in urban landscapes.

Our results highlight that in addition to urbanization and intensive agriculture, there is an urgent need to consider the impacts of light pollution on biodiversity in land-use planning. Careful outdoor lighting planning with a particular emphasis on the enhancement of dark corridors will be crucial in the next decade, especially if considering the ongoing changes in lighting management and technologies occurring worldwide.

Dim light at night reduces cricket immune function

Theme: Biology and Ecology

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Life on earth evolved under a reliable daily cycle of light and dark, such that many, if not all, behavioural patterns and physiological processes are highly influenced by this circadian rhythm. The presence of artificial light at night (ALAN) has altered this cycle in many environments, and the biological impacts include changes in behaviour as well as changes to individual physiology [1, 2]. One potential explanation for these physiological disruptions in particular, is that exposure to ALAN inhibits the production of melatonin, a key regulator of circadian rhythm and a powerful antioxidant [3]. Melatonin is found in all known taxonomic groups and is highly conserved between vertebrates and invertebrates. It also plays an important role in many pathways of the immune response across taxa [4]. Despite the recent surge in research, few studies have explored the effects on invertebrates. This is surprising given their importance in ecosystems, particularly as a food source for higher trophic levels. Second, a large majority of the studies are correlational, not experimental.

Figure 1: Teleogryllus commodus

This study examined the effects of ecologically relevant levels of light at night on circulating melatonin concentration, and three key indicators of immune function, using a model invertebrate species, the Australian black field cricket, *Teleogryllus commodus* (Figure 1). Cricket eggs (n=1400) were sourced from a 12 hr dark: 12 hr light laboratory adapted population, and reared in either a 12hr light: 12hr dark environment (0 lux treatment) or in one of three ALAN treatments of 1, 10 or 100 lux during the night. Immune function and melatonin concentration were assessed in individual adult crickets (n = 274) through the analysis of haemolymph at 3, 17 and 31 (±1) days post adult eclosion. I found that ALAN as low as 1 lux had a negative impact on immune function. These levels of ALAN are present in and around many urban and peri-urban areas suggesting that the ecological impacts are likely to be large and widespread. Further research is necessary to verify the mechanisms behind the observed effects on immune function and to solidify the links between ALAN, melatonin and individual fitness.

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The effects of light pollution on stress, energy expenditure and personality in free living songbirds: results from an experimental illumination of forest edges

Theme: Biology and Ecology

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Abstract

It is increasingly recognized that artificial lights impact ecosystems and the species that live within them. However, two major limitations in our current knowledge limit our understanding of such impacts. First, evidence so far comes mostly from correlation studies, whereas experiments that manipulate light at night in the wild are still rare (but see [1,2]). Second, the mechanisms that underlie altered behavioural responses to light at night are still elusive.

One of the most studies species in the context of light pollution and wildlife is the songbird Great tit (*Parus major*) (Fig. 1). Great tits sing and breed earlier under light pollution[3,4], as well as showing higher activity rates and more restlessness during the night compared to birds breeding in dark territories [5]. In addition, recent evidence also suggests that both males and females breeding in light polluted territories show higher baseline levels of the avian stress hormone corticosterone [6], which suggests that although effects of reproductive success and survival can be small or absent [4], birds could still show poorer health status when breeding under light pollution.

Fig 1: The Great tit

We wanted to expand on this evidence by assessing both short and long-term physiological costs of light pollution. Specifically, we are currently running an experiment aimed at examining the effects of light pollution on energy expenditure and oxidative stress in great tits, to then link such physiological responses to personality traits. As nocturnal illumination has been shown to effect organismal function due to disrupted sleep [7] and increased workload [5], this in turn could result in higher daily energy expenditure (DEE) and oxidative stress. According to the pace-of-life syndrome (POLS)[8], a higher DEE is hypothesised to be linked to more active, bold, aggressive, and fast exploration behaviour, whereas a lower DEE is predicted to correlate with less active, shy, unaggressive, and slow exploreration [9]. Thus, if light pollution affects activity rates and energy turnover, then we would expect to find a correlation between exposure to light at night and different behavioural syndromes. These experiments are conducted at the Light on Nature experimental facilities (Fig. 2), which provides us with the ability to tease apart the effects of light at night versus other environmental factors[10].

Fig 1: Experimental illumination of forest edges: the Light on Nature project (www.lichtopnatuur.org)

We are measuring DEE using an innovative extension of the classic doubly labelled water (DLW). Birds will be injected with DLW in the abdominal cavity. Instead of relying on blood samples to measure the decay in hydrogen and oxygen isotopes over time, we will obtain these

measurements via laser spectrometry using birds' breath, via a mask directly applied to the beak of the birds [11].

In our contribution we will report on the results of this most recent experiment which will end in June. We believe that these data will be of extreme interest for both ecologists and physiologists interested in studying the effects of light pollution on wild animals but also on humans and model organisms. Indeed, not only birds but humans too are known to be sleep-deprived under bright lights, and sleep deprivation is a considerable health issue developed countries. However, the metabolic costs of higher energy expenditure and poor sleep are relatively poorly understood, at least in wild animal populations. In addition, changes in metabolism and sleep patterns are known to affect personality and cognitive function in humans and model species, but we still understand very little about the potential effects of light pollution on cognitive functions. As urbanisation and associated light pollution are increasing worldwide, to understand the cognitive implications of changes in metabolism that underlie life under bright lights is still a considerable research goal.

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Artificial light at night desynchronises strictly seasonal reproduction in a wild mammal

Theme: Biology & Ecology

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Introduction

Change in day length is an important cue for reproductive activation in seasonally breeding animals to ensure that the timing of greatest maternal investment (e.g. lactation in mammals) coincides with favorable environmental conditions (e.g. peak productivity). However, artificial light at night has the potential to interfere with the perception of such natural cues.

Following a five-year study on two populations of wild marsupial mammals (Fig.1) exposed to different nighttime levels of anthropogenic light, we show that light pollution in an urban environment masks seasonal changes in ambient light cues, suppressing melatonin levels and delaying births in the tammar wallaby. These results highlight a previously unappreciated relationship linking artificial light at night with induced changes in reproductive physiology, and the potential for larger-scale impacts at the population level.

Fig 1: The strictly seasonal breeding tammar wallaby (*Macropus eugenii*) has its reproduction delayed by artificial light at night masking natural light cues.
Image by Kylie Robert

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Title: The LED outdoor lighting revolution : Opportunities, threats and mitigation

Theme: Measurements and Modeling

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Introduction

The presence of artificial light at night (ALAN) in environment is now known to have non negligible consequences on fauna, flora and human health. A real revolution is undergoing in the outdoor lighting industry threatens the night integrity. This revolution is driven by the advent of the cost-effective Light-Emitting Diode (LED) technology into the outdoor lighting industry. The LEDs provides many opportunities: they are long lasting, easily controlled, and generally allow a more efficient photometric design which, in term, may result in energy savings.

After explaining the complex and non-linear behaviour of the propagation of the ALAN into the nocturnal environment, we will outline the potential impact of the ALAN on the human health and we will introduce some dedicated indicators for its evaluation. We willl focus on the role of the blue content of the ALAN in the evaluation of its impact. More specifically we will show how white LED technology, that often shows increased blue light content, compares to the traditional High Pressure Sodium technology. Finally, we will identify the possible mitigations to restrict the adverse impacts of the white LEDs in the urban and rural environment.

Title: Transcontinental Australia, Dark Sky Quality Survey: Perth to Brisbane, one road, 5500km, 9 days

Theme: Remote sensing urban and pristine areas

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Introduction

Efforts to roll back excessive artificial light at night in urban and industrial areas suffers from a lack of baseline data against which light reduction strategies can be measured. Similarly the loss of the dark sky though increasing development is not routinely quantified nor documented. The illumination of the sky over well-established urban areas has become the norm for residents while development of industrial facilities in remote or pristine areas rarely recognizes the conservation value of the dark sky. In this study we present the results from a transcontinental Dark Sky Quality monitoring transect that was conducted in May 2016. Using a Sky42 whole of sky CCD camera (Pendoley et al 2015), a Sky Quality Camera and software (Mohar, 2015) and a logging Sky Quality Meter (SQM) the quality of the night sky was recorded at ~600km intervals along a 5,500km transect extending from Perth in Western Australia via Uluru in Central Australia, Alice Springs in the Northern Territory, Mt Isa in western Queensland and ending in Brisbane in eastern Queensland. The transect encompasses two major Australian cities (pop. > 2,000,000) three large regional centers (pop. 20,000 – 30,000) three small country towns (pop. 1,000 – 7,000) and two desert roadhouses (pop. 10 - 20), with population densities ranging from 0.0025 – 1790 people/km^2. The location of the ground based cameras will be photographed from 450 feet above ground, using a DJI Inspire Pro 1 quadcopter, to provide some local context for light sources and types. The transect crosses some of the most remote and pristine desert areas on earth.

The results will comprise the first Australian trans-Continental baseline Dark Sky Quality dataset. The objectives of the study were;

- Collect baseline Dark Sky Quality data for Australia
- Compare the quantified output of the Sky42 and SQC instruments
- Compare Sky42, SQC and logging SQM output
- Use the ground based Sky42 and SQC output to calibrate/validate VIIRs data from the same time and place
- Investigate the feasibility of using the quadcopter images shot at 450 feet to calibrate/validate the VIIRS data.

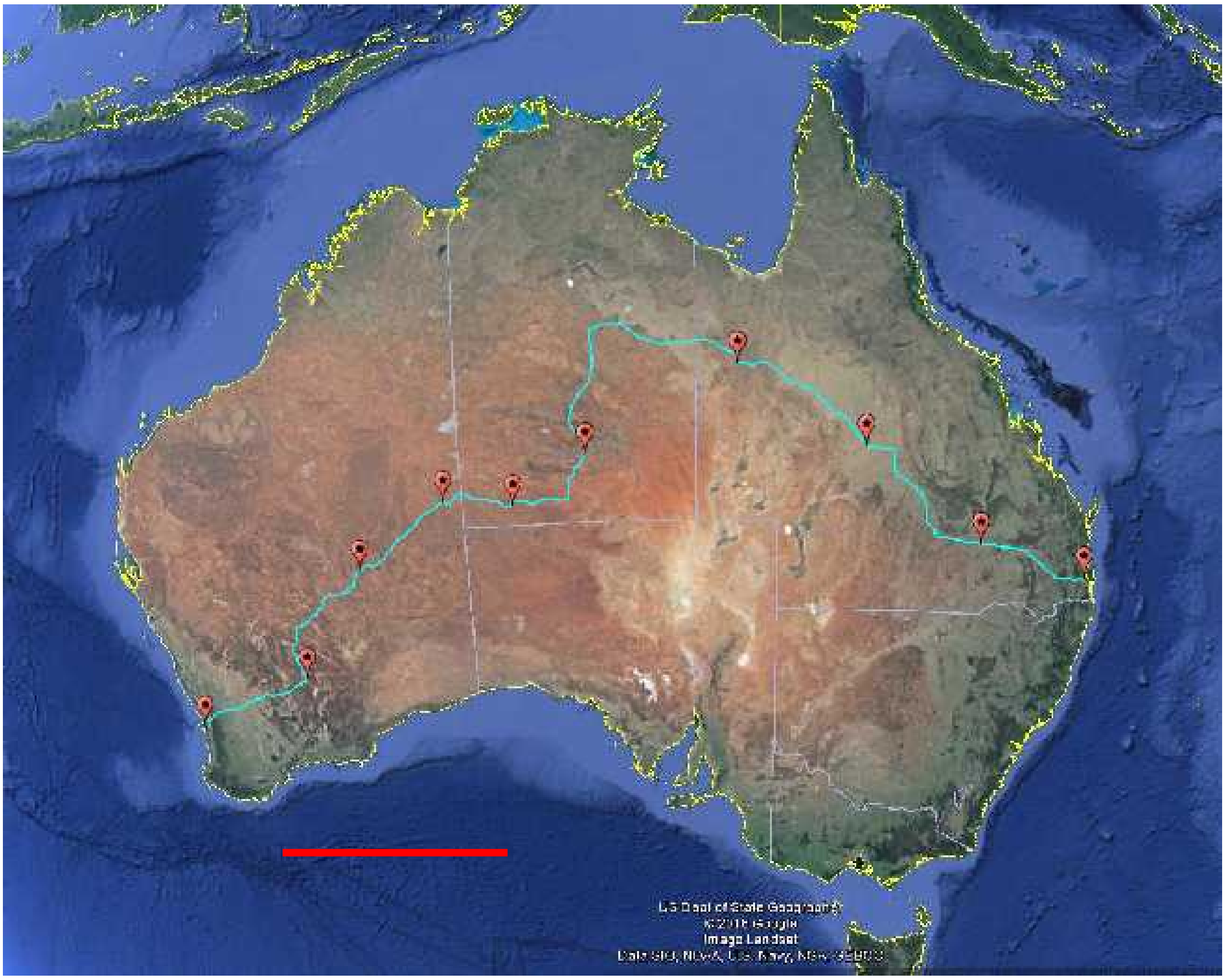

Figure 1: Route taken during the May 2016 Australian Trans-Continental Dark Sky Quality transect, Red scale line = 1000km.

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Title: How clouds are amplifying (or not) the effects of ALAN

Theme: Measurement & Modeling

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Introduction

Light Pollution (LP) is any effect generated by artificial light at night (ALAN). Normally Light Pollution is associated with astronomy, but there are many other effects in natural environment, health or power consumption. One of the most common features of LP is the emission of light to the sky, generating skyglow.

The evaluation of LP can be done measuring the night sky brightness (NSB) using ground-based instruments as telescopes with cameras or stand-alone devices for this purpose. The light emitted or reflected up to the sky can interact with clouds or fog changing dramatically the NSB (see for example Kyba et al 2011, Kyba et al 2015). So the evaluation of NSB can be clearly affected by presence or absence of clouds. This effect is completely different depending of the nature of the site: dark site or urban polluted site.

Sky brightness and clouds data

The determination of the sky brightness has been done using Sky Quality Meter (SQM) devices of the Catalan Light Pollution Network (XCLCat). This new network is a pilot plan of Parc Astronòmic Montsec in cooperation with the Government of Catalonia to evaluate NSB around the region (Ribas 2015). One of the difficulties of compare NSB data with clouds is the quality of clouds data, sometimes only synoptic information has been used (Kyba et al 2011) and not direct measurements of clouds properties. XCLCat have some stations that are installed in areas used for environmental studies. This is the case of Montsec Starlight protected area or the city of Barcelona. Both places have installed a ceilometer, an IR laser device that provides real time information of clouds and aerosols, so we have combined SQM data with ceilometer data in really different situations of ALAN: dark and urban places.

Dark places vs Bright places

The study of combined data in Barcelona city center is showing how the clouds are amplifying the effect of ALAN. In the case of Barcelona, as seen in Figure 1 and Table 1, NSB could be six times brighter (more than 2 mag) with clouds in comparison of a clear (no clouds) night. Also the ceilometer data provide us, for the first time, the comparison of the effect of different kinds of clouds, so low clouds are clearly leading to the biggest increase of the effect of ALAN and high clouds are generating a tiny effect on the measurement of NSB (see Table 1).

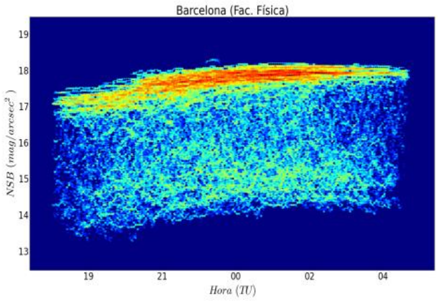

Fig 1: Distribution of NSB measurements in Barcelona urban area in moonless nights. Clearly the measurements that are out of the main density structure, due to clouds or fog, are moving to brightest values.

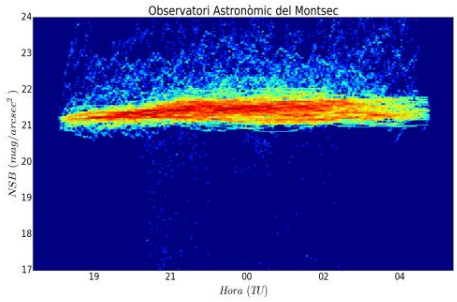

Fig 2: Distribution of NSB measurements in Montsec (OAdM) protected area in moonless nights. Clearly the measurements that are out of the main density structure, due to clouds or fog, are moving to darkest values.

Table 1. Mean values of NSB in different clouds situations

Sample	**NSB in Barcelona ($mag/arcsec^2$)**	**NSB in OAdM-Montsec ($mag/arcsec^2$)**
Total	16.79	21.47
Without Clouds	17.71	21.44
With Clouds	15.79	21.50
Low clouds	15.53	21.82
Medium clouds	16.07	21.50
High Clouds	16.81	21.29

In this study the evaluation has been done for first time in a natural protected area as Montsec mountain range. In this place clouds are not amplifying the effect of ALAN. The effect is just in the opposite direction because clouds can block natural sources and NSB can be reduced to extremely dark values (see Figure 2 and Table 1). This effect is especially important in the Observatori Astronòmic del Montsec (OAdM) site in the top of the mountain, without no lights in the surrounding, where the NSB values can increase up to 24 $mag/arcsec^2$ with low clouds on the night sky (see Fig. 2).

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The ethics of artificial nighttime lighting:
Creating a taxonomy of *darkness* as a moral value

Theme: Society

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This paper will examine artificial lighting at night from a philosophical perspective, analyzing *darkness* as a moral value. Specifically, a classification – or taxonomy – of how darkness manifests as a moral value will be presented, helping to clarify and evaluate moral and political decision-making related to nighttime lighting. This investigation will be situated within the broader field of moral philosophy, but draw mainly from two sub-disciplines of applied ethics: environmental ethics and the ethics of technology.

Towards the goal of creating a taxonomy of darkness as a moral value, this paper will discuss three interrelated issues. First, a definition for *moral values* will be provided, specifically in relation to environmental ethics. Second, the definition of a moral value will be applied to the language and framing of issues within artificial nighttime lighting. Namely, this will be a brief elucidation of darkness as a moral value, including whether *darkness* and *night* should be synonymous, and if darkness implies *natural* darkness. Third, contemporary manifestations of the value of darkness will be discussed. In particular, there will be a focus on the delineation between darkness as an *intrinsic value* (valuable for its own sake), darkness as an *extrinsic value* (its value lies in the relation to some other value), and darkness as a fundamental right. The intrinsic valuation of darkness will be explored in relation to environmental ethics, which argues that nature is something valuable in itself outside of human ends (O'Neill, Holland, & Light 2008). The extrinsic valuation will focus on the instrumental usefulness of darkness for achieving other ends, such as health, happiness, sustainability, and stellar visibility (e.g. Gallaway, 2014; Gallaway, Olsen, & Mitchell, 2010). These two types of valuation will be compared to arguments that we have a fundamental obligation to protect and preserve darkness, and that access to dark nights is a fundamental right (e.g., Starlight Initiative, 2007). For such positions, the idea of duty is more pronounced than an appeal to values. Although there is significant overlap between these three approaches, their different starting points and goals (both stated and implicit) will be the focus. Clarifying the moral foundations and goals of each formulation will allow for a comparison of potential strengths, weaknesses, and ambiguities.

This analysis will help to a fill literature gap existing within discourse on artificial nighttime lighting, as well as within applied ethics. Issues related to artificial nighttime lighting have received increasing attention in a variety of disciplines, as evidenced by the success of the *ALAN* conference series and recent publications (e.g., Meier, Hasenöhrl, Krause, & Pottharst, 2014). However, relevant branches of applied ethics have been too quite on this pressing issue, specifically environmental ethics and the ethics of technology. The issue of nighttime lighting has appeared within the pages of journals on environmental philosophy (e.g., Henderson, 2010), and book's such as Bogard's *The End of Night* (2013) explore the loss of natural nights with a notably philosophical tone. However, a systematic investigation of artificial nighttime lighting within environmental ethics is still lacking. Likewise, no comprehensive examination exists within the ethics of technology, despite the explicit attention on the moral dimensions of technologies (e.g., Epting, 2016; van den Hoven, Vermaas, & van de Poel, 2015; Verbeek, 2011), and the attention given to nighttime lighting within the related field of the history of technology (e.g., Bowers, 1998; Nye, 1990). Applying these theoretical findings will strengthen discourse on artificial nighttime lighting, and vice versa.

In addition to addressing a literature gap, this paper will also contribute to the broadly construed idea of an ethics of artificial nighttime lighting. Such an endeavor requires that we examine the values informing our normative judgments – values supporting evaluations of lighting as good or bad, right or wrong. A review of relevant literature and recent advocacy work shows that the desire for, and appreciation of, darkness is a particularly salient notion. Thus, clarifying and classifying darkness as a value, and more importantly as a *moral* value – something guiding and informing our evaluations of good or bad artificial nighttime lighting – is the main contribution of this paper.

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Title: The Loss of the Night Network (LoNNe)
Theme: All

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What is a COST Action?

COST (Cooperation of Science and Technology, www.cost.eu) aims to enable breakthrough scientific developments with the aim to strengthening Europe's research and innovation capacities. It is the oldest and widest European intergovernmental framework for transnational cooperation in science and technology. For 40 years COST supported networking across all its member countries, financing COST Actions, which allow within four years duration European researchers to jointly develop their own ideas in any science and technology field. COST is funding networking instruments for researchers, engineers and scholars such as workshops, conferences, training schools, short-term scientific missions (STSMs), and dissemination activities. The cooperation was until recently supported by the EU RTD Framework Programme, European Science Foundation, and the Council of the European Union, and is now under the EU Framework Programme Horizon 2020.

The Loss of the Night Network (LoNNe) COST Action ES 1204, 2012-2016

Europe has been in a very dynamic phase regarding policies for technical research and development. The European Ecodesign Directive sets out a framework to phase out particularly energy-intensive lighting products, e.g. high-pressure mercury lamps by 2015. The framework triggers extremely rapid growth in the development and use of new lighting technologies, such as energy-efficient LEDs. A continuous drop in the cost of lighting services will be expected, but with possibly higher energy consumption due to rebound effects and a wider loss of natural nightscapes. LoNNe was granted in 2012 (Hölker et al. 2013), in order to transfer knowledge and to address the most alarming problems with light pollution on the natural environment, biodiversity, ecosystems, human health and society.
In 2011, 10 researchers representing 9 research disciplines and 8 countries initiated the Action. Today, LoNNe has grown to a consortium with 67 active members of 14 different disciplines and representing 18 member states. The interdisciplinary cooperation is organized in four working groups (WG):

WG1: Creating a platform and appropriate sub-networks concerning the significance of AL

This working group aims at enhanced collaboration of researchers involved in the quantification and modelling of artificial lighting. The group organized a unique, international network of light meters and international measurement campaigns, the so called Intercomparison Campains (IC). The international collaboration let to new light pollution models (Kyba et al. 2015 a and b). Fragmented knowledge is getting connected, efficiency of calibration equipment identified, and novel methods and devices established.

WG 2: Assembling existing data concerning artificial lighting and light pollution

The second working group establishes a common catalogue for light pollution and artificial lighting data using analysis tools of existing databases. Selected publications on the biological impacts of ALAN: from molecules to communities were collected in a special issue (Gaston et al. 2015). The working group is elaborating literature reviews on the impact of ALAN on the circadian system, which is linked to significant adverse consequences on sleep performance and health and on the disruption of ecosystems

WG 3: Quantifying the economic value of nights with near-natural light conditions

The third working group investigates the question how dark sky tourism with its potential benefits for the (local) economy can be sustainably combined with environmental protection, including that of the night. The group identifies and negotiates conditions to be successful for the protection of nights with near-natural light. Policies that affect future options for lighting are adopted, as well as political and public support demonstrated. Proposals on effective management plans, lighting policies and regulations are developed for the preservation of natural light regimes in protected areas (http://www.cost-lonne.eu/about).

WG 4: Dissemination of research results to raise awareness of the consequences of LP

Centre point for the dissemination of the networks' activities is the website (http://www.cost-lonne.eu/). The fourth working group raises awareness about the consequences of light pollution, initiates ideas on new concepts of eco-friendly lighting and on the implementations in municipalities and communities. Inter alia, the group has conducted a training school for lighting engineers and designers, and represented LoNNe at various events, for example at the Closing Ceremony of the International Year of the Light in Merida, Mexico or at the 9th International Conference Improving Energy Efficiency in Commercial Buildings and Smart Communities (IEECB&SC) at Light and Building 2016 in Frankfurt, Germany.

Future research and activities

The network has established a fundamental basis for research and development in the field of light pollution. 18 short term scientific missions were conducted to strengthen the network, which will be of benefit especially to young researchers far beyond the funding period of the Action. An interdisciplinary, Europe wide consortium is created for the development of environmental responsible, energy and resources efficient lighting solutions. In 2012 LoNNe became partner in the new EU H2020 funded CAPS (Collective Awareness Platforms for Sustainability and Social Innovation) project STARS4ALL (2012-16). The LoNNe Action will join forces with information and communication technology experts to create self-sustainable light pollution initiatives and actions. A platform will be offered for citizen actions in order to increase the awareness of the manifold environmental problems of light pollution. The actions and initiatives aim at citizens to allow a greater input on democratic processes regarding public lighting and associated policies.

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Title: Comparative Analysis of Artificial Lighting for the Facades of Byzantine Temples in Greece

Theme: Technology and Design

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Abstract

Spaces for worship consist of a special building category. The intense emotional load of the users, their age long life span, the particularity of their architecture and their subsistence as monuments, all compose of an ensemble with special challenges concerning lighting design. The external lighting of this building category ought to respect and to promote all of the above, to create semiotic references, to follow advances in lighting technology and to adapt to nature in terms of light pollution and energy savings. Through different historical sources we have arrived at the conclusion that Greeks from the antiquity until today used to take into account external lighting for several functional (and sometimes not) aspects of their temples.

For Greeks the Byzantine period consists of an integral part of their history and as a result Byzantine monuments retain a distinct place in their collective conscience. Our work attempts to tackle a comparative analysis for existing artificial lighting of the facades of Byzantine Temples in Greece. This comparative analysis will focus on specific characteristics that include:

- The promotion of the buildings as monuments: the use of artificial lighting to signify or not the Temple as a monument.
- The respect and enhancement of their religious character: how the lighting design scheme promotes or denoted the religious character of the building in terms of the emotions that it conveys to its users.
- The connection of the lit façade with the immediate environment: how the artificial lighting takes into account the surroundings of the Temple.
- The energy consumption: the amount of luminaires used and their technology, in comparison to the effect that the designer wanted.
- The avoidance of light pollution: the position and targeting of the lighting sources, as well as their color temperature.
- The effects that the lighting scheme has on the users: acceptance or rejection of the scheme from the public.
- The usage of external lighting depending on the service that takes place inside the temple

The findings of the comparative analysis will be used and documented to propose a new lighting design scheme for a Byzantine Temple of the 11th century A.D. that has been restored

recently. The proposal will include lighting and energy simulations and will finally be compared to the temples that were firstly analyzed.

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Title: A Lamp Spectral Power Distribution Web Access Database for research applications

Theme: Technology and Design or Society

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The effect of lighting on biological processes is highly linked to its spectral content. For this reason, the study of the impact of light on the environment and on the human health must consider the spectral characteristics of the light, not only the total light power.

In order to provide independent information about the spectral characteristics of commercial light bulbs or luminaries products, we implemented an extensive Lamp Spectral Power Distribution Database (LSPDD). The database is available online (www.lspdd.org) under Creative Commons BY-NC-ND license. It is intended to provide information for both to the scientific community and the general public. This data set aims to facilitate studies of the health and environmental effects of artificial light. In the database, each lamp has its associated datasheet providing lamp characteristics, like the Spectral Power Distribution (SPD) data, the Correlated Color Temperature, the percentage of blue light and the Spectral Impact Indices introduced in Aube and al (2013) to name only a few.

Along with lamp spectra, the database contains Biological Sensitivity Curves (e.g. Photopic and Scotopic, Melatonin Suppression), CIE Standards Illuminant curves and mid-latitude ambient SPD from civil twilight to noon during a typical sunny day. Figure 1 shows one example of SPD extracted from the database (a 2500K white LED and a Melatonin Suppression Action Spectrum), while figure 2 shows a screen capture of the web interface.

During this talk, we will present an overview of the newly designed web interface and related tools. We will also discuss correlations found between the CCT, the % of blue and the Spectral Impact Indices for a variety of lamp technologies.

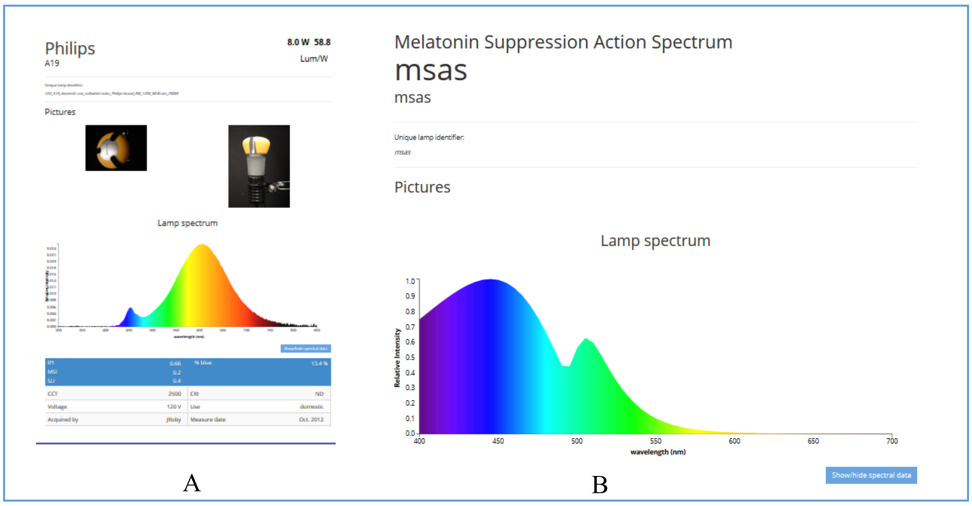

Figure 1. Example of Spectrum Power Distribution extracted from the database a. **A** 2500K white LED and **B**. A Melatonin Suppression Action Spectrum (www.lspdd.com).

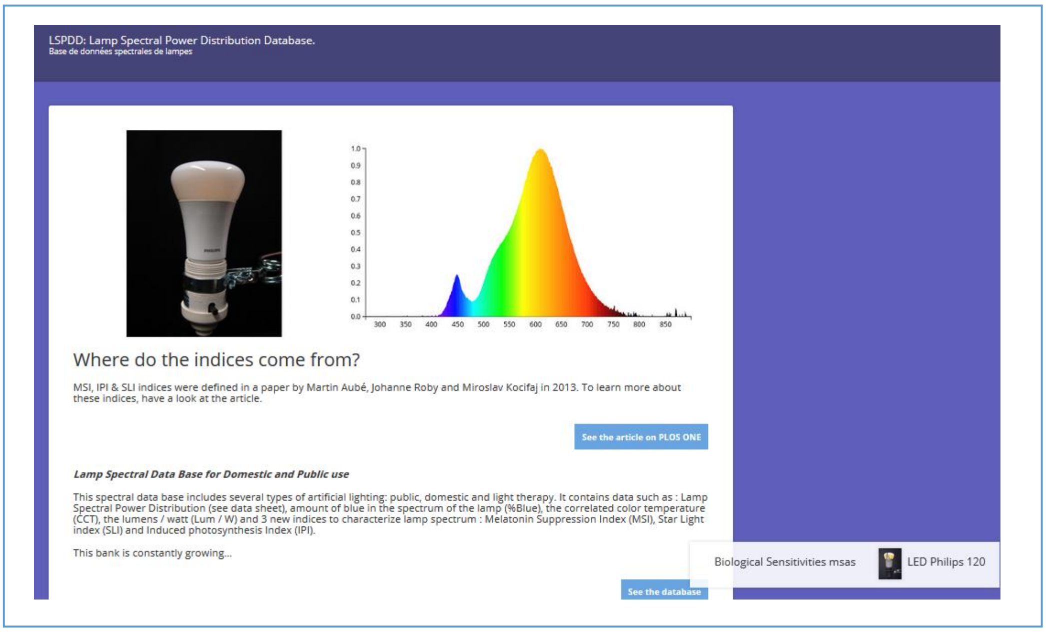

Figure 2. Screen capture of the LSPDD web interface (www.lspdd.com).

Public Lighting: The paradigm Change

Theme: Technology & Design

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Introduction

The light pollution is in direct connection with public lighting, and any improving of the ALAN will be constrained by the regulations. Even EN12301/2015 represent a small progress in the field of reducing of the light pollution. During the audit of public lighting system (for Iaşi City), the author discovered some interesting data, based on measurements of the existing situation. Based on this, a proposal will be available for an important ALAN reduction.

Methodology

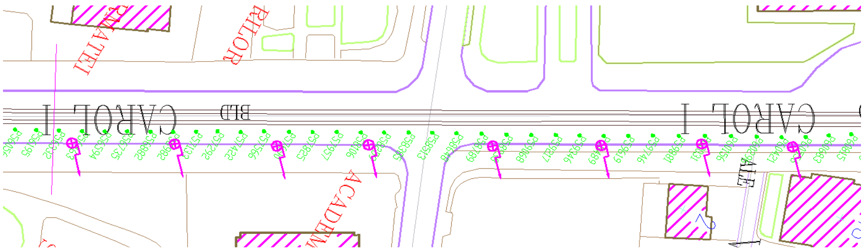

Fig 1: Localization of measurements points for illuminance

In order to realize an extended diagnose of the existing lighting systems, a series of measurements of illuminance was done. Using the recommendation from EN12301, it was used an embedded system, installed in a moving vehicle, with the possibility to link the position of the photometric head with global positioning system (GPS). This was a progress comparing with the previous measurements of the author's, when the values required post-processing for geographical identification.

For the beginning, the purpose of the measurements was to realize a maintenance program, even predictive maintenance. In figure 1 on can observe the poles and the measurement points positions, and in figure 2 we have the results of measurements for illuminance.

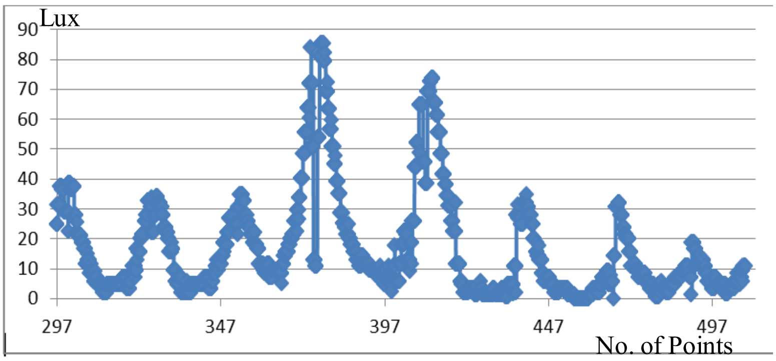

Fig 2: Illuminance values in the street

Some multiannual analyses will be possible, but for the moment, after a fast global view, the average illumination was subject of the main question: are the lighting classes right set for the main streets? For the beginning, an hierarchy of the streets was recognized, but this was the only criterion for lighting classes setting (in the designing phase).

Supplementary Investigation

In Iaşi City some works are developed to implement a general traffic management system. A wide network of sensors are in function, generating information about traffic flow. This data was studied, starting with the most circulated boulevards (figure 3):

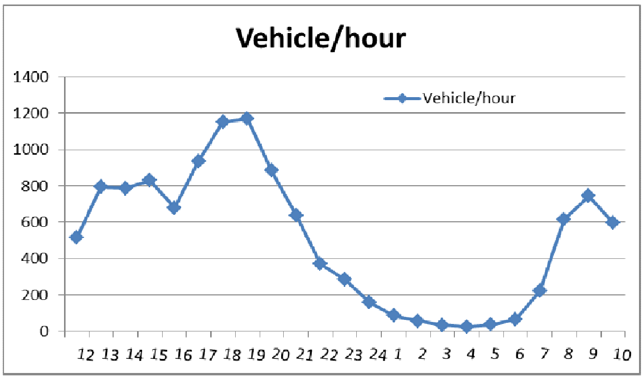

Fig 3: The traffic flow on Bd. Nicolina on 02.02.2016

Analyzing the average traffic intensity, on observe that the total number of cars/day is very different by the number of vehicles circulating in the night (it depends by the street also, but could be 400%). For example in figure 3, Bd. Nicolina, from a total of 11695 vehicles/day, on obtain only a number of 3480 vehicles/night. In any case, this number is very different from 7000 vehicles/day, which is the first threshold for lighting classes B1 or B2. Most interesting was the observation that we have no correlation between the total number of vehicles/day and vehicles per night (could be influenced by the transient street or residential / commercial area).

Results

The main finding was the fact that lighting classes for the boulevards in Iaşi City are overestimated. The question will be to demonstrate that the difference is about one or even two classes of lighting (usual, M3 instead of M5). Translating in electrical power, and off course in total luminous flux, the economy could be even 50%, when we will replace M5 with M3. The intersection density will be also considered, with the observation (not mentioned in EN 12301), that is a huge difference between regulated intersection (with traffic lights) and non-regulated ones, by the point of view of safety. The pedestrian crossing with streets lights change also the visibility exigencies imposed by the drivers visibility, making possible to obtain a safer situation at lower light level (when the traffic lights will be more visible).

Another changing in paradigm of street lighting is the fact that the footway could keep a highest level of lighting (for promenade areas), prior to the street (in contrast to the present situation, when the footway are illuminated just with the peripheral luminous flux of the street luminaires).

The final conclusion consist in the evaluation (for Iaşi City) of the energy savings due the proposal of LED modernization, but with an important supplementary saving due the luminous flux reduction, due the reconsideration of lighting classes (M5 instead M4). This will be an immediate reduction in the total lighting pollution of the Iaşi City.

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Measurement Method of Light Pollution for Decorative and Advertising Lighting in South Korea

Theme: Technology & Design

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Introduction

Owing to the development of lighting industry and increased outdoor activities, outdoor lighting at night has been recklessly used in South Korea. This has caused several problems, including the destruction of ecosystem and harmful effects on our health. As countries around the world pay more attention on light pollution, there have been some efforts on its regulation. In addition, we have been restricting light pollution since 2013 for there are lots of night activities in Korea. The Light Pollution Prevention Act controls the pollution by classifying it largely into advertisement lighting, decorative lighting and lighting for spaces. For measurement of light pollution, there are necessary criteria to maintain its accuracy and integrity. Thus, the purpose of this paper is to introduce the measurement method of light pollution for advertisement and decorative lighting in South Korea.

Measurement Method and Evaluation of Light Pollution

This paper is limited to the decorative lighting (including media facade) and advertisement lighting (including digital multimedia signboards).

The luminance of light-emitting surfaces of advertisement and decorative lighting are measured and evaluated by first selecting the point for measurement (measurement position). Then, the area for measurement is selected, and after its measurement, it is analyzed and assessed. The point for measurement of luminance is basically the place where light pollution is expected among the points that are 45˚ or under, and any objects that may generate shading should be avoided for measurement.

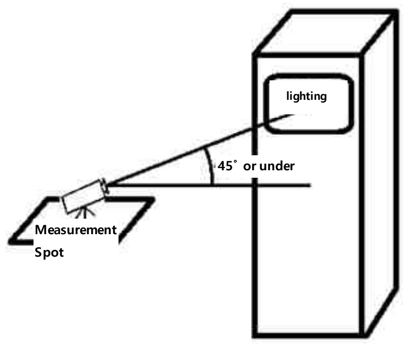

Fig 1: Measurement point

The whole surface of decoration where the decorative lighting (including the architectural lighting, media facade and lighting for bridges) is evenly illuminated (the maximum luminance against the minimum luminance of decoration surface should be less than 50) is the area for measurement of the luminance of decorative lighting surface. In case of the decorative lighting that illuminates only a part of the decoration surface (the maximum luminance against the minimum luminance exceeds 50) includes the maximum luminance point of the decoration surface for measurement, and a polygon area (rectangular or with more angles) that connects the points which are 1/50 times of the maximum luminance is the area for measurement.

When it comes the decorative lighting whose light-emitting part is a linear (or point) lighting, or linear (or point) lighting type which is directly exposed, the whole light-emitting area is the area for measurement. In case of the decorative lighting whose light-emitting part is a flat lighting, or flat lighting type which is directly exposed, the whole light-emitting area is the area for measurement of luminance.

The maximum values of light-emitting surfaces of decorative lighting and signboards are measured and evaluated by first selecting the point for measurement. Then, the area for measurement is chosen, and after its measurement, it is analyzed and assessed. The light-emitting parts of decorative and advertisement lightings that are point, linear and flat types are chosen for measurement of the surface luminance (the maximum values) of decorative and advertisement lighting. When selecting the surface for measurement, the advertisement lighting should be included in the viewing angle of the luminance meter as much as possible. The point for measurement (measurement position) is selected, and then it is measured and assessed.

Fig 2: Measuring lighting pollution

The luminance meters include point-luminance measurement and surface-luminance measurement. When using the latter one, its aperture is F4, and shutter speed is subdivided to measure in order up to the point when it is excessively exposed to light. When using point-luminance measurement, the diameter of measurement angle should be less than 1/3 of the length of one side of the decorative or advertisement lighting, or the area of measurement angle should be less than 1/10 of the total light-emitting surface area of the decorative or advertisement lighting. Luminance is measured with the diameter of measurement angle set as less than the linear thickness of the decorative lighting. The luminance of light-emitting surfaces of digital multimedia signboards is evaluated by first selecting the point for measurement, and then after its measurement, the measured data are analyzed and assessed. The digital multimedia signboards that change and flicker are the subjects for measurement of luminance, and the luminance of light-emitting surfaces is measured. When selecting the surface for measurement, make sure that the light-emitting surface of digital multimedia signboards is included in the viewing angle of the luminance meter as much as possible on a proper time when the damage is expected. Taking into consideration of the cycle of video clips on the digital multimedia signboards, it is measured continuously at a point when light pollution is expected (twice or more), and the maximum value among the mean luminance of light-emitting surfaces becomes the measured luminance.

0.9 (luminance correction) is applied to the measured luminance value to check the evaluated luminance, and then it is assessed whether it exceeds the permitted lighting criteria in comparison with the reference luminance values specified in the Light Pollution Prevention Act.

Conclusion

In Korea, a law was enforced to reduce light pollution. It was the first attempt to propose the method of measuring and evaluating decorative lighting and advertisement lighting. Several limitations were unveiled while measuring the lighting on site. In other words, the difference in errors when it comes to the measurement and values of moving signboards or decorative lighting was extremely great. There was an alternative of measuring the moving lighting using both luminance meters for measurement of spot and flat lighting. In addition, some pointed out that restricting the measurement angle to 45° was not appropriate for LED lighting. Although there are several limitations as described above, the light pollution measurement of Korea is still very useful in controlling light pollution and creating a better light environment.

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Developing Light Spill Criteria Considering the Environment Not Just Mankind

Dr Timothy Shotbolt LFIES RLP

Artificial lighting is for the benefit of mankind, however, human life is only a small portion of what is considered to be life on Earth. Prokaryotes are estimated to be 60 percent of life on Earth by mass, and Eukaryotes 40 percent of which the Animal Kingdom is only a small part and human life a small part of the Animal Kingdom. Since the commercialisation of alternating current electricity last century the proliferation of outdoor lighting has, and, continues to impact otherwise dark environments.

'Pollution' as a term is relative to the circumstances. Natural light at night such as moonlight can be desirable when associated with romance, however, from an astronomy perspective it too can be light pollution as it interferes with specific tasks. The unwanted effects of outdoor lighting at night is of major concern but in some climates does artificial light at night increase the potential carbon sequestration in a positive action for the environment?

In the absence of clear proof that certain quantities of various spectra of artificial light at night, once exceeded, is detrimental to all life, or that below a certain threshold it is not, the next best universal benchmark is moonlight. Using moonlight as a guide, criteria such as the spectral content of artificial light particularly LED, the *'revealing power'* of moonlight, the quantum of radiation, the timing and the cyclical nature are explored as more appropriate light spill criteria when limiting the effects of artificial light on the environment, particularly when adjacent to areas that should otherwise remain dark.

Title: Creating a methodology for presenting lighting designs

Theme: Technology and Design

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Abstract

This paper will try to identify and evaluate the optimal presentation method to be used for lighting design, concerning who receives the presentation (client, contractor etc.) Our goal is to create a methodology that can help lighting designers choose the best method of presenting lighting design information according to specific situations.

The first part of our work will try to identify the parts that structure the concept of lighting. Contrast, colour, texture, shape, positioning, targeting, movement and shadow quality are some of the parameters that will be discussed. Moreover, the means for the visual communication of light will be layed out and compared to different real life situations. Sketches, drawings, reference images, photorealistic perspectives, text, animation, physical models, virtual reality, photometric data presentation, all consist of ways to convey this visual communication of light. Finally the receivers (those that receive the presentation) will be categorized according to their relation with the lighting design project, such as colleague lighting designers, architects, interior designers, electrical engineers, suppliers, contractors, clients, the general public etc.

The methodology will come as a result of a questionnaire that will be distributed among lighting design professionals as the second part of our work. The answers will be statistically analyzed and conclusions will be drawn as to which method for presenting lighting design is more suitable for each category of receiver.

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Light pollution modelling and measurements of the effects of county rollout of blue rich LED lighting on an Area of Outstanding-Natural-Beauty.

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The Highways Agency have has a new policy for lighting specification on motorways, with a categorised environmental impact based point system that can accommodate LED lighting, based on the author's modeling.

Blue rich colour (CCT 6000K) LEDs could increase skyglow significantly compared with CCT 3000K, due to blue content enhanced reflection off vegetation and greatly increased atmospheric molecular Rayleigh scattering. The directional propertoies of LEDs, if fully utilized in lulinaire designs, could minimise this, and even result in less light pollution to the sky.

This papers builds on the work done for this, with full spectral integration of different CCT LED lighting, and for traditional types, including human eye response at various low light levels. The skyglow caused was found to be low, when using HA policy, and even less in some designs.

Modelling was then done for the Herefordshire county LED rollout replacement programme, with the specific manufacturer's LED photometric data. Although of lower G classes, the LED photometry showed a significant reduction in sky glow, through the very sharp cutoff for each class.

A Dark Sky Survey for the Malvern Hills AONB in 2012 formed a base reference, and has been followed up with new data measurements since the rollout, confirming these findings. It would require National adoption for the reduction to be very significant.

Integrated study of Sky Glow, Calgary, Alberta, Canada

Theme: Measurement & Modeling

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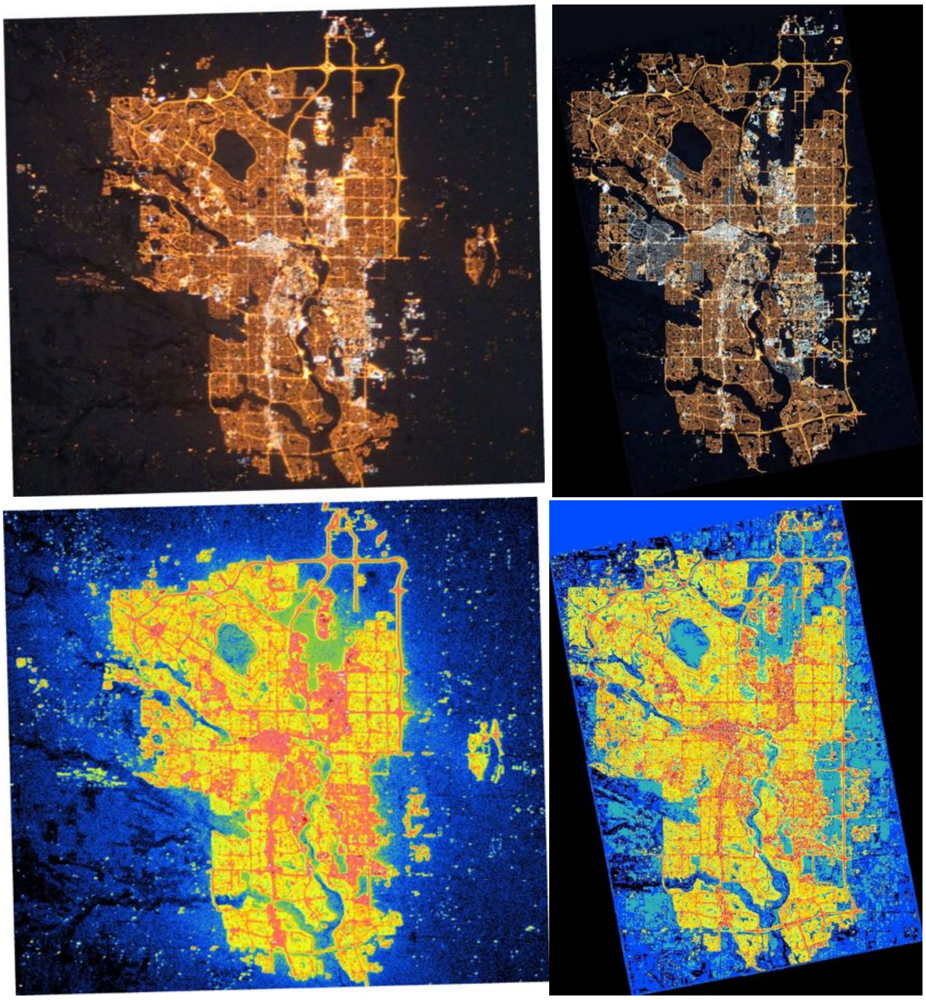
Using orthorectified photos taken from the International Space Station, ground-based Unihedron Sky Quality Meter data, and visual star count data collected over time, ground level and sky glow brightnesses were measured throughout the City of Calgary to characterize the effect of changing from HPS to LED street lighting on sky brightness.



Left top: Pre retrofit image of Calgary. Right top: Partial LED retrofit in some neighbourhoods. Left bottom: Pre retrofit intensity map. Right bottom: Partial retrofit intensity map. Intensity levels matched between images to facilitate comparison.

The new luminaires chosen by the City of Calgary are primarily 'cool white' LEDs with apparent colour temperatures of 5000 K for arterial roadways and 4000 K for residential streets. These high colour temperatures were selected despite one of the metrics in the City's request for proposals (RFP) was for lower colour temperatures. The luminous efficiency requirement in the RFP apparently precluded lower colour temperature LEDs in the submitted bids (City of Calgary, personal communication).

It is anticipated that the high colour temperature LEDs would create a larger amount of sky glow than the previous HPS lamps based on the increased Rayleigh scattering of the blue-weighted spectrum and because these LEDs have greater outputs in the part of the spectrum where human eyes' scotopic vision is most sensitive.

While LED streetlights are being introduced into cities around the world in replacement of HPS luminaires, the City of Calgary's retrofit program (dubbed the "e2 Street Lighting Program") is unusual in that many of the out-going HPS fixtures are full cutoff (with a U rating of 'zero' in the IES BUG classification), especially in residential neighbourhoods. Between 2002 and 2005, the City of Calgary undertook a complete retrofit, titled the "EnviroSmart Streetlight Retrofit", of approximately 37,500 residential streetlights, switching to lower-wattage (typically 100 W) HPS fixtures from the dropped lens fixtures originally equipped with 200 W HPS. Arterial roadways were also retrofitted, typically with cutoff luminaires with higher wattages. The current "e2 Street Lighting Program" thus contrasts those in other municipalities where, typically, semi-cutoff HPS designs are being replaced LEDs. Because of this, the present-day City of Calgary retrofit program provides a real-world laboratory to compare the resultant sky glow from different lamp types with broadly similar photometric footprints and cutoff characteristics.

The International Space Station photographic data suggest that up-light from the LED retrofitted neighbourhoods is not greatly different than the full cutoff HPS areas. This is an expected result since both pre- and post- luminaires are full cutoff, and the lighting engineers were striving for similar brightness levels before and after the changeover.

Visual glare is slightly worse with the LED fixtures due to a combination of increased blue-mediated glare response and the higher luminance of the typically smaller luminous area of the luminaire.

Sky glow data collection is currently underway.

Night sky quality monitoring in existing and planned dark sky parks by digital cameras

Theme: Measurement and modeling

Anita Dömény[1], Zoltán Kolláth[1], and István Gyarmathy[1,2]

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Introduction

A crucial part of the qualification of international dark sky places (IDSPs) is the objective measurements of night time sky luminance or radiance. A standard method for doing this task is the use of Sky Quality Meters (SQMs – Cinzano 2005). However, single measurements with this device provide only information about zenith luminance and possible light domes close to the horizon are hidden. A more precise measurement system for this task is the method introduced by the US National Park Service (Durisco et al. 2007), where an astronomical CCD camera is used to produce a mosaic of the sky. Although this technique provides the most precise measurements, it is not available for all organizations or individuals who are interested in the formation of an IDSP. Modern digital cameras provide an alternative way to perform all sky imaging either by a fisheye lens or by a mosaic image taken by a wide angle lens. Such a method was used in the application of the Hungarian dark sky park in Zselic and Hortobágy (Kolláth 2010).

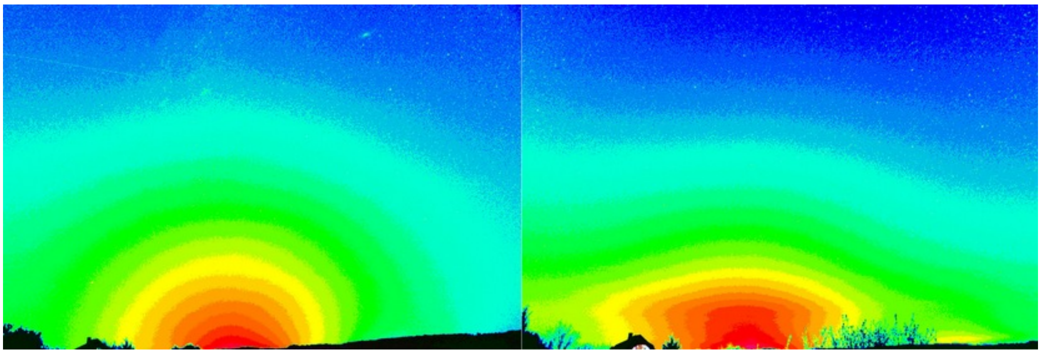

Fig 1: The light dome of Kaposvár before and after the lighting remodelling.

Long term monitoring

We started the sky quality monitoring with a digital camera in the Zselic Landscape Protection Area and in its neighborhood in 2008. Now we repeat the measurements with several cameras, included the one which was used during the first survey. Therefore it is guaranteed that all the measurements during the 8 year long timespan are comparable. The long term monitoring is especially important, since the public lighting in the vicinity of the dark sky park has underwent major changes during this period of time. For example, the high pressure sodium lighting was replaced with LED based luminaries in the largest city (Kaposvár) in the region. The ULR of the lighting has significantly decreased as reflected in the shape of the light dome. However, due to the rebounding effect, the effective light pollution is not decreased (Figure 1). Using the RGB information of the photography, the variation in correlated colour temperature is easily recognized in the light dome of the city. It indicates that scotopic measures of the light pollution in the dark sky park originated from Kaposvár is significantly increased.

Preliminary survey of the Munții Bodoc–Barault

Munții Bodoc–Barault is one of the Natura 2000 protected areas in Romania located in Covasna county in northern direction from Sfântu Gheorghe. Besides the rare bird and amphibian species living in this nearly 57000 hectare alpine area, the starry night sky without disturbing light sources has to be protected as well. Therefore, it is important to initiate further acts to preserve the nighttime environment for the future.

Fig 2: Typical fisheye picture from Muntii Bodoc-Barault

In the aim to establish the first International Dark Sky Park in Romania, we started a measurement survey in cooperation with the Vadon Association, Sfântu Gheorghe in 2014 to qualify the light pollution level of the area. We measured the brightness of the night sky with an automatic Sky Quality Meter and a calibrated DSLR camera with a fisheye lens.

Conclusion

It is demonstrated that digital cameras provide a useful tool in characterizing the night sky quality of dark sky places. With consistent calibration, long term monitoring is also possible, which gives the possibility to detect even minor, otherwise hidden changes threatening the nocturnal quality of the area. Finally, we provide recommendations for performing night sky quality surveys and for the preparation of the appropriate parts of IDSP applications.

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The growth in lighting in Ireland pre- and post-Celtic Tiger: population and economics

Theme: Measurement and Modelling

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Introduction

We report on measurements of Irish lighting conditions to understand the historical growth in light levels pre- and post-Celtic Tiger. Our aim is to determine the rate of increase in light level, and to compare Irish light use with that of other countries in order to provide a point of reference for Irish light use and its influence on the environment.

Using a combination of space-based measurements with the Defense Meteorological Satellite Program (DMSP) satellites and the more recent SUOMI/VIIRS instrument we show that light levels in the Irish Republic have increased much faster than in neighboring Northern Ireland and the United Kingdom which have similar lifestyles and use similar public lighting approaches. Over the period 1995 – 2007 the light output of the Republic increased at 6x that of Northern Ireland, and has remained high subsequently, with towns in the Republic typically producing 1.5x–2x as much light per capita as their northern counterparts. Over 35% of the country now emits light at 10% of the peak value or above, accounting for roughly 24,500 km^2.

Fig. 1. SUMI/VIIRS DNB data for Ireland. Major cities and towns are easily visible, but note that there remain some near-pristine areas, which include two International Dark Sky Association Gold Tier sites: Kerry International Dark Sky Reserve in the south-west and the Mayo International Dark Skies Park in the north-west.

By comparing the space images with Council lighting inventories and census data we examine the light output of towns of differing sizes over time. Furthermore, by coupling these measurements with data obtained on the ground, we can also estimate the overall light output and cost.

A more detailed study: the influence of Dublin City on its environs

Using ground-based Sky Quality Meter observations we have made a more detailed study of the light output from Dublin to examine the radial dependence of sky brightness and its variation with weather conditions. Dublin is the major city of the Irish Republic, with a population of over a half-million inhabitants in the City proper. Lighting is mainly of low- and high-pressure sodium types, typically 100W electrical/luminaire and a total electrical installed capacity of 4.67 MW. The light emission is concentrated on the central commercial and port areas, and measurements show that the City influences a region out to ~30km from the City Centre.

We report on a study of the trend of light output measured along a number of radial directions from Dublin City Centre. In this case we find that the emission obeys a power-law dependence with radial distance and, for the sample sites selected is largely independent of the direction and details of location (viz. sea-level vs. foothills, nature reserve vs. suburban). Over the period covered by the survey, samples of both cloud-free and cloudy nights were used to estimate the amplification of the sky brightness due to the city, and compared with IYA2009 lightmeter data to estimate the total W/m^2 due to integrated light.

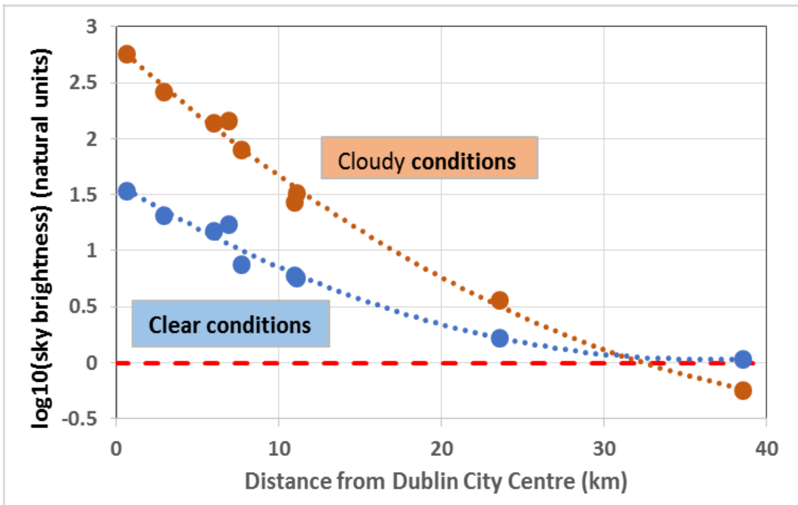

Fig. 2. Data obtained under clear and cloudy conditions are shown separately, plotted in units of logarithmic natural sky brightness. The horizontal dashed line indicates the natural sky level. Note the strong amplification under cloudy skies, yet the presence of relatively unpolluted skies in the Glendalough area of the Wicklow Mountains National Park nearly 40km from the City.

Summary

The unconstrained growth in the Irish economy together with an increasing population has led to a resulting increase in light output. Despite the fall-off in the economy post-Celtic Tiger, the light level and electrical energy use continues to remain high. To preserve dark skies in the future, and to reduce the amount of light output, we need to consider a more balanced growth, particularly in vulnerable rural areas where relatively pristine night skies are still present. The more extensive use of full cut-off light fixtures and the introduction of trimming and dimming practices in the coming years should help to reduce light waste and light pollution, although protection of dark sky areas and the introduction of new lighting such as LED technology needs to be more carefully considered as part of a more comprehensive protection plan.

The recent award of the highly-coveted Gold Tier status to two areas in Ireland shows that there can be a positive eco-tourism benefit from this approach. Eco tourism can be more fully capitalized on and a number of additional areas are currently under study. It is to be hoped that UNESCO World Heritage Sites such as the Burren and Brú na Bóinne (the location of the Newgrange tumulus, which is aligned with the winter solstice) might achieve protected status for their night skies in the coming years.

SQMDroid – A universal SQM measurement device

Measurement and Modelling

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The Unihedron Sky Quality Meter SQM has become a widely used easy to use instrument to measure the night sky brightness (eg. Kyba et al., 2015). It is offered offered in different versions. The SQM-L measures and displays the sky brightness in mag/arcsec which are noted together with the geographic coordinates of the place, which can be determined with a GPS or from a map. SQM-LE, -LR, and –LU have no displays but provide Ethernet, RS232 or USB interfaces to be connected to a computer, which stores the measured brightness values at certain intervals. One model (SQM-LU-DL) is delivered with an internal data logger that must be programmed with a computer.

Normally brightness values are measured near the zenith, but to get a better value for the whole sky, measurements at different altitude and azimuth directions can be taken (Zamorano et al., 2014). This measurement method was integrated in the recent model SQM-LU-DL-V which contains an accelerometer/compass module allowing measuring altitude and azimuth of the instrument. The measurements can be used to draw a contour map of the measured sky brightness with the included software (Unihedron, 2016).

Another utility called Roadrunner was developed by Daniel Rosa Infantes from the Sociedad Malaguena de Astronomía (2011). The Windows PC software takes simultaneous measurements of the sky brightness with a SQM-LU mounted on the roof of a car and the position as measured with a GPS. By this way a large number of measurements can be efficiently taken over large areas, limited by obscuration (through bridges, trees) or road lighting. Similar solutions are possible with a Raspberry Pi or with custom-built solutions using low-cost microcontrollers as proposed by Espey and McCauley (2014).

Android smartphones contain a multitude of sensors, like GPS and orientation sensors and higher quality models can also be used as USB hosts, called USB On-The-Go (OTG). Therefore the idea was to connect a SQM-LU directly to an Android smartphone with an OTG adaptor cable and mount both devices parallel. Then simultaneous measurements of the time, the position (with the GPS), the orientation (with the orientation/acceleration sensors) and the sky brightness should be possible, integrating all different solutions into one instrument! We developed a new Android software called SQMDroid which allows taking measurements manually or continuously at specified time intervals and stores them in a csv file (with date, time, mag, azi, alt, lat long) on the smartphone that can be used for further evaluation. As with handheld SQMs individual zenith brightness measurements can be taken with the registration of date, time and position. Using it on a car (or due to the compactness by feet or a bicycle) measurements at different position can be taken like with the RoadRunner software. And measurements towards different azimuth and altitude directions can be taken like with the SQM-LU-DL-V. We will report about first experiences with SQMDroid.

Further development could include a presentation of the measurement points on a map and a system that assists the user for taking all sky measurements similar to the system for taking 360° pictures in the smartphone.

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Using fisheye-lens imagery to track the reach of skyglow under clear and partly cloudy conditions near Montsec Astronomical Park in Spain

Theme: Measuring and Modeling

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Introduction

Artificial skyglow is detrimental to astronomical observations and it is supposed to have an impact on the environment as the presence of significant skyglow can disturb nocturnal animals and possibly whole ecosystems [1,2]. The amount of skyglow depends on many factors: spatial and spectral emission pattern of light sources, shape of settlements, landscape, vegetation and weather conditions. Clouds can dramatically increase the amount and the reach of skyglow [3]. Both measuring and modelling of artificial skyglow is challenging. Knowledge of the night sky brightness (NSB) and the illuminace (irradiance, repsectively) at a specific site is important to investigate its ecological consequences. Such information can help to design laboratory experiments to mimic skyglow in a controlled way. However, commercially available illuminance meters are not designed for the relatively low light levels relevant for skyglow (10µlx – 100 mlx). Most commonly, NSB observations are performed in zenith using single sensors with a limited field of view.These sensors can be used to track the dynamics of skyglow at stationary sites [4] and to compare different locations with stationary and portable devices [5]. However, spatial information of the sky hemisphere is not provided, making it difficult to identify the origin of skyglow or to infer the resulting illuminance as in most cases the brightest regions at the horizon are not observed. All-sky imagery using DSLR cameras with fisheye lenses can provide the illuminace information as the full spatial information of NSB is available [6, 7, 8].

(a)
(b)

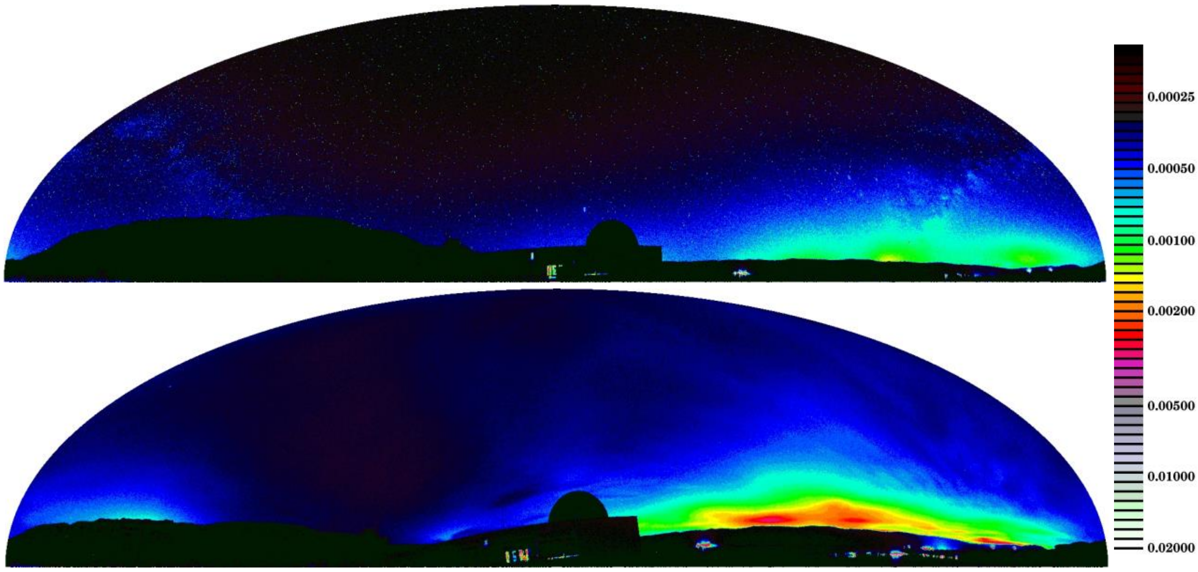

Fig 1: Panoramic false color luminance maps (in cd/m) of the night sky at Montsec astronomical park calculated from all sky images for (a) clear conditions on May 04 2:55 a.m. local time and (b) partly cloudy conditions on May 06 2:10 a.m. local time. Increase of distant skyglow is clearly visible near the horizon.

Experimental results

We used a DSLR camera (Canon EOS 6D) with a fish-eye lens (Sigma f=8mm) to image the NSB at different distances from the town Balaguer, Spain in two different weather conditions. The town of Balaguer is located close to Montsec Astronomical park. In the park, zenith NSB can reach near-natural conditions on a clear night (21.8-22.0 mag_{SQM}/arcsec measured with a sky quality meter - SQM). All sky imagery unravels skyglow from distant and nearby towns at the horizon, which is increased with the presence of clouds (see Fig. 1). To investigate the reach of skyglow a transect from the town of Balaguer towards the astro park was performed on two nights with clear and partly cloudy conditions, respectively. Figure 2 shows the data acquired on two nights at different distances from the town of Blaguer. The upper row (a,b,c) shows all-sky images obtained on May 04 2016 under clear conditions and the lower row shows all-sky images taken at the same locations on May 06, 2016 under partly cloudy conditions. Images in the same column (a and d; b and e; and c and f) are taken at the same location. To our knowledge, this is the first report of such a data set.

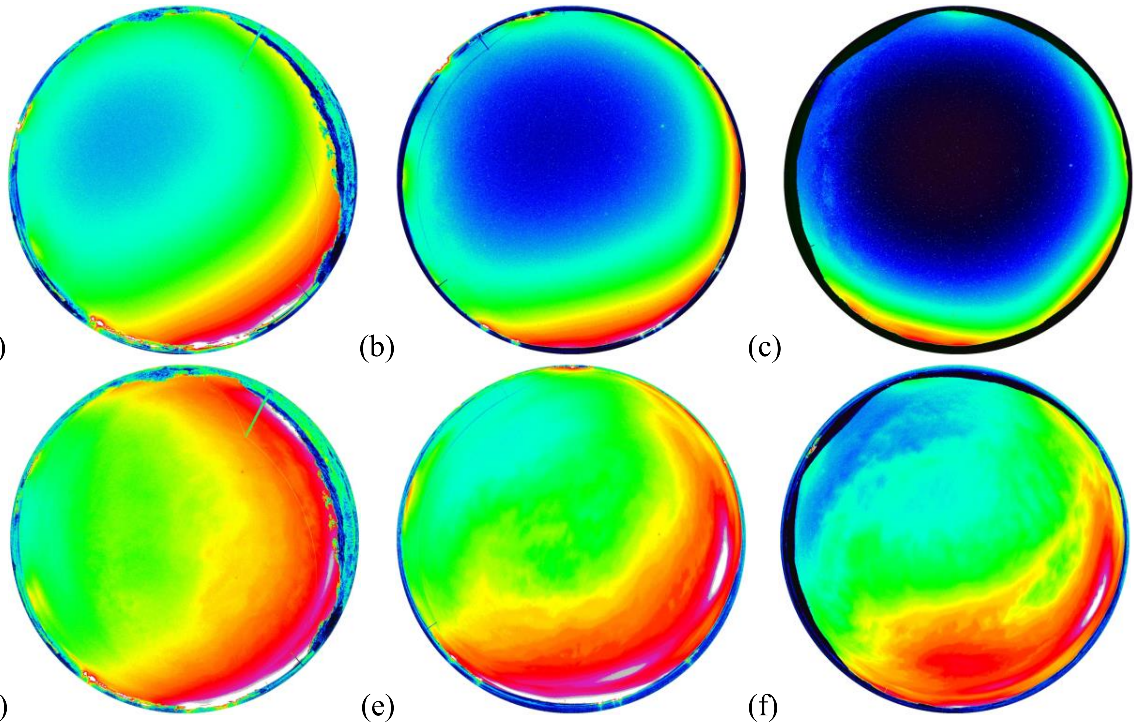
(a) (b) (c)
(d) (e) (f)

Fig 1: All-sky false color luminance maps (in cd/m same scale as in Fig. 1) of the night sky at different cloud conditions and different distances from the town of Balaguer. Rows show images obtained on different locations in the same night: (a,b,c) clear conditions on May 04 2016 and (d,e,f) partly cloudy conditions on May 06 2016. Columns (a and d; b and e; c and f) show the same location at different nights.

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Measuring the night sky brightness in coastal environments: fisheye-lens imagery from a boat

Theme: Measuring and Modeling

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Several studies have shown that artificial light at night can have an impact on the environment [1, 2]. In the past, the main focus of these studies was on terrestrial animals and plants. However, human settlements concentrate along freshwater reservoirs and coastlines and therefore, light pollution research is recently moving towards aquatic systems [3, 4]. With this new research focus, a demand for data about existing nocturnal illumination and night sky brightness (NSB) levels has arisen. While satellite data and modelling can provide a good estimate of the NSB for clear skies [5], it is not (yet) applicable to overcast situations. Standard NSB measuring methods such as single sensors and fisheye-lens photometry are almost exclusively used in a terrestrial context. We have recently quantified the night sky brightness at a freshwater lake in Germany from a floating platform [6].

In this work, we utilize fisheye-lens imagery to quantify NSB in a coastal environment from a boat. Data was acquired on the Gulf of Eilat/Aqaba in Israel starting in the city of Eilat. Fisheye images were taken at three stops (Fig. 1). We used a Canon EOS 6D with a Sigma fisheye lens with f = 8 mm. Aperture was 3.5, exposure time 0.5 s and ISO 6400. The standard settings for land-based studies have lower ISO settings and longer exposure times. We had to find a compromise for the gently rocking boat with short exposure time as the camera was mounted just on a tripod without a stabilization system. The all-sky pictures shown in Fig. 2 indicate that this coastal region is affected by light pollution. For comparison, data from an unpolluted freshwater lake in Germany is shown in Fig. 2d. We believe that this is the first time that such data was acquired from a moving vessel. Our proof-of-concept data is promising for future studies of NSB on open waters.

Fig 1: Map of the transect on the Gulf of Eilat/Aqaba.

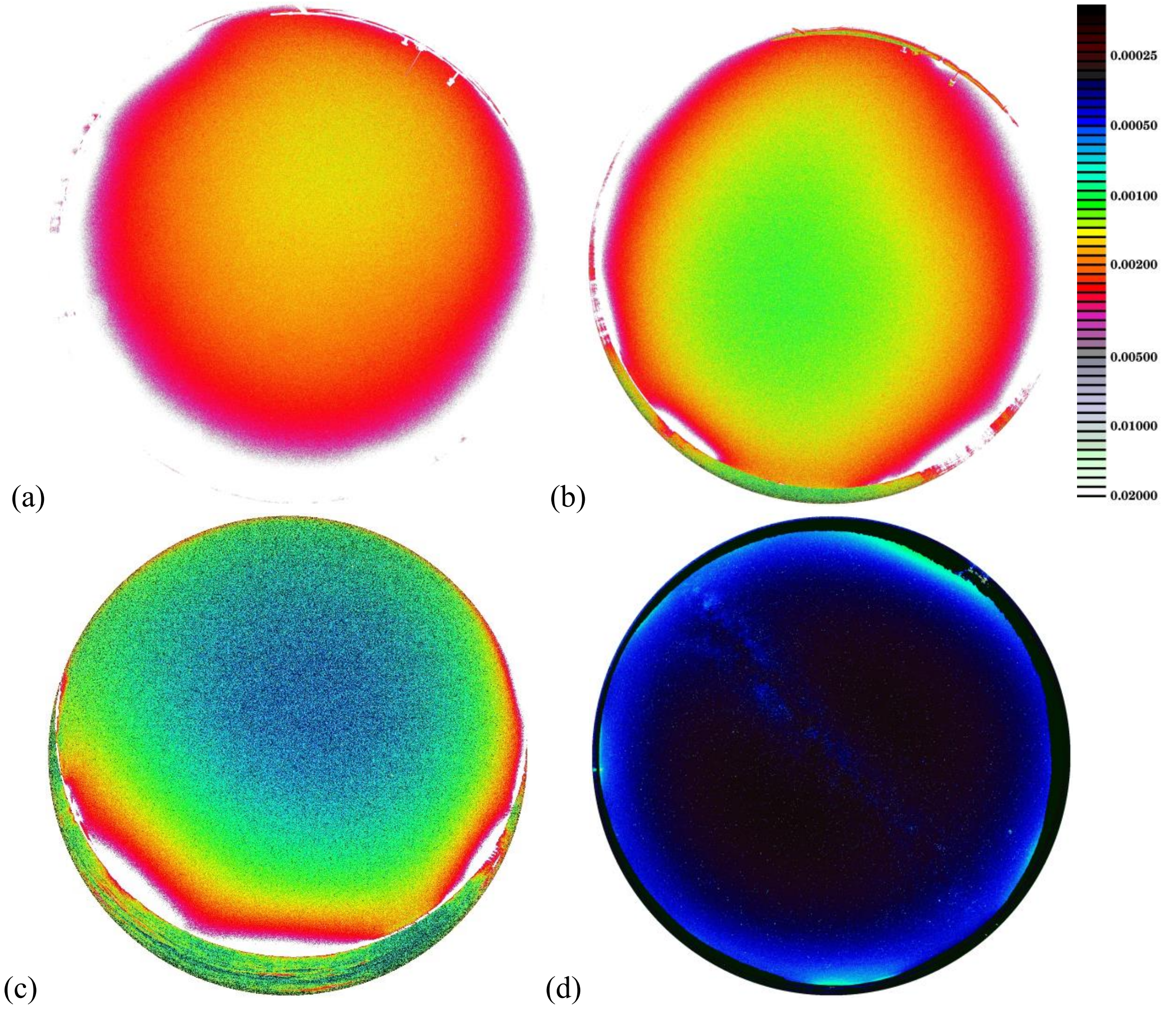

Fig 2: Fisheye-lens images taken from a boat on the Gulf of Eilat/Aqaba (a) close to the city of Eilat, (b) along the northern shoreline and (c) in open waters. (d) All-sky image from an unpolluted sky at a freshwater lake in Germany (see [6] for details about the location). The scale is in cd/m .

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Real survey measurement and process for the determination of lighting environment management zone in South Korea

Theme: Measurement & Modeling

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Introduction

Scientific research has, beyond doubt, indicated ties between artificial lighting and several health-related issues. For instance, links between different forms of cancer and artificial lighting are becoming more prevalent. Other than concerns of a healthy and well-being, artificial lighting also presents an added disadvantage of energy consumption. A significant proportion of the total energy produced worldwide goes into lighting in buildings, streets and so forth. All this has led to a robust movement made of countries and private institutions with an aim of restricting the use of artificial lighting within the built environment. The involved parties are now leaned towards the implementation of regulations to help limit the use of artificial lighting.

In Korea, outdoor lighting at night is a common phenomenon. This is partly due to the economic development attained over the years. And, as this development grows even further, the use of artificial lighting is increasing rapidly making Korea vulnerable to the adverse effects of artificial lighting. Consequently, debates regarding the proper use of artificial lighting have been on going within the Korean lighting profession personnel. The discussions are focused more on the current status of artificial lighting in Korea, how to effectively design lighting fixtures for a sustainable lit -environment and how to prevent light pollution, which is a major consequence of improper artificial lighting. The current paper therefore discusses the issue of light pollution in relation to sustainable lighting. The discussion is based on recent findings obtained from field measurements and analysis of the lit environment in Korea.

Measurement and determination of light pollution

After the enactment of the Light Pollution Prevention Act in Korea, a number of measurements on the impact of light pollution on Seoul city were conducted. The field studies focused on assessing the degree to which space lighting and advertisement lighting had deviated from the lighting level limitations issued through the Light Pollution Prevention Act. The measurements were carried on in accordance with the Lighting Environment Management Zones, which were created to differentiate areas on the basis of their purpose (See Fig. 1).

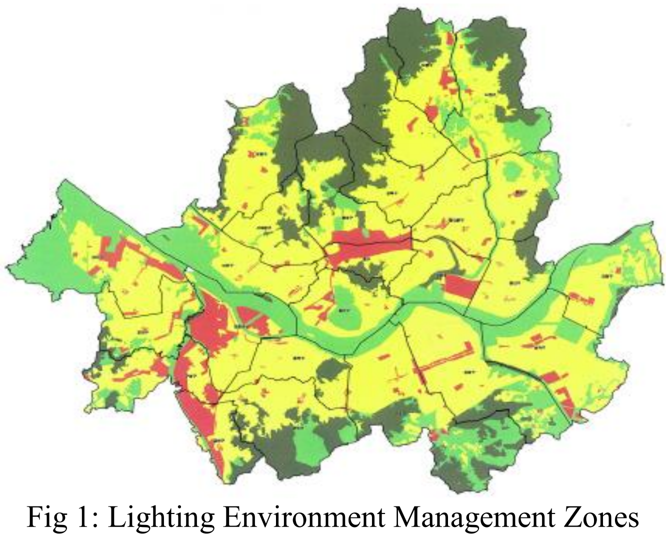

Fig 1: Lighting Environment Management Zones of Seoul City, South Korea

The processes involved in creating a visually comfortable lit environment are rather complicated. Several techniques must be applied for satisfying outcomes to be obtained. This is also true when evaluating a given lit environment for light pollution. A number of existing methods can be utilized to attain accurate results. The High Dynamic Range (HDR) Imaging method is one of such techniques [1]. It can be utilized to discover the amount and element of light radiated within a space by a light source. As a result, through the use of the HDR method, the National Institute of Environmental Research of Korea has developed a measuring protocol that determines the amount of light pollution given off by a light source. The current study applied the same technique to conduct light pollution-related measurements in more than 300 locations in Seoul city. The aim was to prevent light pollution obtained from artificial lighting while at the same time maintaining visually safe and beautiful scenery at night. The evaluation technique adopted calculates the photometric quantity of light by taking the target area and converting it into an individual surface or a single point [2, 3]

Findings

The results obtained from the field measurements indicate that a large percentage of the investigated areas contained lightings that were above the lighting limits issued through the Korean light Pollution Prevention Act. Also, the result indicate that most measured spots from each area contained higher lighting levels than those specified by their respective Lighting Environment Management Zones of the Light Pollution Prevention Act (See Fig. 2). Furthermore, during the field measurements, it was discovered that the light fixtures in Seoul city have been in use for a long period of time and thus leading to poor functioning and possibly an increased spread of light pollution.

In conclusion, there is no visible change between the status of light pollution today and that before the enactment of the Light Pollution law. This lack of significant change can be attributed to the absence of strategies that reinforce the law that was put in place. The current paper therefore shows the urgent need for such strategies in Seoul city and other cities in Korea.

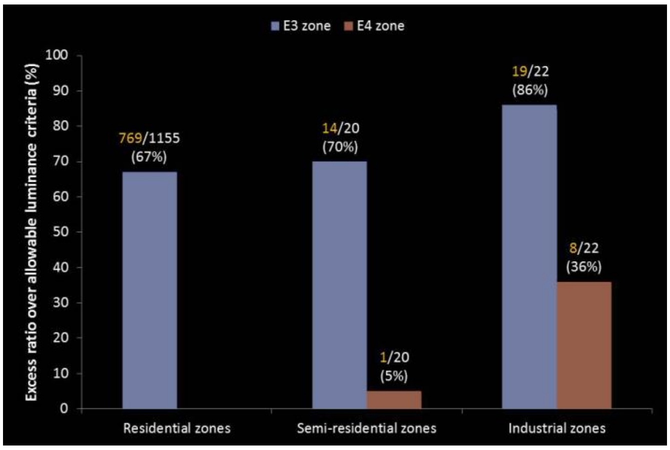

Fig 2: Ratio of areas with space lighting exceeding the recommended lighting limits

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Estimating the height of low-level stratiform clouds at night by photometric measurements

Theme: Measurement & Modeling

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Motivation

Cloud base height (CBH) is an essential characteristic of cloudiness. It has an importance of general weather forecasting but in case of *low-level clouds CBH is a critical parameter in aviation safety*. Although several methods exist for remote sensing of clouds there are still imperfections in regularly available information considering the users' needs. Conventional infrared satellite images could only map the upper part of the clouds. For determining CBH, the only routinely available and reliable technique is the laser ceilometer measurement. These expensive instruments are installed only in a few places, usually at airports, but CBH information in extended geographic area could be highly beneficial for meteorological and aeronautical applications.

Weaknesses of existing sky camera applications

In recent years sky cameras became more and more popular as a meteorological observation tool. Some applications even provide CBH, but those *methods mostly based on contrasts on the sky* and usually dedicated to work only in daytime (Kassianov et al. 2005, Seiz et al. 2007, Janeiro et al. 2010, Chulichkov et al. 2015, Savoy et al. 2015, Wang et al. 2016). For aviation purposes mapping the low-level stratiform clouds has the highest importance which usually has a homogenous appearance and weak contrasts on the sky.

Light pollution as cloud ceiling projector

Before the laser ceilometer era, some airports used a so-called *cloud-base searchlight ceilometer* or ceiling projector for measuring CBH (Ashford 1947). Basically, it consisted of a very strong reflector, which directs the light upwards to the clouds. Then, a human observer determined the elevation angle of the light spot with an alidade at a fixed distance. The height of the cloud base could easily be calculated by simple triangulation. It is worth mentioning that such an intense light beam had serious consequences for birds (Howell et al. 1954).

It is a well-known fact that artificial lights can effectively illuminate the clouds (Kyba et al. 2011). *Artificial lights on the ground can be regarded as passive cloud ceiling projectors*, so the same triangulation principle can be applied for CBH calculations (Fig 1.).

Fig 1: Reflection of ornamental lighting of the Parliament, Budapest. Known the distance of the light source, orientation of the camera and characteristics of the lens we can estimate the cloud base height. (CBH is ~600 m in this case). Source: Hungarian Meteorological Service

Opportunities in recent digital camera techniques

Recent commercial *digital cameras with increasingly sensitive sensors provide cheap opportunities for nighttime photometric measurements of the sky* (Kollath 2010, Hiscocks 2014). We can get luminance values on a physical scale via calibration of the camera/lens system, but relative brightness values of the sky could be enough for matching ground sources of light and brighter spots formed on the illuminated cloudy sky.

Challenges, limitations, difficulties, plans

Compared to an active searchlight ceilometer, light pollution of towns and villages are more diffuse and can change in time. Depending on the local characteristics and distribution of light pollution, *matching the light sources and their reflectance on the clouds* may be impossible or ambiguous. Moreover, visibility can limit the observation of the cloud base above the light source. Scattered and multi-layered clouds and of course the Moon can also cause difficulties.

The main problems to be addressed are: *How reliable* calculation of CBH can be constructed? *What are the optimal local characteristics of light pollution* which allow better quality measurements? Could we effectively use *nighttime visual satellite images* for determining light sources around observation sites? How *light pollution modeling* can contribute in evaluating the sky camera images in cloud observation purposes? *How can we assimilate nighttime sky camera data into other routine meteorological observations* available at night? *Is it possible to crowdsource* the installation and maintenance of usable sky cameras in order to have higher number of observations?

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An Installation Guideline of Preventing Light Pollution in Residential Area's Street Lighting in South Korea

Theme: Measurement & Modeling

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1. Introduction

The purpose of this Directive is to provide a guideline for installation of street lighting and security lighting, which could inhibit the usage of indiscriminating space lightings and correctly install space lightings by considering outdoor lighting environments.

In particular, it laid the basis to manage street lightings and security lightings systematically through considering effects of light pollution in the first stage of installation in order to minimize light pollution of public lighting.

Fig 1: Light trespass caused by the security lighting of residential area's

2. Public lighting installation reference parameter and analysis methods

2.1 Coverage

It provides a guideline for installation and management considering suppress of light trespass from public lightings and effects of light pollutions. It suggests appropriate installation distances in the general road for typical luminaires, including street lightings and security lightings in Cut-off, Semi Cut-off, and Non Cut-off types.

2.2 General Information

This section describes the parameters and criteria applied to the applicable luminaire installation guide.

2.2.1 By Variables

- Installation height: 8/10/12 m (Street lights), 4/5/6 m (Security lights)
  * Rationale: KS(Korea Standards) C 7658 LED street lights and security lights - Safety and performance requirements
- Type of road: Residential area / commercial area
- Traffic density: The frequent passage / infrequent regional traffic
- Luminaire installation location: edge-type (Edge)
- Angle: 0 ° ~ 5 ° (Street lights), 0 ° ~ 15 ° (Security lights)
- Maintenance factor: 1.0 equally applied
- Overhang: 2 m (Street lights), 1 m (Security lights)
- Analysis points: Measurement above 1.5 m from building's floor considering window height in

ground floor

2.2.2 Applicable luminaire

Each luminaire (street lighting and security lighting) is in the shape of Cut-off (LED Cut-off type included), Semi Cut-off, and Non Cut-off. (Each of four types)

3. Simulation analysis method (Use IES file)

It used a simulation program that can make a virtual wall in front and back of public lighting installation area. (Virtual wall: 20 m x 5 m / horizontal and vertical) It was analyzed by forward or backward movement of the virtual wall. Then, simulation was performed by changing the reference value of the parameter from at least 1.5 m in height above of the residential floor. Through this, it obtained an appropriate distance of light trespass standard with less than 10 lx.

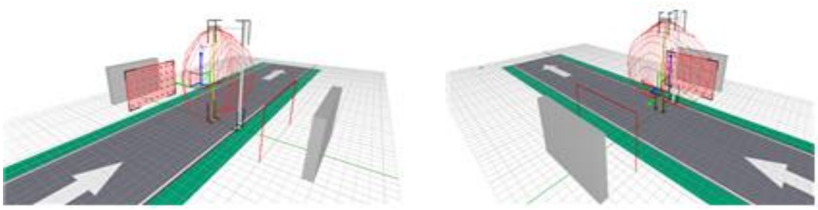

Fig 2 : Simulation analysis of forward light and backward light

4. Conclusion

The guideline for light pollution prevention derived from this paper is a reference for manufacturers, designers and installers. In fact, it is an effective guideline, which may set an appropriate installation distance in residential areas for users. Furthermore, it is also expected to save cost and time for installing and identifying current status of road lightings in regards to light pollution prevention.

4.1 Examples of results

Proposal for appropriate distance according to the height and angle of street lights (Installation height: 8 m)

Division		Residential area's appropriate distance according to the high street lights installed		
		Installation angle 0°	Installation angle 3°	Installation angle 5°
Cut-Off	Forward	More than 1.7 times	More than 1.7 times	More than 1.8 times
	Backward	More than 1.2 times	More than 1.1 times	More than 1.0 times
Semi Cut-Off	Forward	More than 1.6 times	More than 1.7 times	More than 1.8 times
	Backward	More than 1.1 times	More than 1.0 times	More than 1.0 times
Non Cut-Off	Forward	More than 1.6 times	More than 1.7 times	More than 1.7 times
	Backward	More than 1.0 times	More than 1.0 times	More than 0.9 times
LED Cut-Off	Forward	More than 1.3 times	More than 1.4 times	More than 1.4 times
	Backward	More than 0.6 times	More than 0.6 times	More than 0.5 times

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Republic of Korea (2013), A Standard Measurement Method of Light Pollution in Korea

Title: Updated high-resolution map of light pollution

Theme: Measurement & Modeling

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Introduction

We present an updated map of night sky brightness. Model that was used to create this map was originally created by Berry (1976) and then was improved in our previous work (for details see Netzel & Netzel 2016).

Using the previous model we obtained promising results, but it dealt with two main problems: it did not take into account the shadowing effect - important factor in mountainous areas, and it was not perfectly fitted to observations, especially over high urbanized areas. Updated model attempts solving these problems. Results are compared with many observations collected from regions of different kinds of land urbanization and topography. To obtain the most reliable calibration of the model we used genetic algorithm method and more observations than in our previous study. The model was also significantly modified to include the shadowing effect.

Updated model provides better results in mountainous terrain. We investigated this effect in details in Sudety mountais. Night sky brightness is significantly lower when shadowing effect is included in the model. For better results we used, besides our own measurements, we used selected measurements from publicly available database (http://www.myskyatnight.com/#map).

The resultant map has resolution of 100 m. The model, even though is more complicated, can be still calculated on a desktop computer in "finite" time (10000 km^2 was calculated in 35 minutes on i5 portable computer).

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Identifying Geographic Location of Research and Educational Activities Using Spectral Properties of Light Emitted During Nighttime

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Educational and research activities (R&EAs) are major forces behind modern economic growth. However data on geographic location of such activities are poorly reported, which complicates a comparative analysis of their patterns and forces behind their geographic concentrations. According to our research hypothesis, intensities and spectral properties of artificial light-at-night (ALAN) can be used for effective identification of different economic activities on the ground, due to the unique light "signature" of each economic activity. In order to develop activity identification models, *in situ* measurements of ALAN intensities and spectral properties were carried out at the locations of different economic activities in the Greater Haifa Metropolitan Area. For this task we used an illuminance spectrophotometer CL-500A portable device, measuring the total and spectral irradiance of ALAN, incremented by a 1-ηm pitch, from 360 to 780 ηm. The total number of measurements was 610, including 148 measurements, carried out near four research institutions, located in the City of Haifa. As our analysis shows, ALAN intensities, emitted by different economic activities at peak wavelengths, help with their identification. In particular, logistic regressions, incorporating ALAN intensities at the peak or near-peak wavelengths, and geographical attributes of the sites as controls, succeeded to predict correctly 98.6% of the actual locations of existing R&EAs. A multispectral image of the Haifa bay area, obtained from the Astronaut Photography Database, was used for the model's validation.

Title: STARS4ALL night sky brightness photometer

Theme: Measurement and Modeling

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Introduction

STARS4ALL is a collective awareness platform for promoting dark skies in Europe, funded by the EU. The STARS4ALL project aims at representing the right of dark and starry skies or "*stars for all the citizens*".

Fig 1: Optics and electronics of the STARS4ALL TESS-V1 photometer inside its weatherproof enclosure.

Light pollution initiatives (LPIs) are local or global open working groups who fight against the negative impacts of artificial light at night. Our plan is to involve citizens within one or several offered initiatives, and also to help them to create their own. One of the LPIs is related to development of a European Photometer Network. Interested citizens will help us in monitoring the light pollution of European villages with a sensor network. The network will extend the current existing professional photometer networks to a citizen-based network of photometers. For this purpose citizens will be able to purchase and install low cost photometers, which will be sold in the STARS4ALL marketplace.

We show in this poster the TESS-V1 photometer, which is the first version of a series of cheap but reliable photometers that will be used to measure night sky brightness. This version has been designed to monitor the sky from fixed places. It communicates to a router via a WIFI module and sends automatically the brightness values to our data repository using IoT (Internet of Things) protocols. This device also measures the ambient and sky temperature to record the cloud coverage. The hardware, software and data will be open and free.

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Light Pollution and its Impact towards Islamic New Moon (*hilal*) Observation

Theme: Measurement and Modeling

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Introduction

Due to religious obligation, Muslims has differentiated between new moon and Islamic new moon (*hilal*). This is based on Quranic verse: "They ask you about the crescent moons; say they are a means to measure your specific times (*mawaqit*) and are also for the commencement of the *hajj*" (2: 189).

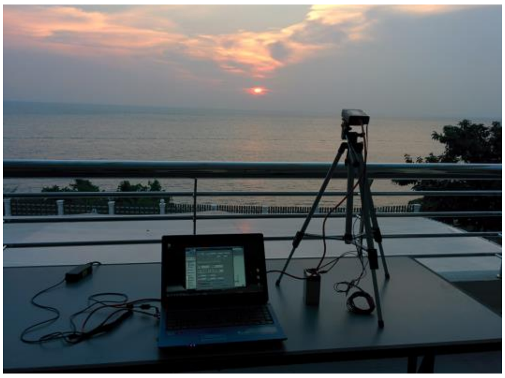

Fig 1: Data taking using Sky Quality Meter (SQM) during the observation at twilight

The new Lunar (hijric) month begins on the next day of sighting the new crescent at west after sunset i.e. during twilight at dusk (Odeh, 2004; Shariff, Hamidi, Muhammad, Zainuddin, & Ibrahim, 2013). This is based on by determination of first day of months based on visibility of Islamic new moon (*hilal*) i.e. sightings of the first sliver of the waxing moon marking the start of each month (Zainal, 2002).

Therefore it is vital to understand the movement and position of the Moon – phases of the Moon. Fig. 2 shows phases of the Moon in a month. As seen from the earth, new moon is the first phase of the Moon. It occurs when moon and sun have the same elliptical longitude or in other word is in conjunction (Meeus, 1999). Conjunction is only an apparent phenomenon due to the perspective. At this point, we cannot see the Moon because we cannot see the reflected sunlight on the Moon's surface.

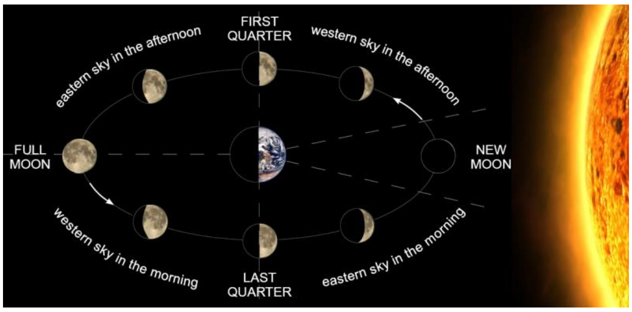

Fig. 2 Phases of the Moon (Credit to Google Image)

Proceeding of the Moon is defined in hours pass after the conjunction or age (Özlem, 2014). Age of the Moon is regarded as one of important parameters in order to determine the first visibility of lunar crescent (Ahmed & Aziz, 2014). After few hours only then we have the chance to witness thin crescent (Ar. *hilal*) which determine the beginning of new Islamic new moon. The word *hilal* means the first light of the Moon when people actually see the crescent at the outset of a month (Yusuf, 2008).

Malaysia opts to choose *imkanur rukyah* (lit. possible of visibility by observation) – one of method in determining new hijric month (Islamic calendar). It is important to note that, it is possible to calculate when this thin crescent will theoretically be visible, but many Muslims will only accept visual confirmation (Aron, 2014). Basically, *imkanur rukyah* has three (3) criteria: 1) 2^{o} of Moon's altitude; 2) 3^{o} of Moon-Sun elongation; and 3) minimum of eight (8) hours of Moon's age. Based on *hilal* observation report[1] by JAKIM (Malaysia Department of Islamic Development), before 1990, the *hilal* was more frequently seen in 29th day. After 1990, the *hilal* was frequently seen in 30th day. Therefore, one major issue that has affected *hilal* visibility for many years is misdirected, excessive and obtrusive artificial light – light pollution. We think this information is sufficed to understand the different between astronomical new moon and *hilal* and we do not intend to discuss this in further.

The objective of this research is to investigate how sky limiting magnitude influences the visibility of *hilal*. From astronomical perspective, limiting magnitude is the faintest apparent magnitude of a celestial body that is detectable or detected by a given instrument. The visibility of new moon is a function primarily of the angle between the moon, observer, and sun (which affects the brightness of the crescent) and the apparent altitude of the moon above the horizon and of the sun below the horizon (which affects the background brightness against which the moon is to be observed).

To conduct this research, we choose west-facing sites – because the *hilal* sets at west. The sites are: 1) Telok Kemang, Malaysia; 2) Kuala Lumpur, Malaysia; and 3) Coonabarabran, Australia. Measurements of the limiting magnitude were made at least one hour before and after the Moon set on dates spread over a period of six months. The data were taken using Sky Quality Meter (SQM) which records the visual magnitudes per square arcsecond (mpsas) to measure sky limiting magnitude. The SQM was pointed to horizon in order to get magnitude value of sky near *hilal*' coordinate – Fig. 1.

Table 1 below are preliminary results of this research which is the limiting magnitude threshold for the *hilal* to be witnessed. The given readings implies that reading within that range, there is high possibility to witness the *hilal*. On the other hand, reading with less than 16 mpsas, the *hilal* was not visible during the observation.

Table 1 Limiting magnitude threshold

NO.	SITE	READING (in mpsas)
1.	Telok Kemang, Malaysia	16-19
2.	Kuala Lumpur, Malaysia	16-18
3.	Coonabarabran, Australia	16-22

The main important result of this research is to find out a vital parameter for *hilal* observations in order to increase its visibility – proposing a new criteria. This research helps us to understand the phenomenon better about the threshold of sky limiting magnitude for *hilal*.

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Title: Potential impact of a transition to white LED on the sky of Hawaii

Theme: Measurement & Modeling

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Introduction

Understanding how artificial light propagates in the environment is a crucial part in trying to control exposure to ALAN. To do this, many models have been constructed during the last 30 years, growing in complexity and precision with time.

The goal of this study is to evaluate the current level of light pollution in the night sky of the Haleakala Observatory on the island of Maui in Hawaii, and the impacts of a change to fully shielded white LEDs while maintaining a constant installed lumen. To accomplish this, the radiative transfer model ILLUMINA is used. Improvements to the model and detailed analysis of the ALAN on the archipelago will be presented. Results show that a transition to white LEDs can more than double the average visible zenith sky radiance at the observatory. We also show that the increase can reach a factor of ten at some specific wavelengths in the blue region of the spectrum.

Fig 1: VIIRS image of the Hawaiian archipelago.
Data from the EOG at NOAA/NGDC
H : Honolulu, Oahu
O : Haleakala Observatory, Maui
L : Lava lakes, Big Island

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Developing an environmental impact category of light pollution for life cycle assessment

Theme: Measurement and modeling

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Introduction

There is increasing amount of scientific evidence on the ecological impacts of artificial lighting. Light pollution (LP), i.e., the sum of all adverse effects of artificial light, changes the environment and has various consequences not only for humans, fauna and flora but also the balance of ecosystems. The amount of LP is globally increasing but its actual impacts are not exactly known in many cases. Even recent studies (e.g., Van Geffen et al. 2015) admit that the ecological consequences of LP are not fully understood. The impacts depend on the intensity, wavelength, duration and timing of the exposure making it complex to model.

Life cycle assessment (LCA) is a standardized method to evaluate the potential environmental impacts of a product system throughout its life cycle from raw material acquisition to end-of-life (ISO 2006a, 2006b). Generally, a number of environmental impacts are assessed in a LCA, such as global warming, human toxicity, ozone depletion and acidification. In addition, new impact categories are established for evaluating less renowned impacts, such as noise and electromagnetic fields. There is currently no method for quantifying and evaluating LP in the LCA. Yet, it has been suggested that an environmental impact category for LP should be developed (EC JRC 2011; Cucurachi et al. 2014). This paper preliminary investigates the development of a method to evaluate the impacts of LP in a LCA.

Development of impact category

Comparing LP to existing environmental impact categories, an analogy can be found particularly with noise: like any sound is not noise, any light is not LP, i.e., obtrusive or considered harmful. In fact, artificial lighting is installed for its positive impacts on visual performance and visibility. Keeping in mind the special characteristics of LP, the development of impact evaluation method for noise can be used as a proxy in creating one for LP.

A type of cause-effect method has been proposed to be used for the evaluation of the environmental impacts of noise (Müller-Wenk 2002, 2004; Garraìn et al. 2008). The 4-phased scheme includes *fate, exposure, effect and damage analyses*. Fate analysis investigates what kind of change in pollutant concentration is caused by a given emission. Exposure analysis estimates the number of individuals exposed to the pollutant. Effect analysis determines the effect of the increased pollutant concentration if individuals are exposed to the pollutant for a certain time. Damage analysis evaluates the total measurable damage caused by the exposure to the pollutant. The unit of measurement was proposed to be DALY (disability-adjusted life years). Due to the similarities in pollutant characteristics, the same cause-effect method is estimated to be suitable for the development of an impact category of LP.

In order to develop an evaluation method for an environmental impact, sufficient scientific evidence needs to be collected on fate, exposure, effect and damage of the impact. By conducting a preliminary literature survey, it is hypothesized that the LP impacts on human health are quantifiable and notable, so that an environmental impact category and a characterization factor model may be created for LP. At least, the preliminary and suggestive findings may be used for creating a model for the environmental impacts. In the scope of artificial stationary outdoor lighting at night, artificial lighting has been found to affect humans, both physiologically and non-physiologically. Potential impacts on human health have been suggested to increase, possibly through the disruption of circadian rhythm, the risk of cancer, cardiovascular diseases, depression, diabetes, gastrointestinal and digestive problems, obesity, and sleep disorder (e.g., Stevens et al. 2014, Smolensky et al. 2015, Fonken & Nelson 2014, SCENIHR 2012).

In addition to the impacts on humans, artificial light has been suggested to affect animals and plants. Sea turtle hatchlings are disoriented by artificial light at night, so are migrating birds and many insect species, potentially resulting to disruption of the ecosystem balance. Such effects have frequently been found to differ not only among species and populations but also depending on the lighting characteristics. Artificial light is generally used in horticultural lighting to improve the crops of cultivated plants, and the adverse impacts of artificial light on vegetation are less researched. Thus, the impacts of LP on fauna and flora are excluded from the scope of this first attempt to develop an impact category of LP but they are recommended to be studied and their impact included in an environmental impact category model in the future. Astronomical LP is also excluded from the current study.

Conclusions

Based on a preliminary literature survey, there may be partially sufficient robust scientific evidence on the impacts of LP on human health so that an environmental impact category for LP can be developed. LP has strongly been suggested to affect the circadian rhythm of humans, which, in turn, is linked with the development of several health problems, including cancer and obesity. To continue the development of the environmental impact category model for LP, a cause-effect method is suggested to be followed. Thus, it is necessary to analyze the fate, exposure, effect and damage of LP on human health. An extensive literature survey, including the impact of spectral and temporal parameters and the intensity of the light, is needed for developing the model. Later on, the impacts on animals, vegetation and ecosystem balance may be analyzed and added to the model of LP environmental impact category.

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Title: The effects of screen illumination on: sleep efficiency and architecture, physiology, emotion and behavior- possible effect on human health

Theme: Health

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Introduction

Millions of computers, tablets, TVs, and smart-phones are sold every month worldwide and the use time of these devices is increasing constantly. Today, people are exposed to long-term illumination that emerges from the screens of these devices that emit short-wavelength (SWL) lighting, during day and night hours. The results of previous studies showed that these devices emit SWL-lighting, which can suppress melatonin (MLT) production and affect sleep (Cajochen et al., 2011, Chang et al., 2012; Wood et al., 2013). In order to better understand the relationship between exposure to SWL-screen illumination and human behavior, measurements that examine the effect of luminescence from these screens on sleep structure and quality should be used, as well as on functioning indicators, such as cognitive (CPT-III), emotional (BSI), and physiological tasks variables that were not simultaneously tested in previous studies.

Research layout: 19 subjects were studied using repeated measurements on two independent variables. The first independent variable is two levels of light intensity: low level - 84 lux and high level - 350 lux. The second independent variable is two wavelength conditions: short-wavelength – blue, about 485 nm, and long-wavelength – red, approximately 610 nm. Each participant was experience all four experimental conditions.

Procedure: Subject were asked to sit in front of a computer screen for two hours at a distance of about 60 cm from the screen and perform the on-screen tasks between the hours of 21:00 and 23:00 h. At the end of two hours of exposure to screen light, the subjects were connected to the sleep test system. Body temperature was measured at 21:00, 23:00, and close bedtime. Three measurements were taken 0, 60, and 120 min after awakening CPT test, BSI questionnaire, and the ESS questionnaire were preformed at the morning.

Results:

Body temperature: According to the hypothesis, exposure to SWL caused non-dropping of body temperature in contrast to normal dropping of body temperature after exposure to illumination with long wavelength light ($F_{(5,14)}=6.9$, *$p<0.05$)*. **Sleep architecture:** We found a main effect of type of wavelength on sleep architecture, time and sleep efficacy (SE). Short wave length caused a significant decrease in Total Sleep Time $F_{(1,18)}=21.45$, $p<0.05$, deceased SE $F_{(1,18)}=24.5$, $p<0.05$, increased Sleep latency $F_{(1,18)}=14.03$, $p<0.05$, and increased nocturnal Wake time $F_{(1,18)}=24.39$, $p<0.05$, decreased Slow Wave Sleep $F_{(1,18)}=42.549$, $p<0.05$, compared to long wavelength. **ESS**: We found a main effect of wavelength on the ESS, with subjects reported higher sleepiness scores after exposure to SWL compared to long wavelength, $F_{(1,18)}=4.8$, $p<0.05$. **BSI:** Analysis did not yield significant results, although subjects did report more negative feelings after exposure to SWL in the high intensity light condition. **CPT**: Two of eight CPT parameters were significant. SWL increased significantly d' and omissions $F_{(1,18)}=5.34$, $p<0.05$, $F_{(1,18)}=6.019$, $p<0.05$.

Discussion: SWL screen illumination prevents the normal decline in the body temperature curve at night. SWL decreased total sleep time (TST), sleep efficiency (SE), and slow wave sleep (SWS), increased sleep latency and light sleep. Subjects reported significant sleepiness after SWL illumination at night. In CPT test subjects made more errors in the SWL condition. The results of this study show that exposure to SWL from computer screens at night may have negative effects on health

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Evidence for the Waking Effect of Sunlight during Winter in Social Media Data

Theme: Health

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Introduction

Scheffler and Kyba (2016) recently examined the occurrence of the German phrase '*Guten Morgen*' ('good morning') on Twitter. They showed that the use of the phrase is strongly associated with the morning in central Europe, that the timing of when Twitter users say 'good morning' differs between work days and free days, and that in Winter and early Spring the use of the phrase is closely related to the timing of dawn. Here we summarize and re-present these results.

Methods

Scheffler and Kyba (2016) used the method of Scheffler (2014) to record tweets including the word '*Morgen*' from the Twitter streaming application programming interface during the period of August 15, 2014 to August 14, 2015. The dataset consists of tweets from 206,633 individual users, with 1,443,004 unique tweets (retweets were not included). The data were filled into histograms according to the time of occurrence, with a bin width of 15 minutes. The time at which the rate of good morning tweets reached half of the maximum (= "onset of Twitter activity") was found by interpolation, and this time was used as a proxy for the typical user's "wake time". The relation of this time to the sunrise time in Frankfurt, Germany was examined.

Results

Scheffler and Kyba (2016) found that the onset of Twitter activity on free days tracks the sunrise time, especially during Winter and early Spring (Fig 1). This relationship ends with the start of daylight saving time, and as a result the difference between wake times on free and work days grows considerably. These results are consistent with the observations of Kantermann et al. (2007) based on sleep survey data. It is not yet known whether the difference between Saturdays and Sundays is related to time of wake up or is specific to onset of Twitter activity.

Discussion

The results indicate that social media activity can be used as an indicator for wake timing in an extremely large population. This suggests that social media data could be used to evaluate the impact a future policy change in the onset of daylight saving time has on sleep at a population level. The data also suggest that reducing the duration of daylight saving time would allow many more people to wake up on workdays without the need for an alarm clock.

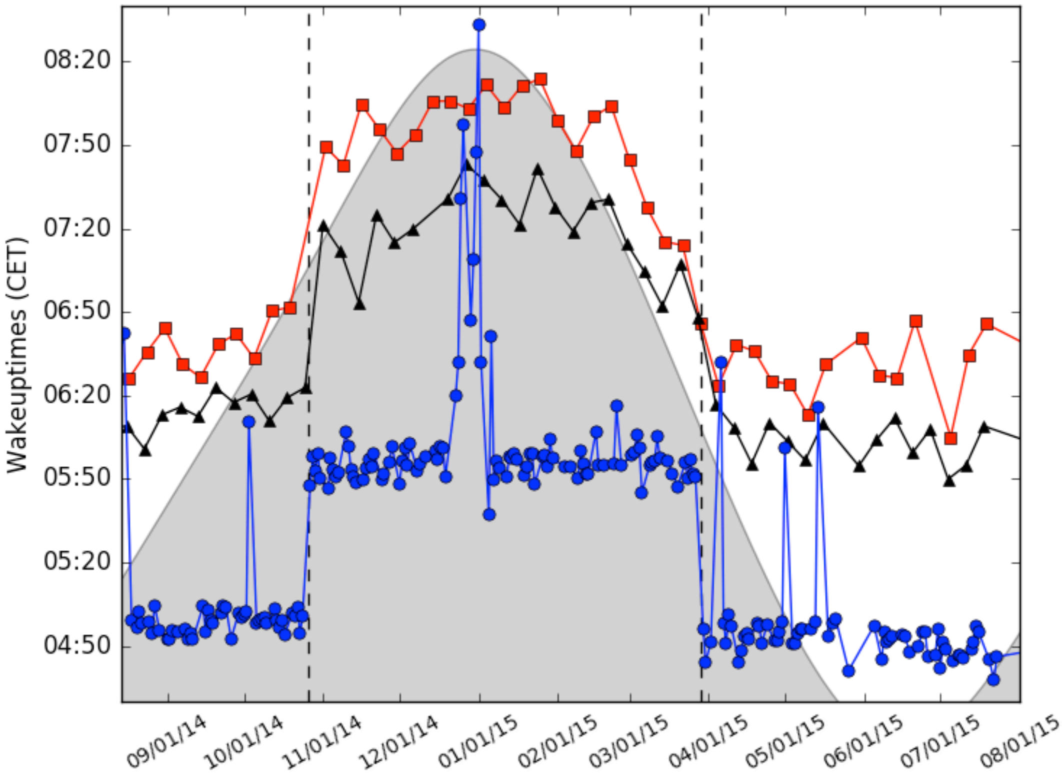

Fig 1: Onset of twitter activity in Central European Time on weekdays (blue circles), Saturdays (black triangles), and Sundays (red squares). Dawn time in Frankfurt, Germany, is the boundary between the white and gray regions. Dashed lines show the end and start of Daylight Saving Time. Figure reproduced from Scheffler & Kyba (2016).

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Different intensities of light exposure during the sleep and its impact on concentration of melatonin and sleep quality

Theme: Health

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Introduction

Light contamination is a common factor of modern society and can interfere with innate circadian rhythms. The circadian system has developed in response to regular changes of darkness and light over 24 hour cycle. Hormone melatonin is an internal signal transferring information about external photoperiod to organisms. High levels of melatonin are found during the dark time and light exposure during the night has a suppressive effect on melatonin syntheses.

The aim of our study was to determine if low intensities of light exposure during the night have an impact on concentrations of melatonin metabolite 6-sulphathoxymelatonin (aMT6s) in urine of young volunteers. Furthermore, we evaluated sleep quality during light exposure in these persons.

Material and methods

Twenty six volunteers (23 women, 3 men) agreed to participate in the study (23.8 ± 3.8 years average ± SD). Volunteers slept during 3 control nights in their home environment in standard dark room. During next two nights they slept in light contamination environment (ALAN). There were two intensities of light exposure – below 1 lx (n=18 volunteers) or below 5 lx (n=8) (ALAN 1 lx, ALAN 5 lx). Light intensity at the level of the subject head was measured by spectrophotometer (Konica Minolta) or daysimeter (Rensselaer Polytechnic Institute, Troy, NY, USA). Samples of urine were taken every day of the experiment immediately after waking up (the first morning urine) and stored by –18 °C until analyses.

The levels of aMT6s were determined by radioimmunoassay (Stockgrand Ltd., Guildford, UK). They were normalized on the levels of creatinine in urine with liquid reagents for enzymatic determination of creatinine in serum, plasma and urine (Erba Lachema, CZE). Sleep-wake pattern and sleep quality was measured by wrist actigraphy (CamNtech, UK).

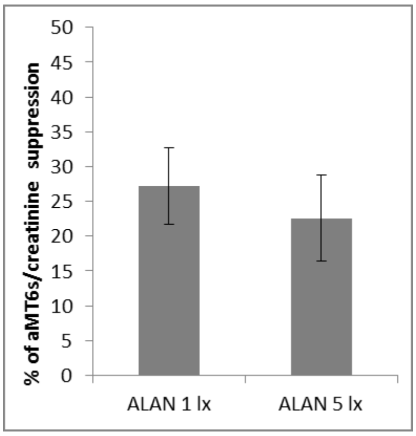

Figure 1: Suppression of aMT6s/creatinine (%) in urine of young volunteers. ALAN 1lx group - 9 volunteers from 18 volunteers (50 %) respond with melatonin suppression. ALAN 5lx group - 6 volunteers from 8 (75%) respond with suppression of aMT6s/creatinine in urine.

Results and conclusions

Concentrations of aMT6s/creatinine in the first morning urine after ALAN 1 lx and 5 lx exposures were not significantly different in comparison with control days. We found an extensive variability among individuals in the melatonin metabolite levels. Individual evaluation of melatonin suppression based on own aMT6s/creatinine levels during control nights demonstrate, that 50 % of subjects exposed to ALAN 1 lx and 75% of subjects exposed to ALAN 5 lx exhibited the aMT6s/creatinine suppression in average 27.19% ± 5.5% and 22.58% ± 6.15%, respectively (Figure 1).

Sleep quality analysis revealed a higher sleep fragmentation index during ALAN exposure as compared to control days in both experimental groups. Elevated fragmentation index is an indicator of interrupted sleep and restlessness during sleep period.

We conclude that even low intensity ALAN can suppress melatonin production in sensitive persons. Moreover, exposure of young healthy people to very low intensity of light during the whole night can negatively affect sleep quality without affecting melatonin production. Taken together, also very low intensity of ALAN can have negative consequences on circadian synchronization, sleep quality, disturbs performance of people and potentially also their health.

This research was supported by grants APVV 0150-10 and APVV 0291-12.

Going for The Gold:
Quantifying and Ranking Visual Night Sky Quality in International Dark Sky Places

Theme: Measurement and Modeling

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The International Dark-Sky Association (IDA), a U.S.-based NGO, offers accreditation through its International Dark Sky Places (IDSP) Program to protected public and private lands that proactively manage their use of outdoor light at night and educate visitors on the value of natural nighttime darkness. IDA Dark Sky Parks, Reserves and Sanctuaries must establish their eligibility for participation in the program in part by submitting night sky zenith luminance measurements. Candidates are currently ranked according to increasing mean zenith luminance in 'Gold' (>21.75 magnitudes per square arcsecond, or mpsa), 'Silver' (21.74-21.00 mpsa) and 'Bronze' (20.99-20.00) tiers. These values, typically obtained using the Unihedron Sky Quality Meter (SQM; Cinzano 2005), are supplemented with horizon photography documenting artificial light domes, narrative descriptions of observed faint night sky phenomena, and naked-eye limiting magnitude and Bortle Scale (Bortle 2001) estimates. A histogram of over 5,000 individual SQM-L (narrow acceptance cone) measurements obtained from 29 IDSPs around the world, shown in Figure 1, illustrates the range of sky luminances encountered on various protected lands considered 'dark' at some level.

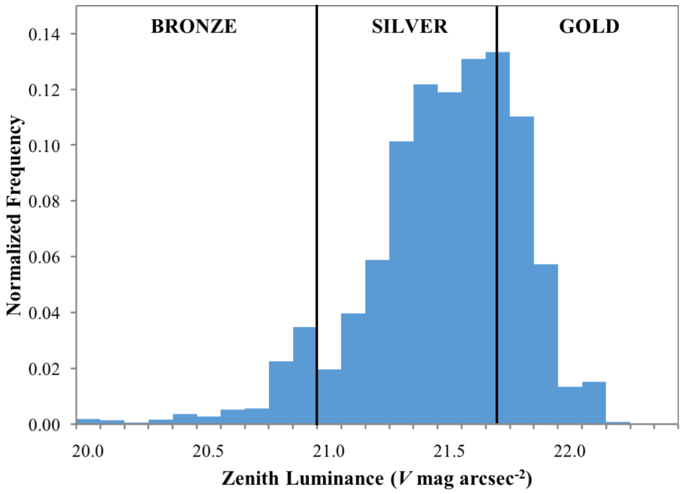

Fig 1: Frequency histogram of 5,343 SQM-L measurements obtained in IDA Dark Sky Parks, Reserves and Sanctuaries from 2011-2016. Thresholds for the Gold, Silver and Bronze IDA sky quality tiers are indicated.

It is increasingly clear that while SQM measurements reliably characterize sky luminances in the presence of significant skyglow from anthropogenic light pollution, their reliability breaks down in situations where there is little or no artificial skyglow (Bará+ 2014). In those circumstances, the temporally variable intensity of airglow often dominates, and in all cases the zenith luminance is at best a quasi-periodic function of time. Furthermore, although zenith luminance measurements offer better inter-comparability of different sites, they fail to account for light domes along the horizon that may significantly affect visibility over a large fraction of the sky. Reliance on qualitative descriptions of night sky quality and quantitative measurements obtained solely at the zenith anecdotally undercuts the integrity of the Gold/Silver/Bronze tier scheme, which itself has been criticized on the basis of visibility studies (Crumey 2014). Even the names of the tier labels are problematic, evoking a psychology of winners and losers, and creating the potential for misrepresentation of sky conditions by IDSP applicants when site reputation and future tourism revenue are considered to be at stake.

We are left with remarkably fundamental questions unanswered in the context of natural nighttime landscape protection: What is a 'dark sky,' and how do we describe the quality of 'darkness'? And two specific (and increasingly acute) programmatic needs have emerged: first, to amend or replace the current tier system according to our best understanding of human visual perception of the night sky and the various natural and artificial light sources that influence it, and second, to develop low-cost, readily deployable best-practice methods and data collection protocols for characterizing and monitoring night sky quality.

Several potential solutions to the problem exist, all of which lead toward a holistic approach to measuring the brightness of the entire night sky. Grids of SQM-L measurements taken around the sky may be interpolated to produce crude all-sky luminance maps (Zamorano Calvo+ 2014), but they lack spatial resolution of individual light domes. Progress has been made in developing calibrated all-sky camera systems that provide information on the spatial distribution of both natural and artificial sources of light (e.g., Duriscoe+ 2007; Rabaza+ 2010; Kolláth 2010; Aceituno+ 2011; Nievas Rosillo 2013; Rabaza+ 2014); however, these systems are generally expensive to procure and often require expertise to properly operate. Another option is to combine zenith SQM-L measurements with uncalibrated horizon photography; given that most of the artificial sky luminance observed toward the zenith originates from ground sources within ~25 km of a given location (Aubé and Roby 2014), this method can help identify the nearest problematic sources to target for mitigation.

There is presently an increasing demand for an affordable, off-the-shelf imagery system for obtaining simultaneous all-sky measurements of night sky luminance for both initial site evaluation and ongoing monitoring. Duriscoe (2016) suggests a number of useful metrics that can be extracted from spatially-resolved luminance data; combined with visibility studies, these may lead toward a more robust and objective means of deciding which candidates are best suited for IDA Dark Sky Place recognition.

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Participatory Dark Sky Quality Monitoring from Italy: interactions between awareness raising and research

Theme: Society

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The BuioMetria Partecipativa (BMP) project was started in 2008 in Italy with the aim of encouraging non-professionals to collect data on light pollution as a strategy for environmental awareness raising. The BMP project conjugates this component with a scientific approach, making an extensive combined use of various technologies, and allows the collection of valuable quantitative environmental data, using a low-cost device, called Sky Quality Meter (SQM). Measurements can be produced borrowing an SQM from the BMP instrument pool, if the users do not own one. The measurements are loaded to a database on the project web site, and are published in a variety of formats (maps, reports, charts).

When it started, the BMP project was one out of two worldwide (and the first in the Western hemisphere) configured as a citizen science initiative involving sensors for night sky quality.

In 2011 the system was extended to collect data from fixed SQM stations for continuous monitoring of night sky brightness, with the development of data harvesting procedure ans leading to complement the citizen science measures with more high-quality time series of light pollution data (http://www.cordilit.org).

At the national level, the project has obtained considerable recognition, in terms of actual citizen participation, media coverage (in the press, on the radio and on TV), and has received a national award for innovation and environmental awareness raising.

Internationally, the BMP project represents one of the longest-running experiences of participatory monitoring of night sky quality, and has developed a significant network of relationships with other institutions engaged in research, awareness raising, and policy support. Among these, the collaboration with the Institute of Biometeorology at the Italian National Research Council has represented a key case. On one side, the collaboration led the institute to investigate further the issue of artificial light at night, deploying sensors and conducting additional outreach activities. On the other side, Attivarti.org -the organization running the BuioMetria Partecipativa project- was exposed to other cases of outreach and environmental education.

The presentation will provide an overview of the key accomplishments by these two subjects, including the cooperation with other organizations in Italy and in Europe, including activities related to the Loss of the Night Network.

Outdoor lighting design as a tool for tourism development. The case of Valladolid.

Theme: Society

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Fig 1: The illuminated City Hall

Practices and policies related to urban illumination have dramatically changed in the last decade. Under pressure from several different contexts — cuts to their budget (Peck, 2012), technological developments (Meier, Hasenöhrl, Krause & Pottharst, 2015) and the demands of climate-change mitigation (Bulkeley, Broto & Edwards, 2012) – local authorities are looking towards changes in their lighting strategies in order to reduce financial burdens as well as energy consumption (Shaw, 2014). At the same time a growing awareness that artificial light is not purely benign has emerged in research and policy. The concept of light pollution is now widely adopted to describe the negative effects that the excess of outdoor illumination can have on ecosystems, animal behaviors and human well-being (Longcore and Rich, 2004) as well as the aesthetical qualities of the nocturnal landscape and the visibility of the stars during night time (Rodrigues, Rodrigues & Peroff, 2015). As a consequence, new forms of lighting regulation designed to reduce light pollution are becoming increasingly common at local and even national levels. By way of example Slovenia has introduced a national law in 2007, with France following in 2013. However, lighting design has also followed another path of development. A more theatrical deployment of light has emerged in the contemporary cultural economy and new modes of illumination are increasingly employed to enhance the experience of the urban night (Ebbensgaard, 2015a; Edensor, 2015b; Edensor and Lorimer, 2015). Initially restrained to temporary events, this new approach to urban design is no longer confined in controlled environments but is becoming a distinctive feature of the contemporary city, increasingly affecting everyday illumination. This has led to a dramatic change in the scale, scope and policies of urban lighting strategies resulting in an increase in the sphere of intervention and the application related to urban illumination (Köhler, 2015). The traditional safety purpose has been progressively matched by new ones and the use of light for city beautification and as directive beacon is becoming a major concern of urban lighting strategies (Van Santen, 2006). As a result, an increasing number of municipalities have started to consider urban illumination as a potential tool for urban development (Alves, 2007). This aspiration is mainly motivated by the idea that new spectacular forms of illumination contain the possibility to draw visitors and tourists leading a growing number of cities to explicitly include the development of nocturnal tourism among the objectives of their lighting policies and strategies (Deleuil, 2009; Guo, Lin, Meng & Zhao, 2011).

Nevertheless little attention has been paid in academic research to the evolution of this phenomenon. Therefore this communication presents the experience of the internationally renowned lighting project "Ruta de los Rios de Luz", developed in 2011 in the Spanish city of

Valladolid, in order to show how innovative forms of illumination design can help to expand the temporal spread of tourism activities while at the same time create a clear commitment toward environmental sustainability.

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Light Pollution Prevention Act in Korea

Theme: Society

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Introduction

The Light Pollution Prevention Act (hereafter "Act") has been enforced since February 2013 in Republic of Korea (hereafter "Korea"). The purpose of the Act is to protect people's health and ecological system from inappropriate and excessive outdoor lighting, and manage the artificial outdoor lighting in an environment-friendly manner, thereby to enable all people to live in the healthy and comfortable environment (Article 1). This paper briefly introduces the Act: legislative process, Lighting Zone and its designation process, permissible standards of illuminance and luminance, and administrative fines.

Legislative Process

Dr. Youngah Park, a member of the National Assembly, submitted the Light Pollution Prevention Act to the Assembly (9 September 2009), after a public hearing (18 August 2009), and the Assembly passed it in December 2011. During 27 months of legislation process, many kinds of public hearing, nation-wide discussions, academic symposiums, coordination meetings between the related industries and the relevant public officials have been held. The Act and the Enforcement Decree has entered in force since February 2013 by the Ministry of Environment (hereafter "MOE") of Korea government. The Act consists of 5 Chapters with 18 Articles and Addenda with 3 Articles.

Lighting Zones and Permissible Standards

The 'Lighting Environment Management Zone (hereafter "Lighting Zone, LZ")' shall be specified as LZ1 to LZ4 in accordance within the National Land Planning and Utilization Act of Korea. These zones reflect the base light levels desired by a community and an environment originally developed by the CIE. Permissible standards shall be determined by vertical illuminance on the windows and luminance of buildings' and advertisements' surface or object (see Table 1).

Table 1: Permissible standards

Type of lighting	standard	LZ 1	LZ 2	LZ 3	LZ 4	time
Trespass light on window (lx)	maximum	10	10	10	25	1 hour after sunset ~ 1 hour before sunrise
Advertisement lighting with moveable image (cd/m²)	average	400	800	1000	1500	1 hour after sunset ~ 24:00
		50	400	800	1000	24:00 ~ 1 hour before sunrise
Advertisement lighting (cd/m²)	maximum	50	400	800	1000	1 hour after sunset ~ 1 hour before sunrise
Decoration lighting (cd/m²)	maximum	20	60	180	300	1 hour after sunset ~ 1 hour before sunrise
	average	5	5	15	25	

Designation Process of Lighting Zones

There are 17 Majors/Governors (heads of 7 major cities and 10 provincial governments) and 226 local administration heads in Korea. Each Major/Governor should conduct the environmental impact assessment of light pollution on current outdoor lighting conditions. If the Major/Governor intends to designate the LZs after the environmental impact assessment, he/she shall prepare a public announcement plan and forward it to the local administration heads. The heads of local administration should publicly notify such matters as related to a district for not less than 14 days, so as to make those matters available to the general public for inspection. After that, the Major/ Governor finally announce a light pollution prevention plan and Lighting Zones with deliberation of a local light pollution prevention committee. The Major of Seoul metropolitan city (population: 10 million) has announced the enforcement of Lighting Zones in August 2015 after the assessment survey project (PI: Jeong Tai Kim, with 319 sample areas and 0.25 million Euro of fund). The biggest province of Gyeonggi-do (population: 12 million) has completed the assessment in October 2015 with 539 sample areas and 0.4 Million Euro of the field survey project (PI: Jeong Tai Kim) and is now being processed the next step.

Administrative Fines as Penalties

Any person including building owner, lighting facility manager who violates the Act shall be subject to an administrative fine. Administrative fines for negligence shall be imposed and collected by a Mayor/Governor by Presidential Decree (see Table 2).

Table 2: Administrative fines on violation

Type of violation	Amount of fines (US Dollar)		
	1st violation	2nd violation	3rd and more
Any person who fails to keep the maximum permissible standard of vertical illuminance or luminance under Article 11			
1) Below 1.5 times of the maximum permissible standard	50	500	1000
2) Between 1.5 and 2.0 of the maximum permissible standard	100	1000	2000
3) Above 2.0 times of the maximum permissible standard	150	1500	3000
Any person who fails to the local administration's order to prohibit or restrict the use of lighting facilities under Article 13(4)	2500	5000	10000
Any person who rejects, interferes or evades the entry or inspection of the relevant public officials under Article 17(1)	250	500	1000

Conclusion

The MOE has notified four recommend standards on the installation and maintenance for street, decoration, advertisement and security lighting for the practicing lighting designers and engineers, lamp manufacturers and public officials since 2013, and monitored the operation situation of the Act in Seoul, the only city that has Lighting Zones. The Act does not deliver the visible effects and expected performance at this time because the existing outdoor lighting facilities shall enter into force five years after the date of designation of Lighting Zones. However, citizens' awareness on light pollution's damage and dark sky's heritage has increased. It is believed that this Act can change the way we light Korea in the near future.

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Title: Lighting and the urban space – Illuminating the collective memory

Theme: Society

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Introduction

The research attempts to investigate ways in which lighting can be used to activate the collective memory of social groups associated with the urban space. In this perspective, lighting is being studied as a mean of creating sensory triggers, related to the history of the space. The questions constituting the starting point of this research are: In which way the collective memory could be activated through the light? How light and color could guide and recount? How could we recall memory through experiencing the urban space?

Methodologically, the paper is divided into two distinct parts, one theoretical and one compositional. The first starts with the analysis of the characteristics of the urban space, regarding the limits, the content, the quality and the concept of time in this, in order to clarify the way that the intervention in space will be perceived by the user. Having light as an artistic mean, the paper analyzes how the different visual principals of light are associated with the visual perception, in order to be able for someone to feel a previous experience.

In the compositional part, the paper attempts a study in Exarchia region in Athens-Greece, in order to identify points of the urban space that are considered to bear collective memory. Through lighting, we try to connect these individual points into a single route, where the visitor, guided by the light, could sense the history of the region. Finally, in one of the route's points we propose an artistic lighting intervention that attempts to create specific emotions to the observer. These emotions are associated to specific political conditions and collective memories of the society related to that spatial point. The objective is that the visitor is not only guided by the light but at the same time, while passing through different spaces, is moved by senses that emanates from the city's history. In this way, the light in urban space is challenging the observer to sense the presence of memory.

The proposal, works at the opposite side of the new available technologies related to artistic lighting (video mapping, projection, media façade, etc.) that use the urban space as surfaces for images' projections, as spaces for representing scenarios connected with historical events and memories of the past. Instead, we propose the organic connection of light and space. The light does not intend to illustrate a story, but to mobilize the human perceptual mechanism to handle slow sensations and visual concepts that will recall memories of the past, associated with the space.

The conclusions of the paper are related to the different roles that urban lighting can play both in terms of its contribution to the nocturnal image of the city, as well as to its use as an artistic tool. Initially, lighting can act as an element of surprise, able to trigger the visitor's interest. Through the control of the different visual principles of light, as designing parameters of every lighting composition, it is possible to guide the observer and create patterns of moving, standing or wandering. These two possibilities could be potentially associated with the role of urban space as a social space.

At the same time, the artistic use of lighting in urban spaces, could provoke particular emotions to the user-inhabitant of the city. By activating the emotions that are relate to specific political conditions and collective memories of today's society, the observer can either recall memories, or sense and wonder about the events that are associated with those memories. In this sense, the urban lighting could be used to activate the collective memory associated with the urban space.

Figures 1-4: Lighting Installations in Exarchia region- Greece. Image by Alexis Efstathopoulos

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Societal Contributions to Globe at Night Observations in the Last 10 Years
Constance E. Walker

Celebrating its tenth year, Globe at Night (www.globeatnight.org), hosted by the U.S. National Optical Astronomy Observatory, is an international citizen-science campaign to raise public awareness of the impact of light pollution. Participating citizen-scientists measure and submit their night sky brightness observations via a web app on any smart device or computer.

From the island of Malta in the southern part of Europe, to Madeira Island and the Azores west of Europe (and Canary Islands to the west of Africa) to 68.33 degrees North in Finland and Sweden, Globe at Night participants (especially in Eastern Europe) have contributed a huge amount of data points to the citizen-science campaign over the last ten years.

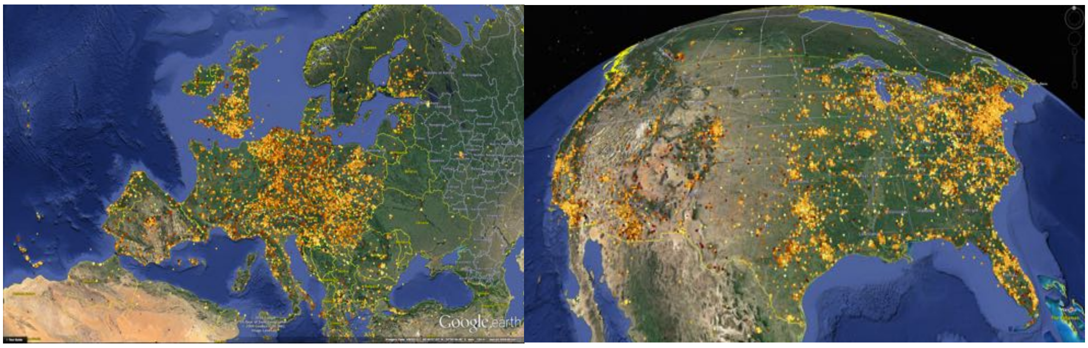

Figure 2: Ten years of Globe at Night observations in Europe and North America.

Cities in Central America that have contributed many data points to Globe at Night during the last ten years include: Mexico City, Guadalajara, Monterrey and near Cancun, Mexico; Guatamala, Guatamala; San Salvador, El Salvador; Liberia and San Jose, Costa Rica; and Panama City, Panama. The people on the island of Puerto Rico engulfed their island with at least 1500 data points.

In Chile, Talca, Concepcion, Santiago, La Serena and Coquimbo lead the way with the most contributed data points. There were many other contributions from towns surrounding the astronomical observatories. Montevideo, Uruguay takes one of the prizes for most data points in South America with over 1300 data points in 2015 alone.

For the eastern part of the USA, observations from Chicago, Detroit, Cleveland, Cincinnati, Toronto, Atlanta, Washington DC, Philadelphia, New York City, Hartford, Providence, Boston, Rayleigh-Durham, Orlando as well as other cities are seen in the USA map. For the mid-western part of the USA, observations from Chicago, Minneapolis, St. Louis, Kansas City, Oklahoma City, Dallas, Houston, Austin, San Antonio, and a little from Santa Fe as well as other cities can be seen in the map. For the western part of the USA, observations from Denver, Salt Lake City, Phoenix, Tucson, Las Vegas, San Diego, Los Angeles, San Francisco, Sacramento, Medford, Portland, Seattle, and Vancouver as well as other cities can be seen in this map. Especially note the measurements by Roland Dechesne and others in and around Calgary. In 2013 they mapped 394 data points in as many kilometers to create maps to strengthen laws.

For 2015, Globe at Night was invited to be an official citizen-science program for the International Year of Light. By the end of 2015, Globe at Night exceeded all records for the number of observations in a year, topping at over 23,000 observations from 104 countries and all 50 US states. 56% of the observations were taken with mobile devices (smart phones and tablets) versus desktops; nearly three-quarters of the mobile device measurements were made by iOS devices versus Android devices; 3 out of 5 mobile device measurements were with the Dark Sky Meter (DSM) app and 1 out of 5 mobile device measurements were with the Loss of the Night (LoN) app. (The data from both the DSM and LoN apps feed into the Globe at Night data base.) Nearly 9000 measurements included readings from the handheld Sky Quality Meters devices.

Figure 2: More than 23,000 Globe at Night 2015 campaign observations worldwide!

The overall results for limiting magnitudes from campaigns in 2015 were distributed as follows: 2030 measurements at Limiting Magnitude 1, 3285 measurements at Limiting Magnitude 2, 4827 measurements at Limiting Magnitude 3, 4290 measurements at Limiting Magnitude 4, 3410 measurements at Limiting Magnitude 5, 2759 measurements at Limiting Magnitude 6 and 248 measurements at Limiting Magnitude 7.

Twenty-two countries qualified for the “Over 100 Club” for Globe at Night in 2015. Five countries got over 1000 measurements: United States (8216), Croatia (2276), South Korea (1568), Uruguay (1455) and Germany (1363). The other Over 100 Club countries are: Poland (987), Japan (808), Chile (739), United Kingdom (669), Spain (477), Macedonia (FYROM) (423), France (404), Canada (368), Australia (324), Italy (232), Austria (179), Switzerland (159), Puerto Rico (156), Mexico (156), the Netherlands (133). Costa Rica (113) and Belgium (111).

Citizen-science is a rewardingly inclusive way to bring awareness to the public on the disappearance of the starry night sky, its cause and solutions. Citizen-science can also provide meaningful, hands-on science process experiences for students. Globe at Night will continue to do both in the decades to come.

The Quality Lighting Teaching Kit: Inspiring our Society to be Part of the Solution to Light Pollution

by Constance E. Walker & Stephen M. Pompea

Introduction: The U.S. National Observatory's Education and Public Outreach group has produced a Quality Lighting Teaching (QLT) Kit, as an outcome of the International Year of Light 2015. The kits are an integral part of a cornerstone project sponsored by the International Astronomical Union, with additional funding from the OSA Foundation. The night sky has inspired people for thousands of years. Light pollution is a by product of unbridaled expansion, slowly washing away our view of the night sky, but also negatively affecting wildlife, health, energy consumption and safety. Through the QLT Kit program, practitioners will learn how to inspire the public (mainly students) to take an active part in implementing solutions to light pollution.

The QLT Kits: The kits are designed around problem-based learning scenarios. The kit's six activities allow students to address real lighting problems that relate to wildlife, the night sky, aging eyes, energy consumption, safety, and light trespass. The activities are optimized for 11-14 year olds but can be expanded to a year younger and a few years older. Most of the activities can be done within in a few minutes with the exception of the Energy Activity. The activities can be done during class or in an afterschool program and as stations that the students rotate through or as stand-alones, one at a time.

NOAO EPO staff have made all aspects of the program as turn-key as possible for practitioners. First, everything you need to do any of the six activities is included in the kit container (e.g., 11 posters, a luxmeter, an eyechart, an animal game, a light shielding demo, a calculation mat, etc). Second, every file associated with the program can be found on the webpage, www.noao.edu/education/qltkit.php, as well as on the flash drive in the plastic box labeled "General Supplies" in the kit container. Third, tutorial videos have been created to assist you on how to do the activities. The tutorial videos can be found at the bottom of the program's webpage as YouTube links and as downloadable files. Fourth, NOAO EPO staff will offer two Google+ hangouts per activity starting in late May and ending the first week of August 2016. The hangouts will address any questions on the activities. Fifth, NOAO EPO staff have provided assessments in the form of pre- and post-surveys for the students and as post-surveys for the instructors (or practitioners).

The Premise of the Activities: The instructor is the mayor of a fictitious city in which the students live (inspired by the *City of the Future* Poster). The mayor has been receiving complaints from citizens of the city, which all have to do with the lights in the city (stated on the Issues Poster). The students have been assembled into 6 different task force groups, to determine the underlying problems expressed in each of the 6 complaint categories, as well as to come up with feasible solutions to those problems.

The students start by reading the information presented in their group's poster. The "Now Try This!" section gives instructions for an experiment, game, or activity to complete in order to gain more understanding of the problems with which they are presented. They use the materials in their box and/or envelope to complete the activity. Using what they know along with help from the *Problem Solving Poster*, the students brainstorm solutions to their problem. The students then carefully consider the implications (both positive and negative) of their solutions as well as any exceptions where their solutions may not work. They determine if there is any other information they need to better understand the problem or have better solutions. This may involve using the links provided or key ideas from the poster to research more about their problem.

After the students have completed their research and activities, they present this information to the mayor of the city and other task groups. Presentations can take many forms, such as oral (e.g. Powerpoint) presentations, posters, videos, skits, songs, brochures, or pamphlets. After all groups have presented, the instructor leads a discussion in which the groups meld their ideas together. After the presentations and discussion have concluded, a short assessment is given, mainly to evaluate student understanding and growth during the project. Note that the instructor can include, adapt or omit as much or as little of the above steps as desired.

Project Partners: Eighty-five kits have been distributed to the IAU's Office of Astronomy for Development for their Regional Nodes, International Dark-Sky Association chapters, the student chapters of The Optical Society (OSA) and the International Society for Optics and Photonics (SPIE), the National Committees of the International Commission on Illumination (CIE), the Astronomical Society of the Pacific, the International Association of Physics Students, Yerkes Observatory and the Cerro Tololo Inter-American Observatory to work with educators in their communities.

Kit Distribution: Presently there are 29 countries to which 85 kits have gone out. The 29 countries are Argentina, Armenia, Australia, Belgium, Canada, Chile, China, Colombia, Denmark, Egypt, Ethiopia, India, Ireland, Italy, Japan, Jordan, Latvia, the Netherlands, New Zealand, Nigeria, Portugal, Russia, Russian Federation of Tartarstan, Singapore, Tanzania, Thailand, United Kingdom, USA and Zambia. The countries were chosen on the basis of need, interest, dedication and commitment of the recipient or receiving organization.

Closing Remark: Like the changes in cultural perceptions and actions on smoking and littering, we use the Quality Lighting Teaching Kit as a stepping stone to bring awareness to the (younger) public on how quality lighting locally can redress light pollution issues globally. For more information, contact Connie Walker (program co-director) at cwalker@noao.edu.

The effects of different lightning regimes on activity rhythms of the eastern spadefoot (*Pelobates syriacus*)

Theme: Biology and Ecology

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Introduction:

One of the most efficient mechanisms by which organisms can predict and prepare themselves to the cyclic biotic and abiotic changes in their habitats is the biological clock, which is synchronized to the environment by the light and dark cycle, one of the most important and reliable environmental cues (2,3).

Nowadays, anthropogenic changes occur in most, if not all natural habitats. Artificial light exist in great portions of the habitats on earth, disrupting the predictability in light intensity and duration and dramatically reducing the reliability of light as a cue for predicting other environmental changes, both biotic and a-biotic. Hence, light pollution has a great potential to influence the biological clock and therefore the behavior, physiology and ecology of species.

Despite the increasing recognition of light pollutions as a threat to biodiversity (4), along with chronobiology being a well-studied growing field, and although the interaction between artificial light and the biological clock is potentially important for nature conservation and is important for creating generalizations which may have implications on urban planning policy and conservation (1), the influences of such changes in light regimes on amphibians, a class suffering from a dramatic decline in populations due to anthropogenic changes. are still barely studied.

At 2013 a breeding colony of a locally critically endangered species of toads - the eastern spadefoot (*Pelobates syriacus*) was established at the Zoological garden of Tel Aviv University. The toads were collected as tadpoles from a pond that was about to be destroyed for construction. The future tadpoles that will be produced by the breeding colony will be release in a new, artificial pond, which location and construction plans are still being developed. Artificial light surrounds most of the toad's habitats and therefore the influences of light pollution on the biology of the toads is crucial, both for its conservation and for specifying the conditions needed for the artificial pond.

Research goals:

To characterize the influence of different light intensities, spectrum and duration on activity patterns and the mechanisms underlying it in the eastern spadefoot toad.

Methods:

Randomly selected individuals from the breeding colony are being measured in individual tanks by a set of night vision cameras (IR). The measuring system documents movements in a room with controlled light, temperature and humidity. We started by describing the toads activity pattern in a 12:12 light - dark conditions, then we exposed them to continuous darkness to see the expression of their internal clock. Currently we are exposing the toads to different intensities and frequencies of light pulses in order to examine the masking and entraining effects of light pollution on those organisms.

Results:

Under a 12:12 light- dark conditions (marked by black and white bars on top of the figure) the toads are showing a classical nocturnal pattern of behavior - active during the night and inactive during the day- mostly buried under ground. When the toads where exposed to continuous darkness (marked by a continuous black bar) they showed a free running pattern with a period of about 23h and 40m, which ratify the existence of an internal oscillator that is timing the circadian activity and synchronized by the light. When the toads were exposed again to 12:12 light- dark cycle (marked by black and white bars), a strong negative masking response was documented, evident by the abrupt termination of activity when the lights were turned on, and it took the toads about 11 days to re-synchronize to the light- dark cycle. Currently we are conducting light pulses experiments for further exploring the toads masking and entraining responses to different intensities and frequencies.

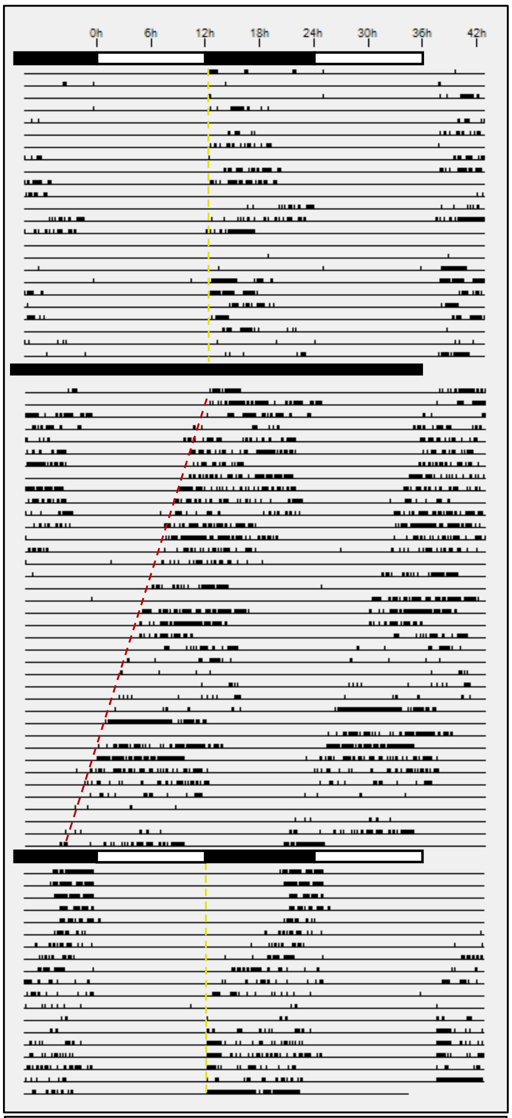

Fig 1: Double-daily plot of individual activity pattern under: 12:12 light- dark conditions (a), continues darkness (b) and 12:12 light- dark conditions (c).

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Spotlight on fish: The impacts of artificial light at night on biological rhythms of European perch and roach

Theme: Biology & Ecology

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Abstract

Light is fundamental for the existence of flora and fauna on earth. It serves not only as a source of energy but also as a source of information to organisms that drives daily and seasonal biological cycles. The natural alteration and length of day and night sets the internal clock of organisms and ensures that behavioural patterns and physical processes are synchronized with time of day and season. Thus, there is a pressing need to understand the negative effects of artificial light at night (ALAN), commonly referred to as “light pollution”, on biological processes.

Aquatic ecosystems can be strongly influenced by light pollution, as humans settle in the proximity of water ever since. In fish, many traits underlie either daily or seasonal rhythms. ALAN can interfere with rhythmical, light controlled processes by diminishing the distinction between day and night. The pineal complex is considered the major circadian pacemaker in fish, though other tissues are known to be light sensitive as well and may play a role in modulating the biological rhythm. However, for most fish it seems to be mainly the pineal organ that receives light signals, translate it to melatonin signals in a rhythmical manner and can therefore act as messenger for other parts of the organism. The melatonin rhythm reflects the current photoperiod and provides the fish with information about daily and calendar time. Light at night can suppress the nocturnal rise in melatonin and consequently may influence processes that are based on this rhythm including seasonal processes like reproduction. The aim of this work was to evaluate the effect of low intensity ALAN on the melatonin rhythm and reproduction of two of the most abundant fish species in European freshwaters.

In laboratory experiments European perch (Perca fluviatilis) and roach (Rutilus rutilus) were exposed to four different light intensities during the night, 0 lx (control), 1 lx (potential light level in urban waters), 10 lx (street lighting at night) and 100 lx (positive control, strong streetlight). Melatonin were measured from water samples of the fish tanks every three hours during a 24 hour period. Reproduction experiments were made under natural conditions in the field. Perch and roach were exposed to street light or natural (control) conditions in a net cage for four weeks in August/September. Concentrations of sex steroids were determined from blood samples and gene expression of gonadotropins was measured from pituitary tissue.

The melatonin rhythm is suppressed in both species already by the lowest intensity of white light. In the control treatment the expected rhythm of high levels in the night and low levels during the day could be observed. At all tested light intensities nocturnal melatonin concentrations were significantly lowered. Hence, the threshold light intensity for melatonin suppression must lower than 1 lx. Levels of sex steroids and gene expression of gonadotropins was significantly reduced in the light treatment. The onset of the reproductive phase in perch as well as in roach is around August, when the field experiment took place. This is in accordance to studies in other species, where a photo-labile phase was found around the onset of the reproductive phase.

In conclusion, light pollution has a great potential to impact biological rhythms of fish. The suppression of the melatonin rhythm can yield several adverse effects that are not studied so far.

Impacts on the immune system, growth and development as well as behavioural traits can influence not only individuals but whole populations. Impacts on reproduction and species specific differences in sensitivity to ALAN may cause unnatural shifts of biological niches, affect predator prey relationships and influence species communities and whole ecosystems.

Title: Behaviour of migrating toads under artificial lights differs from other phases of their life cycle.

Theme: Biology and Ecology

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Introduction

During annual spring migration in Western Europe many amphibians are killed by traffic when they cross roads moving to reproduction sites (van Gelder 1973). Especially in urban settings these roads are often equipped with street lighting. Many amphibians, including common toads (Baker 1990), are known to be attracted by light and street lighting may therefore increase the time amphibians spend on roads and thus the risk of being struck by traffic. Until now it was unknown how street lighting affects amphibian migration. In cooperation with volunteers, organised through padden.nu (Fig.1), we experimentally illuminated locations where toads are being helped to cross roads during spring migration (Fig. 2). We tested whether nocturnal artificial light affected the migration and toads were attracted to light during spring migration. By using different spectral compositions we tested if adjustment of the spectral composition could mitigate potential effects. Common toads were not attracted to the light but avoided sections that were illuminated with white or green light. Red light was not avoided compared to the dark control. Street lighting thus affects migrating toads but not as expected and red light, with low levels of short wavelength light, can be used to mitigate effects.

Fig 1: Padden.nu supports volunteers that help toads cross roads.

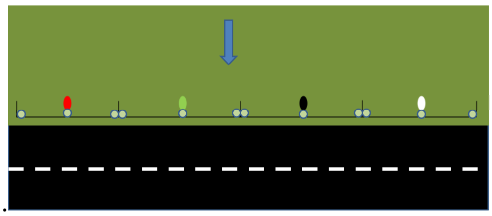

Fig 2: Schematic representation of the experimental setup.

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Title: Hortobágy National Park – an island of undisturbed nighttime environment

Theme: Society

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Introduction

Hortobágy ‐ the first proclaimed Hungarian national park ‐ is an almost flat plain landscape, a great and continuous grassland area with wetland mosaics, the most extended in its category in Europe, occupied by alkaline marshes, meadows, dry alkaline pastures and remnant loess-steppe vegetation. The National Park is not only the first, but also the biggest (82 000 hectares) Hungarian national park, also a world heritage, Ramsar site and Biosphere reserve (1).

Fig 1: The logo of Hortobágy Starry-sky Park

Hortobágy as one of the biggest unpopulated areas in Hungary has dark and pristine (almost unpolluted) starry sky. Recognizing the dark-sky value of Hortobágy, the National Park got a silver tier Dark-sky Park designation from the International Dark Sky Association in 2011 after about 2 years nomination procedure.

The dark-sky park's significance is mostly related to undisturbed nighttime landscape, the shepherd tradition related to starry sky and the protection of the high biodiversity, especially the great number of migrating bird species and special nocturnal insect species. It is notable that many of the important breeding and nesting bird species (geese, cranes, spoonbills, etc.) and other species, especially many rare insect species are light-pollution sensitive.

To be a dark sky park is an important tool to protect the nocturnal wildlife habitats as well as the landscape values of Hortobágy which is an outstanding and an unaltered wilderness area in the Great Hungarian Plain, in the middle of Europe (2).

The Park included the articles of the Lighting Plan of the Dark Sky Park to its Management Plan to protect the natural and scenic values of the undisturbed nighttime environment. The lighting regulation and zoning policy give possibility to control artificial lights within the park. The park leads light pollution monitoring across its area and a permanent SQM has been installed. A biomonitoring program of the effects on nocturnal species especially insects is under construction.

The National Park organizes nighttime stargazing walks, special interpretive programs related to the Dark Sky Park values and good lighting practices. There is a high interest by the general public to attend these night adventures. Astronomy became part of the park's Field Study Center's curriculum. Since 2015 a public astronomical observatory is part of the Center.

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Baseline lighting data for landscape biodiversity conservation

Theme: Biology & Ecology

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Introduction

As the evidence base grows for the ecological impacts of artificial lighting (Hölker 2010, Gaston 2012), there is greater expectation that these results will be of practical use for biodiversity conservation. However, a range of barriers still need to be overcome, including basic questions about where and when Artificial Light At Night (ALAN) occurs within a particular landscape. A variety of options exist for mapping ALAN, which differ in their spatial, temporal and spectral sensitivity. In addition, whilst some datasets have broad coverage and availability, others are much more restricted, with patchy coverage or logistical barriers to gaining access. We present a case study of baseline mapping of ALAN for the entire country of Switzerland to illustrate some of these issues. All potential sources of spatial lighting data have been reviewed, with the aim of developing national ecological risk maps related to ALAN. Satellite data (DMSP OLS and VIIRS) are freely available and provide good temporal information, but their low spatial and spectral resolution limits spatial analyses which aim to identify the sources, or precise locations of light pollution. At the other end of this gradient are aerial night photographs and streel lamp inventories, which provide much more information on lighting type and fine-scale location, but are limited in spatial and temporal coverage. Astronaut photography from the International Space Station (ISS) is a relatively new source of data that bridges these extremes. It can provide good spatial coverage (in this case 80% of the surface area of Switzerland), and locations are often photographed more than once (largest temporal gap in Switzerland is 3 years). Recent research has made it possible to correct these colour images for fixed effects and to radiance calibrate them (A. Sánchez de Miguel 2015), providing ecologically relevant information. At a spatial resolution of ~ 100m (for the images selected), the ground sources of lighting emissions are relatively easy to identify, and the results of an analysis using Swiss habitat/land-cover data and ISS images will be presented.

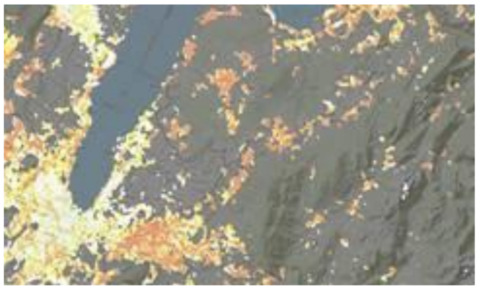

Fig 1: Geneva at night. Lamp classification based upon an ISS astronaut photograph. Data courtesy CitesatNight/NASA/ESA

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Title: Effects of different types of artificial light at night on a small mammal

Theme: Biology & Ecology

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Abstract

Natural light functions as an important zeitgeber in many animal species which use this external stimulus to adapt to predictable environmental changes throughout the day and the season (Zordan et al. 2001). The increasing spread of artificial light at night was found to have strong effects on animals leading to for example alterations in activity, body condition and reproductive behavior (Gaston et al. 2013, Schroer & Hölker 2016). However, besides the increasing spatial spread and intensity of nighttime illumination there is also a shift in spectral properties as new lighting techniques such as light emitting diodes (LEDs) emerge (Gaston et al. 2012). For example, it has been described for voles that artificial light at night modifies the daily rhythm of core temperature (Haim et al. 2005). What is lacking at this point is a well-developed understanding of how the biological impacts change with the shift of spectral properties.

Fig 1: Experimental species (bank vole, *Myodes glareolus*) with radio collar to assess activity pattern via automated radio telemetry.

In this study, the effect of artificial light at night emitted by high pressure sodium lamps and LEDs on the behavior and physiology of the bank vole (*Myodes glaerolus*) was investigated in semi-natural outdoor enclosures. The experiment aims at obtaining an in-depth look on how these two different types of nighttime illumination affect the activity pattern, foraging behavior, melatonin concentration, chronic stress level and body condition of voles. Results and implications for nature conservation will be discussed.

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Influences of exposure to different LED illumination wavelengths on activity patterns in common spiny mice *(Acomys dimidiatus)*

Theme: Biology and Ecology

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Introduction

Ecological light pollution has become a global concern, influencing most living organisms. A main issue is its influence on biological rhythms. Many biological functions show daily and seasonal rhythms. Light affects these rhythms by entraining an internal clock, or directly, by an effect termed masking. Although light pollution is receiving increasing attention, many aspects remain unstudied. These include the effects of different light intensities and wavelengths on activity levels via masking and entrainment. Both aspects were shown to influence activity levels in free-living organisms, and understanding them is essential for nature conservation and science based decision making aimed at reducing the adverse effects of light pollution.

In mammals, the biological clock resides in the SCN (suprachiasmatic nucleus) of the hypothalamus. It controls numerous functions, from gene expression to behavior, all of which show daily and seasonal rhythms. The SCN receives light input from melanopsin photoreceptors in the eye retina, synchronizing the SCN clock to its environment. The mammalian melanopsin photoreceptors are specifically sensitive to short wavelength blue light (460 – 490 nm) (*1*). Few studies investigating the effects of exposure to other wavelengths in mammals other than laboratory mice and rats have been conducted. Moreover, the masking effects of different wavelengths and the mechanism underlying it were hardly studied.

Research goals

In this study, we examine the influences of exposure to different light wavelengths and intensities during the dark on the common spiny mouse (*Acomys dimidiatus*), a nocturnal desert rodent, focusing on the effects of short daily exposure to white, red and blue led illumination on activity rhythms via masking and entraining, in order to gain a better understanding of the possible ecological effects of light pollution on the dial scale. The common spiny mouse is a nocturnal rodent found in rocky deserts. In its natural habitat, it reduces foraging activity and has higher cortisol levels during full moon nights(*2-4*) and shows both masking and entrainment response when exposed to a white light pulse during the dark phase both under laboratory conditions and in the field (*2, 5, 6*). During the years we have accomulated a larg body of information regarding its ecology and physiology. For these reasons, it forms a good model for studying the effects of different illumination wavelengths and intensities on nocturnal mammals.

Since melanopsin receptors are most sensitive to short (blue) wavelength light, we hypothesized that exposing common spiny mice to blue light will cause a response similar to white light, having a significant masking and entrainment effect. Exposure to long (red) wavelength light was expected to cause no response.

Methods

12 spiny mice were held in individual cages in 12:12 LD conditions 7:00 A.M lights on 7:00 P.M lights off. Activity levels were monitored continuously for each spiny mouse using infra-red detectors throughout the experiment. After 3 weeks of acclimation, on the first day of the each week, the spiny mice were exposed to 3 hours of white\red\blue LED light illumination (600 Lux) from 9:00 P.M - 12.00 A.M. Masking was determined by comparing activity level during the light pulse compared to activity level the night before during the same time, entrainment was determined by comparing activity onset during the nights before each pulse, to the night after the pulse.

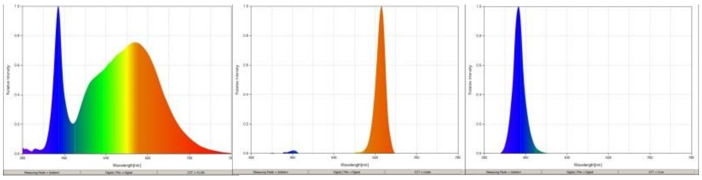


Fig.1: Spectral distribution used for the pulses. Right to left: white pulse, red pulse and blue pulse.

Results

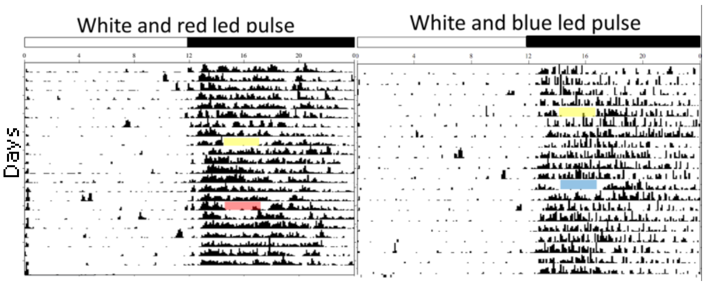
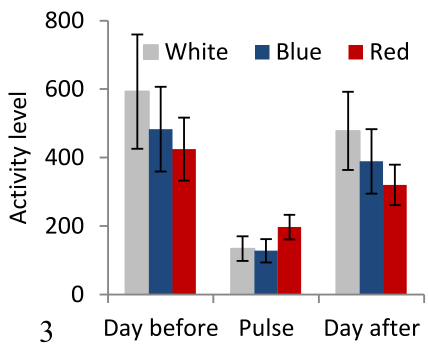


Fig.2: Examples of actograms depicting masking and entraining influences of white, blue and red led illumination (600 lux) on activity levels. Bar on top or the actogram represents light (white) and dark (black) hours. Light pulses are indicated by boxes (yellow- white pulse, red – red pulse, blue – blue pulse).



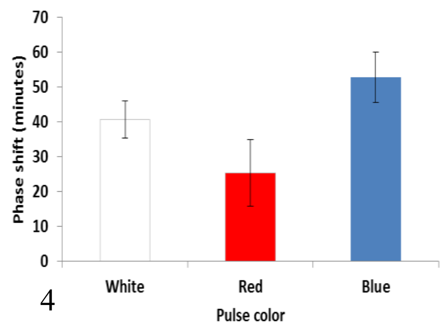


Fig.3: Masking influences of white, blue and red led illumination, N=8. All three light wavelengths caused a significant reduction in activity levels during the light pulse (masking response).

Fig.4: Entraining influences of white, blue and red led illumination, N=8. All three light wavelengths caused a significant phase shift, with activity starting 30 - 50 minutes later the day after the light pulse.

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The First Dark Sky Park in Asia: Yeongyang Firefly Eco Park in South Korea

Theme: Biology & Ecology

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Introduction

Economic growth and more time spent on leisure and cultural activities are bringing about an increased interest in the importance of the ecological environment and eco-friendly living. This change in interest stimulates local governments to plan on protecting the ecosystem and boosting local tourism. With this context, Yeongyang International Dark Sky Park, the first designated in Asia, draws great attention from other local governments in Korea. This paper introduces the case of Yeongyang County.

Fig 1: Asia » South Korea » Yeongyang Firefly Eco Park

Designated: 31 October 2015
Category: Dark Sky Park(Silver Tier)
Address: Yeongyang, South Korea
Land Area: 3.9 Km^2

Geographical Location

Yeongyang Firefly Eco Park is a 390-hectare site in Yeongyang County, an administrative region of North Gyeongsang Province in the most eastern part of South Korea. Situated in the valley of the Wangpi River, the park is surrounded by mountainous terrain, making the land difficult to farm (See Fig. 1).

The Goal of the Local Government

Through the designation of IDA International Dark Sky Park (IDSP), Yeongyang County has had the goal of maintaining the stability of the ecosystem and securing a healthy image of the region by efficiently managing lighting systems. The county also aims to change its negative image as a back country into a positive one by acquiring international recognition of the area's clean and pure night sky.

Local Government Processes for IDSP Nomination

- September 2013: Commissioned a research project on a plan to boost eco-tourism through designation of the region as an IDSP
  (This project was conducted by Prof. Wonkil Jeong as PI.)
- October 2013: Discussed Korea members's visitation to the IDA headquarters in the USA
- January - September 2014: Reviewed the applications of designated IDSPs around the world and prepare standards.
- October - November 2014: Visited by officials of the IDA headquarters; held discussion and hosted a seminar

• June 30, 2015: Prepared final report
• October 2015: Nominated Yeongyang Firefly Eco Park, as a Silver-tier International Dark Sky Park

Recent Activities of the Local Government after designation

Yeongyang County set IDSP as a newly developing brand and invited the public and local residents to join in a prize contest for ideas. It is continuously working on related projects.
• Developed and implemented plans for outdoor lighting management
• Carried forward international exchange with 28 local governments designated as International Dark Sky Parks
• Trained professional guides and multicultural family guides for foreign visitors
• Carried out positive attitude education courses for the local residents
• Opened auto-camping sites
• Completed the building of the National Endangered Species Restoration Center
• Improved accessibility by opening a highway connection
• Communicated with the county residents in real time via SNS (20~35% increase of friends, fans, and followers)
• Engaged in active media promotion of IDSP
• Hosted a free access on the commemoratory observatory event
• Built the National Wild Vegetable Food Cluster, a national project for the region
• Created a synergy effect by developing the Center for Mountain Village Culture Experience and the wind farm as tourist destinations
• Worked with an astronomical enterprise toward attracting projects and related research institutes for astronomical studies
• Held a national photo contest to celebrate the designation of IDSP (See Fig. 2)

Fig 2: National photo contest poster

• Invited the public to join in an idea competition for tourism products related to IDSP
• Invited the public to join in an idea contest for experience programs

Conclusion

For autonomous management and operation of the park, the local residents founded a private, non-profit organization called the Yeongyang International Dark Sky Park Association. After the designation of the IDSP tourists increases and the county is preparing to enact municipal ordinances of outdoor lighting. Recently several local governments show an increased interest in the designation of IDSP advance clean sky environment at night.

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Title: Dark corridors: accounting for light pollution in connectivity modelling for urban bats

Theme: Biology & Ecology

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Introduction

Light pollution constitutes a major threat to biodiversity and especially to nocturnal species. Indeed artificial illuminations cause habitat loss and fragmentation as they represent a barrier to animals movement and decrease the quality of habitats. In order to preserve and recreate structural connectivity between fragmented habitats, European Environmental policies aim at restoring ecological corridors, i.e. green infrastructures (semi natural vegetation). However, those corridors are mainly based on landscape criteria and light pollution is not taken into account which can greatly affect their efficiency for nocturnal fauna such as bats. In this study we aimed at representing potential « dark corridors », i.e. corridors accounting for light pollution, and identifying areas of prior concern that need to be preserved or restored to have a connected landscape. We compared the activity of light sensitive and light tolerant bat species in three large cities of France presenting a variety of urban landscapes. For each city and each bat species group, we built two fine resolution models predicting bat activity with environmental variables, one taking into account light pollution and the other not. We tested different light variables based on either a geolocation of street lamps or a satellite photo taken at night. We then used the predictions to model the connectivity according to the Least-Cost Path modeling technique and represented the resulting corridors. The methodology developed in this study allows to represent functional "dark corridors" taking into account light pollution. Associating those results to the existing ecological corridors could help making them more efficient for nocturnal species. This technique could also be used to explore the impact of specific public lighting management plans to prevent a rupture in the connectivity or help to restore a connection.

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Light pollution affects body mass and oxidative status in free-living nestling songbirds: an experimental study

Theme: Biology and Ecology

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ABSTRACT

Light pollution or artificial light at night (ALAN) is an increasingly important anthropogenic environmental pressure on wildlife, affecting animal behaviour and physiology. Since early life experiences produce effects that can persist throughout life, light exposure during development may have profound effects.

Here, we experimentally investigated for the first time the impact of ALAN on body mass and multiple metrics of both oxidative damage and antioxidant defences during development, using nestlings of a free-living songbird, the great tit (*Parus major*). Body mass and oxidative status were determined at baseline (13 days after hatching) and again after a two night exposure to ALAN.

Light exposed nestlings showed no increase in body mass, in contrast to unexposed individuals (Figure 1). Furthermore, there were sex-specific effects of ALAN on enzymatic antioxidants. In females, glutathione peroxidase (GPX) activity increased in the control group but not in the light group. In males, ALAN caused an increase in catalase (CAT) activity.

Our study provides rare experimental field evidence that ALAN negatively affects free-living nestlings development, which could have adverse consequences lasting throughout adulthood.

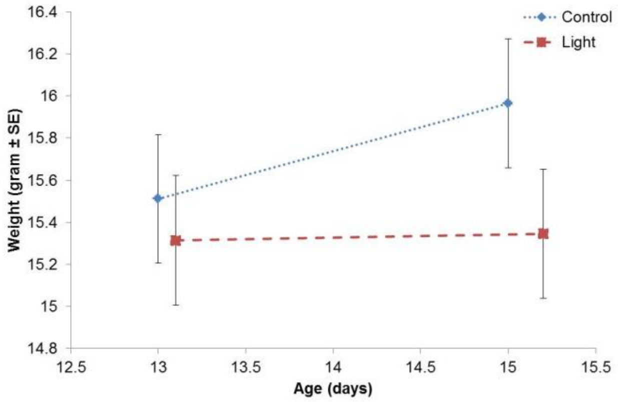

Figure 1 Effect of artificial light at night on nestling body mass. Estimates were obtained from linear mixed models with individual (*N* = 224) nested in nest (32) as random factor. Nestlings in the control group gained body mass between day 13 and day 15 (*t* = 7.41, *P* < 0.001) contrary to individuals in the light group whose body mass did not change (*t* = 0.047, *P* = 0.6; Raap et al. 2016).

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Long-term population effects of experimental artificial illumination of a forest edge ecosystem

Theme: Biology & Ecology

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Introduction

Across different species and taxa, a variety of direct responses to artificial light are known, such as attraction or deterrence by light and changes in behaviour and physiology. These effects can directly impact individuals but the effects of artificial light on long timescales and at the population level are however virtually unknown. Although we would expect that the effects on the individual level of different species must – eventually – have consequences on the population and ecosystem level (Fig. 1), almost no data exist. With the global increase in artificial illumination, it is crucial to better understand these responses of ecosystems to a prolonged presence of artificial light.

With the LED revolution it has now become feasible to illuminate the environment with light of any spectrum. In the Netherlands there are already roads that are illuminated with green light as this may reduce any negative ecological consequences of ALAN. But little research has been done on the effect of lamps with different spectral composition (but see Spoelstra et al., 2015).

To experimentally address these questions we have set up experimental lighting with light posts with different spectral composition (white, green, red lights and a dark control) in a forest edge habitat at eight different locations in the Netherlands. We have monitored the presence of many species of birds, bats, mammals, moths, insects and plants on these locations for the past six years. The presence of the species has been assessed with

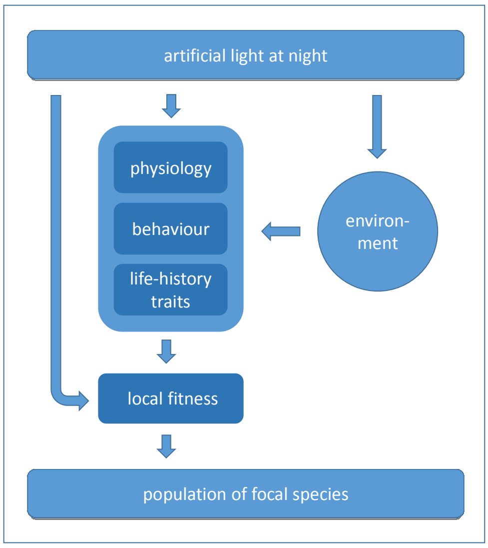

Fig 1: Flow-chart on how artificial light may affect species at the population level. The most direct way is immediate impact on the survival of the individual (left arrow). However, light may have effects on the physiology, behaviour and life-history traits of the individual. For example, if light leads to untimely reproduction causing high juvenile mortality, fitness is affected and hence population size may decrease. Effects of light on the environment of a species may cause even more indirect effects on fitness of a species. These effects include general habitat changes, and cascading effects, for example by the availability of prey species which may themselves be affected by all possible routes shown. From Spoelstra et al. 2015.

standardized protocols repeated in consecutive years, with data collected by scientists and with a citizen science based approach.

Our results clearly show a strong variation in responses of species and species groups to the presence of artificial light and a progression in the response of species to prolonged presence of light. The key challenge is to distinguish direct form indirect effects of ALAN on populations. We will present the first results of ecosystem wide analysis and will discuss how modifying the spectra of the lighting can be used to reduce any negative impact on species.

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