ALAN 2018

5th International Conference on *Artificial Light at Night*

November 11-14 Snowbird, Utah

Conference Handbook

Millions of meteors burn up every day as they enter our atmosphere. As a result, Earth receives ten tons of dust from outer space. Not only do we take in the world with each breath, we are inhaling the universe. We are made of stardust.

-Terry Tempest Williams
When Women Were Birds

ALAN

International Organizing Committee

Christopher Kyba
GFZ German Research Centre for Geosciences, Germany

Dietrich Henckel
Technische Universität Berlin, Germany

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Consortium for Dark Sky Studies

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University of Utah Graduate School, Department of Physics and Astronomy, Co-Director Consortium for Dark Sky Studies

Stephen Goldsmith
University of Utah Department of City and Metropolitan Planning, Co-Director Consortium for Dark Sky Studies

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International Dark-Sky Association

Booklet Design by Bettymaya Foott and Ariadna Garcia
Photos: Bettymaya Foott

ALAN 2018

Sponsors

Cosmos: for making Alan 2018 possible

Galaxy: underwriting the Celebratory Dinner

Star: support of student and diversity registration

In-Kind Support

ALAN

UTAH: THE BEEHIVE STATE AND THE BEEHIVE CLUSTER

Utah is one of only two states to have a state astronomical symbol.

In 1996, on the one-hundredth anniversary of statehood, the Utah Legislature passed a bill designating as the state astronomical symbol an open-cluster of stars (in Cancer) known as the Beehive Cluster.

"This symbol, composed of a hive of stars, transposes our beehive symbol to a new and grand level as we enter our second century as a group of people living in a place where we can still see, with our own eyes, the beautiful and dim features of the starry universe."

The Consortium for **Dark Sky Studies**™ at the University of Utah

12 November 2018

On behalf of the Consortium for Dark Sky Studies, we are pleased to welcome you to Utah and the beautiful blue skies and starry night skies of the Intermountain West.

The State of Utah has more recognized dark sky parks than any state or country other than the U.S. in the world. Utah forms the centerpiece of what is known as The Great Western Starry Way: nearly 60 dark sky parks and places from the Canadian to Mexican border, accredited or in-process by the International Dark-Sky Association.

We meet at the Snowbird Ski Resort in the glacier-sculpted Wasatch Range, the dramatic mountain interface between the Rocky Mountain highlands to the east and the Great Basin Desert to the west. The renowned "snow of Snowbird" is made possible by predominant weather patterns; desert winds pick up moisture from the Great Salt Lake, and the uplift of the Wasatch Range causes the annual deposit of an average of 500+ inches of snow. Snowbird's Cliff Lodge (elevation 7,760 feet) is a prime beneficiary of this weather pattern, while the summit of Hidden Peak (elevation 11,000 feet), receives a fine, light powder that has been called "The Greatest Snow on Earth."

Located on the foothills of the Wasatch in Salt Lake City, the University of Utah, a Tier One Research University, has taken advantage of its unique, strategic location to develop internationally recognized academic programs and research centers that explore the interconnectedness of life in limited-resource environments.

The Consortium for Dark Sky Studies is a part of that broader undertaking and carries a corresponding objective: to explore the interconnectedness of life in one of the last great reservoirs of dark sky in the developed world. We use a highly interdisciplinary and research-based approach--developing integrated management, engineering, and planning initiatives to understand the value of dark skies and assist in the preservation and restoration of this valuable natural resource. We also seek to work with international partners to advance a global understanding of the importance of dark skies and develop solutions that are matched to the distinct socioeconomic, political and environmental systems encountered around the world.

We welcome you to the work of ALAN 2018 with a keen sense of kindred spirit. We look forward to exploring common interests and insights, from the environmental and economic value of dark skies to the health of our communities and countries. We seek to develop with you a deeper understanding of the contribution of dark skies to global cultural legacies, the broader human spirit, and our collective future.

With anticipation and warm regards,

Dave Kieda and Stephen Goldsmith
Co-Directors, Consortium for Dark Sky Studies

The Consortium for
Dark Sky Studies™
at the University of Utah

Local Organizing Committee: Collaborative Research

The Consortium for Dark Sky Studies
University of Utah

The Consortium for Dark Sky Studies (CDSS) is dedicated to the discovery, development, communication, and application of knowledge across a wide range of disciplines and professional fields pertaining to the quality of night skies, growing light pollution and the varied human, animal, and environmental responses to the "disappearing dark."

CDSS is an academic center, based at the University of Utah (formal recognition in 2017), with numerousaffiliated colleges/universities and a decidedly trans-disciplinary approach.

Disciplines and departments include: Anthropology, Architecture, Fine Arts, Astronomy, Atmospheric Sciences, Biology, Business Management and Public Administration, Chemistry, Economics, Education, Engineering, Environmental Humanities, Environmental and Sustainability Studies, Geography, Geosciences, Health Sciences, Law, Multi-disciplinary Design, Parks Recreation and Tourism, Physics, Political Science, Psychology, and City & Metropolitan Planning.

CDSS invites interest from ALAN 2018 participants in collaborative research across all disciplines.

Email: janet.e.muir@gmail.com

Dear ALAN participants,

On behalf of the international steering committee, it's my pleasure to welcome you to the **5th International Conference on Artificial Light at Night.** It looks like ALAN 2018 might be our most exciting conference yet, and for that we must thank all of the attendees who have submitted abstracts for presentations.

In the time since ALAN 2016, the field of artificial light at night research has continued its rapid expansion, and many of this year's attendees will be joining us for the first time. As we grow, it is important to the steering committee that ALAN maintains a welcoming environment. We want to be a conference where people who are new to the field find it easy to make professional connections. We hope those connections will help to advance their careers, and that some of the informal discussions will eventually lead to new and exciting ALAN research.

In order to maintain a welcoming atmosphere, the steering committee is issuing two challenges to the attendees. The first is the "Pac-Man" challenge. Whenever you are having a discussion with n people, try to arrange yourself as if there were n+1 people involved in the discussion – in other words, instead of forming a closed circle, form an open circle with a pac-man shape. This will signal that you are open to having another attendee join you. The second challenge is the "introduction" challenge. If this is your 2nd ALAN conference, try to introduce yourself to at least two people you've never met per day. If it's your 3rd ALAN, try to meet 3 new people per day, and so on.

At ALAN, we strive to encourage broad participation in the Q&A and discussion periods after the talks. This year, we have decided to try an experiment with allowing audience members to ask questions using an online form. The chairs will usually ask one or two of the submitted questions before asking audience members to raise hands for further questions. We hope that this will both increase the total number of questions that can be asked, and offer participants a low stress way to pose questions. You can find the form to submit online questions here: **http://tinyurl.com/alan2018q**

The hashtag for the conference is **#ALAN2018**. If you do not want audience members to live tweet your talk, please make this clear at the start of your presentation.

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 welcome your help in identifying extraordinary researchers and practitioners who's work deserves greater attention, especially those from outside of Europe and North America, those 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 conference wouldn't exist without your participation.

Sincerely,

Christopher Kyba
Chair of ALAN steering committee

LPTMM 2019

Light Pollution Theory, Modelling, and Measurement

25-28 June 2019
Zselic Valley Leisure Farm, Hajmás, Hungary

Invited speakers:
John Barentine
Xi Li
Andreas Jechow
Jaime Zamorano
Tomasz Ściężor

http://lptmm.org/

ONLINE

ALAN RESOURCES

COMMUNITY

ALAN Research database

http://alandb.darksky.org/

LPResearch mailing list

Sign up by sending a mail to:

lpresearch-subscribe@yahoogroups.com

International Dark Sky Association

darksky.org

Consortium for Dark Sky Studies

darkskystudies.org

LPTMM Conference

darkskystudies.org

ALAN Conference

artificiallightatnight.org

DATA

VIIRS DNB data online visualization

lightpollutionmap.info/

VIIRS DNB data download

ngdc.noaa.gov/eog/viirs/download_dnb_composites.html

Astronaut Photographs

www.citiesatnight.org

World Atlas of sky brightness floating point data

http://doi.org/10.5880/GFZ.1.4.2016.001

VIIRS DNB overpass time predictor

www.ngdc.noaa.gov/eog/viirs/predict/

VIIRS DNB nightly mosaics viewer

maps.ngdc.noaa.gov/viewers/VIIRS_DNB_nightly/

Viewing/accessing Globe at Night data

www.myskyatnight.com/

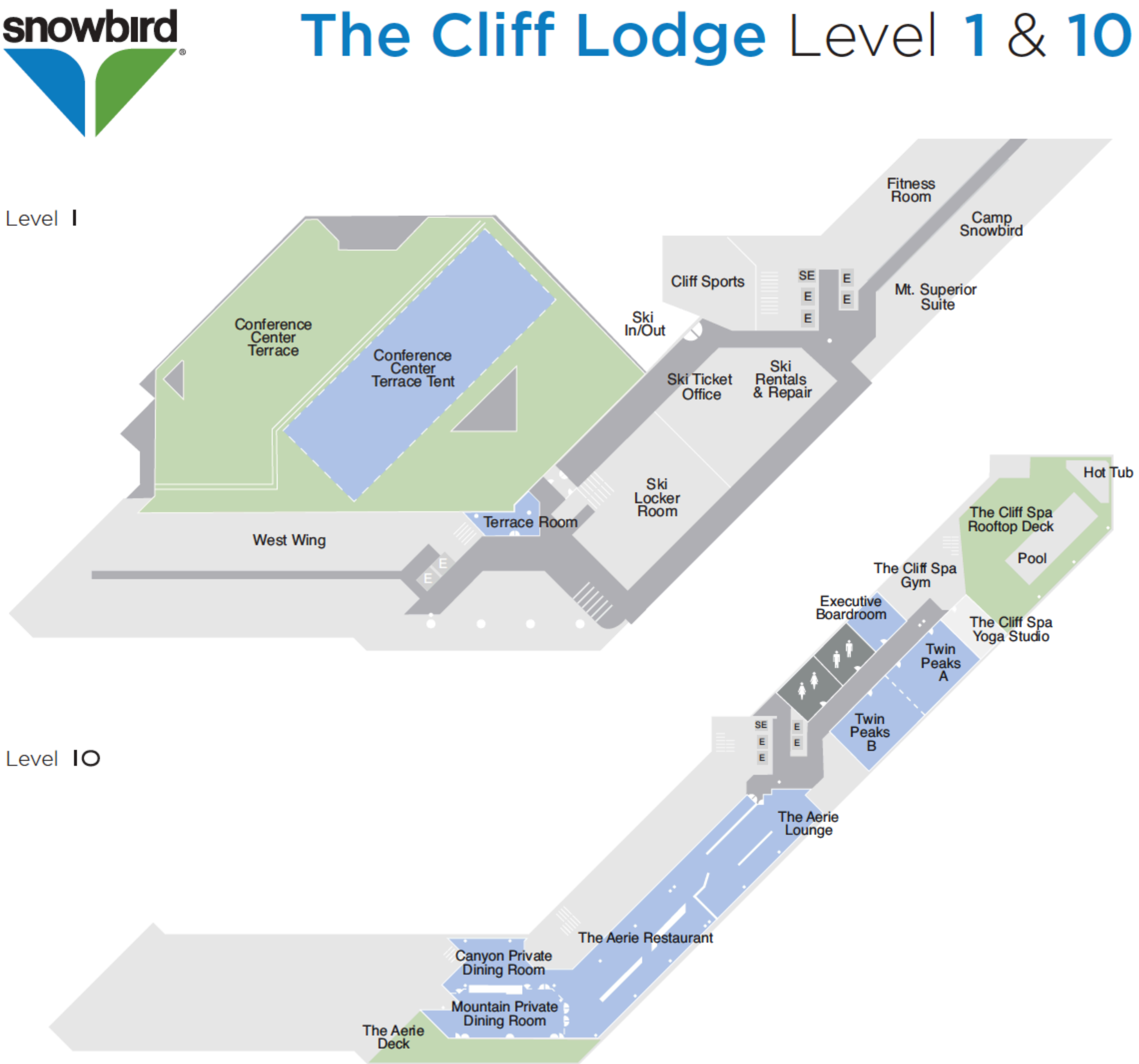
Sunrise/sunset calculator

www.timeanddate.com/sun/

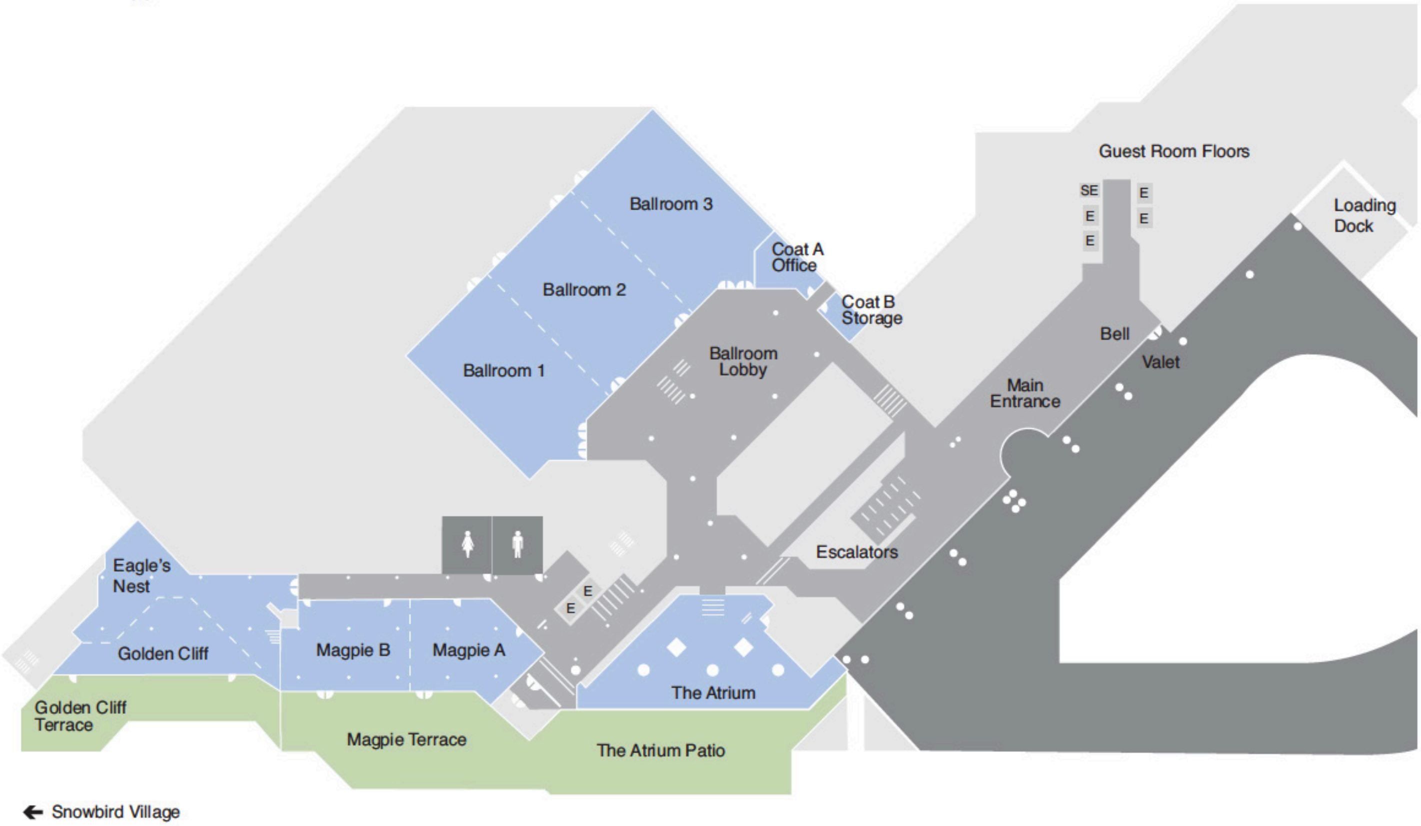
Moonrise/moonset calculator

www.timeanddate.com/moon/

Getting Around



The Cliff Lodge Lower Level L1



The Cliff Lodge Lobby Level L

11

SUNDAY

11

REGISTRATION

Lobby/Ballroom 1

12:00 - 18:00 PM Snowbird Ski and Summer Resort

SKYGLOW PROJECT

Ballroom 1

16:00 - 18:00 PM Event open to the public!

After a grueling three-year journey of over 150,000 miles traveled and 3,000,000 pictures taken, renowned timelapse filmmakers Harun Mehmedinovic and Gavin Heffernan are proud to show you SKYGLOW; a timelapse video series exploring North America's remaining magnificent night skies and the grave threat of light pollution to our fragile environment. SKYGLOW explores the history and mythology of celestial observation, the proliferation of electrical outdoor lighting that spurred the rise of the phenomena known as "skyglow," and the Dark Sky Movement that's fighting to reclaim the night skies.

RECEPTION

Golden Cliff

18:30 - 20:00 PM Evening mixer

11

MONDAY

12

REGISTRATION

7:30 - 8:45 AM	Poster setup	Ballroom 2
8:45 - 9:00 AM	Session Chair Meeting	Cirque

OPENING SESSION

Ballroom 1

Chair: John Barentine

9:00 - 9:25 AM	Welcome to ALAN and Utah
9:25 - 9:50 AM	**Alan Matheson Jr.** Utah Department of Environmental Quality
9:50 - 9:55 AM	**Rebecca Dilg** Utah Governor's Office of Economic Development
9:55 - 10:15 AM	**Daniel Mendoza** Urban Emissions and Nightlights
10:15 - 10:35 AM	**Sara Pritchard & Erin McLaughlin** Describing artificial light at night: Keywords in light pollution literature and why they matter
10:35 - 10:50 AM	**Dave Kieda & Stephen Goldsmith** The University of Utah Consortium for Dark Sky Studies

10:50 - 11:10 AM	Coffee Break	Ballroom 2

TECHNOLOGY & DESIGN

Ballroom 1

Chair: Nancy Clanton

11:10 - 11:25 AM	Poster Session Elevator Pitches
11:25 - 11:50 AM	**Vellachi Ganesan** From Singapore to Salt Lake City: Perspectives of Lighting and Darkness Design
11:50 - 12:10 PM	**Bob Adams** Letting the Stars Shine
12:10 - 12:30 PM	**Bruce Kinzey** Decoupling Outdoor Lighting from Sky Glow
12:30 - 12:40 PM	Discussion and Conclusion
12:40 - 13:45 PM	Lunch
13:45 - 15:30 PM	POSTER SESSION 1
15:00 - 15:30 PM	Coffee Available

SESSION 1

POSTERS

SESSION 1

POSTERS CONT.

Nicole Rodriguez Cavero	Using Astronomical CCD Imagery Techniques for the Study of Urban Light Domes at a Small College	**P 33** A13
Salvador J. Ribas	Interaction of clouds and fog with the measure of Night Sky Brightness	**P 35** A14
Sharolyn Anderson	The All-sky Light pollution Ratio (ALR) characterized using field data and modeled VIIRS data	**P 37** A15
Stan Moaraf	Artificial light at night increases survival of new neurons and suppresses melatonin in birds	**P 38** A16
Susanne Stephan	Effects of skyglow on physiology and diurnal rhythm of phytoplankton strains	**P 40** A17

NOTES:

	MIXED SESSION	LIGHTING REGULATION
	Ballroom 1 Chair: Kellie Pendoley	Maybird Chair: Sibylle Schroer
15:30 - 15:50	**Oren Levy** Coral reproduction and the timing of spawning in the era of rapid urbanization and ecological light pollution (ELP)	**Martin Morgan-Taylor** The Island of Saint Helena as an example of Metrics Based Legislation to Address Artificial Light at Night Problems and to Promote Dark-sky Tourism
15:50 - 16:10	**Andreas Jechow** Winter (and arctic) light pollution: a new frontier?	**Benedikt Huggins** Legal restrictions on artificial light at night
15:50 - 16:10	**Adam Mitchell** LED Lighting: Fighting the brightening on turtle nesting beaches	**Sébastien Giguère** 10 years of social engagement: lessons from Mont-Megantic's International Dark-Sky Reserve
16:30 - 16:50	**Jeremy White** A citizen science approach to quantify illuminance levels of sea turtle habitat in Gulf Islands National Seashore	**Nancy Clanton & April Stevenson** Helping Communities Develop a Lighting Ordinance
16:50 - 17:00	**Discussion and Conclusion**	**Discussion and Conclusion**

17:00 - 18:30 Optional Open Discussion in Poster Room **Ballroom 2**

17:15 - 18:15 Workshop: Discussion of light assessment in epidemiological studies

19:00 **MIXER AND STARGAZING**

Twin Peaks/Pool Level 10

11

TUESDAY

13

SOCIETY

Ballroom 1

Chair: Dietrich Henckel

9:00 - 9:25 AM	**Josiane Meier** Contentious Lighting: Understanding Lighting Conflicts
9:25 - 9:40 AM	**Poster session elevator pitches**
9:40 - 10:00 AM	**Andreas Hänel** From Research to Practice: ALAN in Star Parks in Germany
10:00 - 10:20 AM	**Noelle Glines-Bovio** Best Management Practices for Mitigating Social and Ecological Impacts of Artificial Lighting at Night on BLM-Administered Lands
10:20 - 10:40 AM	**Megan Bonham** Representing the Night Sky: Examining the Roles of 'Lay Experts' and Sensory Experiences in Dark Sky Preservation
10:40 - 10:50 AM	Discussion and Conclusion
10:50 - 11:10 AM	Coffee break - **Ballroom 2**

PARALLEL SESSION

Time	MEASUREMENT AND MODELING	BIOLOGY AND ECOLOGY
	Ballroom 1 Chair: Salvador Ribas	Maybird Chair: Liz Perkin
11:10 - 11:30	**Brian Espey** Monitoring public lighting in Ireland: using space imagery and lighting inventories	**Anat Barnea** Artificial Light At Night Increases Neurogenesis And Suppresses Melatonin In Birds In A Dose-dependent Manner
11:30 - 11:50	**Geza Gyuk** NITELITE: a High-Altitude Balloon (HAB) framework for angularly dependent temporal sensing of light pollution	**Cecilia Nilsson** Migratory birds' exposure to artificial light at night at the continental
11:50 - 12:10	**Kai Pong Tong** Characterizing local properties of artificial light at night	**Itay Malek** Reproductive and Body Mass Responses of Australian Budgerigars (Melopsittacus Undulatus) to Short Wavelength ALAN Exposure: Is it an exceptional Avian Model?
12:10 - 12:30	**Zoltán Kolláth** Spectral survey of sky quality	**Kamiel Spoelstra** Rhythms in the dark: direct and systemic impact of light at night on temporal organization of activity
12:30 - 12:40	**Discussion and Conclusion**	**Discussion and Conclusion**

12:40 - 14:00	Lunch
14:00 - 15:30	Poster Session 2 - **Ballroom 2**
15:10 - 15:30	Coffee Available

SESSION 2

POSTERS

SESSION 2

POSTERS CONT.

Kornél Kolláth	Monitoring the night sky at Lake Balaton	**P 93** B14
Paul Marchant	Major Errors in Research on Lighting and Public Safety	**P 95** B15
Roland Dechesne	Integrated study of Sky Glow, Calgary, Alberta, Canada	**P 97** B16
Randy Nelson	Disruption of endogenous circadian rhythms by exposure to light at night accelerates pancreatic tumor growth in mice	**P 99** B17
Bryant Buchanan & Sharon Wise	The effect of artificial light at night (ALAN) on activity patterns of a nocturnal salamander	**P 101** B18

NOTES:

	MIXED SESSION	BIOLOGY AND ECOLOGY
	Ballroom 1 Chair: Constance Walker	Maybird Chair: Susanne Stephan
15:30-15:50	**Benjamin Banet** From Brighter than the Moon to Dimmer than the Stars: Hemispherical Photography of Nighttime Illumination Across the American West	**Franz Hölker** Illuminating lakes: assessing skyglow effects in ecosystem-scale experiments
15:50-16:10	**Rosalía Lugo** Youth Organization for Lights Out: Engaging Chicago Youth in Light Pollution Research and Activism	**Franziska Kupprat** Melatonin concentrations are decreased by very low intensities of artificial light at night in European perch (Perca fluviatilis)scale
16:10-16:30	**Sibylle Schroer** STARS4ALL – Citizen science to save European nightscapes	**Simone Giavi** Street lamps disrupt flower-visitor interactions beyond the illuminated area
16:30-16:50	**Roland Dechesne** What Went Wrong? The Failure of New York City's Crime-Reducing Lighting Scheme	**Elizabeth Perkin** Stream Insect Acclimation to ALAN
16:50-17:00	**Discussion and Conclusion**	**Discussion and Conclusion**

19:00

Celebratory Dinner

Welcome from Lumican CEO David Mitchell

Keynote: Shirlee Silversmith, Utah Division of Indian Affairs

11

WEDNESDAY

14

HEALTH

Ballroom 1

Chair: Chris Kyba

9:30 - 9:55 AM	**Eva Schernhammer** Night shift work, cancer risk, and beyond: new insights from epidemiological studies
9:55 - 10:15 AM	**Manolis Kogevinas** Artificial light at night (ALAN), blue light spectrum exposure and colorectal cancer risk in Spain (MCC-Spain study)
10:15 - 10:35 AM	**Kristan Aronson** Residential outdoor light at night and breast cancer risk in Vancouver, British Columbia
10:35 - 10:45 AM	Discussion and Conclusion
10:45 - 11:05 AM	Coffee break - **Ballroom 2**

MEASUREMENT & MODELING

Ballroom 1

Chair: Li-Wei Hung

11:05 - 11:30 AM	**Ron Gibbons** The Balance of Roadway and Outdoor Lighting
11:30 - 11:50 AM	**Ranjay Shrestha** NASA's Black Marble nighttime lights product suite
11:50 - 12:10 PM	**Rémi Boucher** IDA's first International Dark-Sky Reserve is 10 years old: Monitoring the evolution of night sky brightness over Mont-Megantic's protected dark sky
12:10 - 12:30 PM	**Christopher Kyba** A proposed method for estimating regional and global changes in energy consumption for outdoor lighting
12:30 - 12:50 PM	**Hector Linares** Modelling the night sky brightness and light pollution sources of Montsec protected area
12:50 - 13:00 PM	Discussion and Conclusion
13:00 - 14:20 AM	Lunch and take down posters

BIOLOGY & ECOLOGY

Ballroom 1

Chair: Franz Hölker

14:20 - 14:45 PM	**Neil Carter** Effects of artificial light at night on wildlife habitats: integrating science with decision-support tools
14:45 - 15:05 PM	**Jeffrey Buler** Nocturnally-migrating birds traverse Earth's most light-polluted regions, and bright lights confound their habitat use en route
15:05-15:25 PM	**Tim J. W. Walles** Zooplankton response to "skyglow" revealed by high-resolution in-situ video in large experimental lake enclosures
15:25-15:35 PM	Discussion and Conclusion
15:35-15:40 PM	**Announcement of ALAN 2020**
15:40-15:45 PM	**Conference wrap up**

TABLE OF CONTENTS

Urban Emissions and Nightlights

Theme: Health

Daniel L. Mendoza,[1,2] John C. Lin,[2] and Robert Paine[1]

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[2] Department of Atmospheric Sciences, University of Utah, Salt Lake City, U.S.A.
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Introduction

Nightlights have been used as a proxy to characterize a region's economic activities. Multiple metrics have been derived from nightlight satellite imagery, including population density, electricity consumption (Proville, Zavala-Araiza, & Wagner, 2017), and carbon dioxide (CO_2) emissions (Oda & Maksyutov, 2011). However, there has been limited work focusing on the association between night lights and health related criteria pollutants at a high resolution.

The Hestia emissions data product (Gurney et al., 2012) was developed to resolve CO_2 emissions at a high resolution (hourly and building, road segment, and individual point source scale) for multiple U.S. cities. Patarasuk et al. (2016) described the development of Hestia for Salt Lake County. Further recent work has developed a similarly-scaled emissions inventory for nitrogen oxides (NO_x) (Figure 1), fine particulate matter ($PM_{2.5}$) (Figure 2), and carbon monoxide (CO).

In this study we compared the annual spatial distribution of Hestia 2015 $PM_{2.5}$ and NO_x emissions to the radiance obtained from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day Night Band (DNB) product (Wang, Qiu, NOAA Ocean Color Team, & Office, 2012) for 2015.

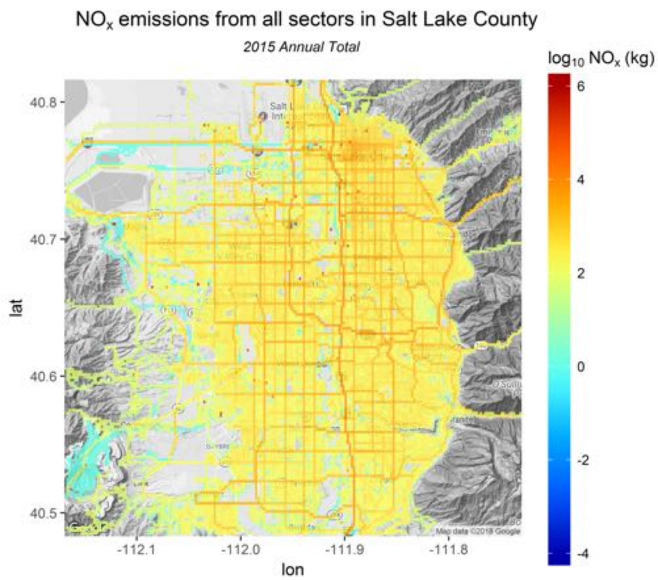

Figure 1. Salt Lake County nitrogen oxides emissions

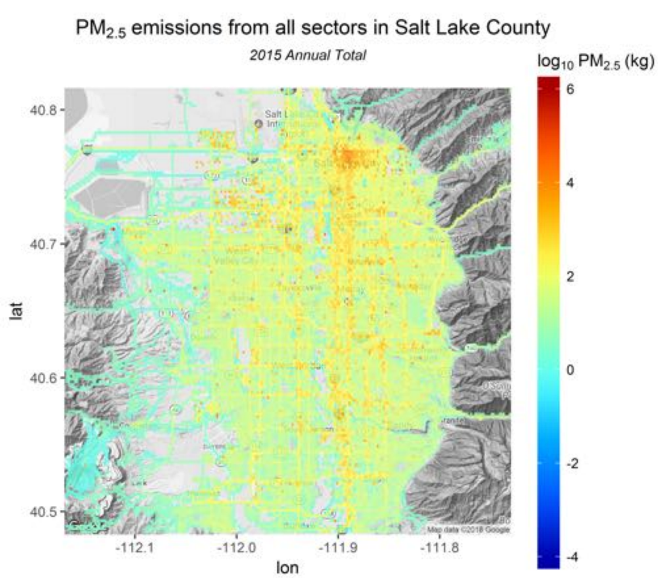

Figure 2. Salt Lake County fine particulate matter emissions

We found a spatial association between the patterns of radiance and emissions. Since NO_x is primarily emitted by mobile (onroad and nonroad) sources, and $PM_{2.5}$ is primarily emitted by point sources, their different, but complementary spatial patterns, resulted in a composite comparable to the observed nightlights. Furthermore, the magnitude of emissions corresponded well with the radiance magnitude. These results will provide guidance for the use of nightlights as additional indicators of health-related pollutants and pollution hotspots.

Future work will focus on the comparison of nightlight radiance with emissions of other criteria pollutants including CO and coarse particulate matter (PM_{10}). Further time disaggregation will include a comparison of monthly radiance and emissions products to determine the impact of seasonality. Lastly, the atmospheric transport of emissions will be included to account for dispersion effects of pollutants.

References

Gurney, K. R., Razlivanov, I., Song, Y., Zhou, Y., Benes, B., & Abdul-Massih, M. (2012). Quantification of Fossil Fuel CO_2 Emissions on the Building/Street Scale for a Large US City. *Environmental Science & Technology, 46*(21), 12194-12202. doi:10.1021/es3011282

Oda, T., & Maksyutov, S. (2011). A very high-resolution (1 km×1 km) global fossil fuel CO_2 emission inventory derived using a point source database and satellite observations of nighttime lights. *Atmospheric Chemistry and Physics, 11*(2), 543-556. doi:10.5194/acp-11-543-2011

Patarasuk, R., Gurney, K. R., O'Keeffe, D., Song, Y., Huang, J., Rao, P., . . . Ehleringer, J. R. (2016). Urban high-resolution fossil fuel CO_2 emissions quantification and exploration of emission drivers for potential policy applications. *Urban Ecosystems*, 1-27. doi:10.1007/s11252-016-0553-1

Proville, J., Zavala-Araiza, D., & Wagner, G. (2017). Night-time lights: A global, long term look at links to socio-economic trends. *Plos One, 12*(3), e0174610. doi:10.1371/journal.pone.0174610

Wang, M., Qiu, S., NOAA Ocean Color Team, & Office, N. J. P. (2012). *NOAA JPSS Visible Infrared Imaging Radiometer Suite (VIIRS) Ocean Color/Chlorophyll (OCC) Environmental Data Record (EDR) from IDPS [VIIRS]*.

Describing artificial light at night: Keywords in light pollution literature and why they matter

Theme: Society

Sara B. Pritchard and Erin McLaughlin[1]

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sbp65@cornell.edu

In August 2017, the cover of *Nature* featured the impact of artificial light at night (ALAN) on pollination. The fact that a top scientific journal dedicated its cover to this research shows how light pollution has received growing attention from mainstream scientists in recent years. Indeed, as entries in the Artificial Light at Night/Loss of the Night Network (ALAN/LoNNe) Research Literature Database demonstrate, scientific publications about ALAN have increased dramatically since the 1970s and especially since 2010. This is, therefore, a timely moment to assess how scientists describe the phenomenon because these terms have significant implications for science, policy, conservation, and activism.

This paper offers the first comprehensive meta-analysis of keywords in articles published about artificial light at night between 1970 and 2016. Of note, "artificial light at night" is our shorthand for the numerous and diverse keywords scholars use to describe the phenomenon; these prolific and heterogeneous keywords are our actual object of study. We assembled a database of publications related to the study of ALAN and its effects. We downloaded all articles from the ALAN/LoNNe database, and conducted a Web of Science search for the terms "artificial AND light* AND night*" and "light pollution." We then identified keywords in the Titles, Abstracts, and Keywords of approximately 800 articles published between 1970 and 2016. In this paper, we present preliminary data and both quantitative and qualitative findings from our keyword tallies.

Our research shows the remarkable heterogeneity of keywords and thus lack of consensus regarding terminology within the ALAN community. For instance, we have identified approximately 150 related keywords in the Abstracts of articles. We have also found that terms in Titles and Keywords tend to simplify complex phenomena described in more subtle ways in Abstracts. In addition, there is a significant geographical bias in research sites, with 19.5% of studies carried out in the United States and 19% in the UK, Germany, Australia, and Japan collectively, thus suggesting how the Global North is disproportionately represented in ALAN research. In our qualitative analysis, we argue that some of the most popular keywords contain both implicit and explicit assumptions about the environment and human/natural interactions. Moreover, as keywords become entrenched in disciplines and the wider ALAN community, they can unconsciously reinforce normative views of nature. In particular, light pollution keywords and research more broadly construct and legitimize certain understandings of nature and relationships between people and the environment, including a tidy artificial/natural dichotomy, the close association of natural night skies and presumed darkness, the simplification of natural variability by studying ALAN under "ideal" conditions, and an assumption that ALAN is undesirable and usually detrimental. These ideas have important implications for regulation, policy, and activism at multiple scales. Furthermore, the heterogeneous terms and lack of agreement may impede communication within an interdisciplinary research community. We conclude with some directions for future research, including tracking change over time in keywords, correlation between certain terms and disciplines, and increased attention to multiple dimensions of light.

From Singapore to Salt Lake City: Perspectives of lighting and darkness design

Theme: Technology and Design

Vellachi A. Ganesan,[1]

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Introduction

I became a lighting designer, for the love of light and all the ways in which it speaks to it, including the numerous shades of darkness. In my generation, within the time from when I was a child to an adult in the rapidly developing island city of Singapore, I personally have witnessed the loss of the night sky- the stars, the moon, the darkness, the quiet, the silence and the connection with the cosmos. Through this experience, I have understood the value of darkness and night sky through my very own yearning for it. While there is so much poetry about the beauty of (the presence of) light, it is foolish to think that the other polarity of darkness is without immense significance in our human lives.

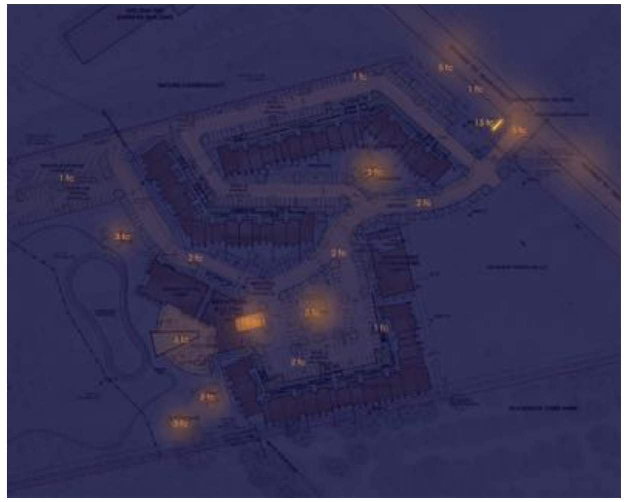

Fig 1: Strategies for lighting and darkness design- lighting hierarchy diagram (Worldmark Moab, Moab, UT)
Image credit: Vellachi Ganesan/Spectrum Engineers

Apart from Singapore, I was educated in Stockholm (Sweden), which is relatively dark city, as well as Paris (France), a city with planned and choreographed lighting. I have practiced as a lighting designer and light artist in various cities including Singapore, Bangkok (Thailand), Ho Chi Minh City (Vietnam), Jukkasjarvi (Sweden), Sydney (Australia), Lyon (France) among a few others. I am now currently practicing in the American Southwest region, mainly in Utah and Arizona, which are among the darkest cities of the developed world. The breadth of the areas that I have lived and worked in, the quality of night in each of these places and the ordinances that are in place in each city, are truly fascinating to explore. We must understand that our relationship with night sky is highly contextual to geography, culture and degree of development.

I started to practice as a lighting designer in Utah, after a number of years of study and work in these other parts of the world. Working in areas like Moab, Phoenix and the darker areas of the greater Salt Lake region as well as working with light pollution reduction credits from LEED and SITES have taught me a number of things. It has also asked me to question my own basis of lighting design, many a time, which has been challenging to the ego of a designer. It has asked of me to be highly creative in creating meaningful luminous environments within the constraints the ordinance. It has taught me to reflect critically about the ways in which these "rules" across various systems, and to distill the essence of a balanced design. It has driven me to spend longer periods of time on site, taking more measurements and understanding the culture of the place. It has pushed me to be more measured, restrained and defined in my designs, running more calculations and paying attention even to the smallest unit of light, which has an immense presence against the extraordinarily dark desert sky. It has pushed me to design custom fixtures where there are gaps in the market. It has taught me to maximize control sytems in such a way there is light, really only when it is needed. Overall, it has given me a whole new layer and perspective to lighting design, and motivated me to a new level of mastery of the medium.

Even within this region, with the same intention to preserve dark sky, I have found a number of ways to design; the same questions have yielded a range of diverse responses. Through this paper, I will share the processes of a few projects, including Worldmark Moab (Moab, UT), Sage Creek (Moab, UT), Nelson Fine Arts Center (Phoenix, AZ). I will talk about site analysis, strategies for darkness design, layering and heirarchy processes, visual design tools, calculations, navigating the ordinances, the relationships with clients, architects and other members of the design team, and their general attitudes toward this new wave of dark sky regulations. These are all works in progress, the learning is continuous, with new questions and perspectives constantly arising.

Fig 1: Visual design process - perspective view of lighting (Worldmark Moab, Moab, UT)
Image credit: Vellachi Ganesan/Spectrum Engineers

Letting The Stars Shine

Theme: Technology & Design

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Introduction

Light pollution is a phrase commonly used to describe undesirable components in the night sky such as unwanted light, dust, smoke, mist, or other alien components that hide the Milky Way and what lies beyond. This work was conducted to measure the spectral characteristics of the night sky above the town of Waikoloa Village, Hawaii. This town of 10,000 people sits on the side of Mauna Kea, the site of largest telescope facility in the world with the cleanest and darkest skies. The location of this town on the shoulders of an inactive volcano offers a truly unique real world night sky laboratory.

Waikoloa Village – Before/After

As specified by the County of Hawaii Outdoor Lighting ordinance, the street lights were one type, LPS (Low Pressure Sodium). Located on an island in the Pacific Ocean and surrounded by black lava, Waikoloa Village presented a unique opportunity to profile a very pure night sky. This study compared light intensity on roadways at ground level, 2000 feet, 3000 feet and 4000 feet above ground level as well as satellite readings. The collected data allowed for evaluation of the influence of hardware designs, spectral differences and intensities for the LPS and the newly proposed Filtered LED [FLED]. Such a comparison on this scale has never been reported; it is unlikely that it has never been done.

The presence of the telescope facility on the top of Mauna Kea required the Big Island of Hawaii to enact the most rigorous outdoor lighting ordinance of any city in the United States, possible the world. This ordinance limits the blue light content for outdoor lighting to <2%, hence the use of LPS starting in 1987. In 2009, the County of Hawaii, however, faced a financial strain resulting from the power cost to operate the inefficient LPS lights. The new LED technology offered the only option at this time as an alternative. After much deliberation, it was agreed by the County of Hawaii and the Astronomy community that FLED lights provided the only path to financial savings with a spectrum free of blue light but having the needed energy efficiency. Following the agreement, a three year test was conducted on roadway lighting to evaluate the FLED. The first test in 2010 consisted of fourteen lights on a single intersection in Hilo, HI to evaluate the impact on driver safety as well as the observatory. The second test in 2012 had 1,000 lights installed to get final data for the possible install of the remaining 11,000 roadway lights. In 2014, after three years of testing, the decision was made to install the remaining lights.

In late 2014 the order was placed to replace the balance of the LPS roadway lights on the island with the FLED full cut off type lights. As the full roll out was started, county officials in the Traffic Division and the IA people considered a study of the impact of these lights on the night sky around Mauna Kea. In 2015 the County of Hawaii Traffic Division agreed to do a study on the impact of the new FLED lights on the night sky at Waikoloa Village, while doing the install of the 11,000 new FLED street lights on other parts of the island. Waikoloa Village is an incorporated area of 4 square miles and has 650 roadway lights. The test was started by driving the roads in the town and measuring light levels, uniformity, and ease of driving with the LPS lights. These lights were of two general types: sag lens and full cut off. These data were collected in August/September 2015 for the LPS. All the lights were then changed from LPS to the FLED. The most common LPS lights were 55W and 90W units. The 55W unit was replaced with 26W FLED, and the 90W with 46W FLED. All replacement lights went on the same 30 foot poles used for LPS, so there were no spacing or height changes. The same methodology was then done in 2016 to evaluate light levels using the new FLED units.

For both the 2015 and 2016 tests, aerial measurements were also taken using a spectrometer mounted in a small plane flying at 2000 feet, 3000 feet and 4000 feet above in precise patterns over the Waikoloa Village during the same phase of the moon. Satellite data were also obtained and used in the data sets.

In addition to the tests just described, high resolution photographs were taken from a helicopter to offer a visual perspective of the town in the before and after state. These high-resolution photos show visual data that could be compared with the numerical data from the spectrometer. These results offered several interesting results that will be discussed in the presentation.

The summation of these different data sets found the reduction of the energy in the night sky to be >70% when measured at the horizon up to 40 degrees. The data collected will be offered with explanations of the significance of each in terms of hardware design, spectral influence and energy efficiency. Energy savings and other benefits to the County of Hawaii will be offered as well as local citizen comments.

As part of the data analysis, a software program was developed to determine the Red – Green – Blue lighting levels around Waikoloa Village with the added benefit of being able to distinguish the type of the light for each source.

Information and comments from the County of Hawaii officials and local community groups will be included in the presentation. The author would like to thank the County of Hawaii Traffic Chief, Mr. Ron Thiel, for his support throughout this period and his staff, especially Mr. Jerez Tehero. Aerial measurements were done by Eric Craine of STEM Laboratories, Tucson, AZ. Photos were done by Bruce Omori of Extreme Exposures, Hilo, Hawaii. Support from the astronomy community through the IFA (Institute For Astronomy), led by Prof. Richard Wainscoat and Prof Bob McLaren was greatly appreciated.

Letting the Stars Shine!!

Decoupling Outdoor Lighting from Sky Glow

Theme: Technology & Design

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Introduction

Earth's use of light at night is increasing, continuing a trend that began in the modern sense with the invention of the electric lamp. The different technologies employed in outdoor lighting have evolved over time, varying in characteristics such as efficiency, degree of optical control and spectral content, but the collective amount of direct and reflected light winding up in the night sky has steadily increased regardless of the technology used. The primary driver of this unwavering trend is the combination of increasing population and economic growth, which leads to the spread of electrification and its associated benefits like nighttime lighting. As is typical, however, benefits also come with costs – in economic as well as less easily quantifiable terms. If ongoing growth of such effects from light at night is to be even partially mitigated while the world continues to expand and develop, lighting technology and practice cannot stagnate. The good news is the continuously improving state of the art in outdoor lighting already offers numerous relevant capabilities that were simply nonexistent with the technologies of the past. This presentation reviews a range of modeled benefits that LEDs and controls enable, to illustrate the levers civilization increasingly has at its disposal for addressing sky glow and its attendant concerns. These results reveal that the future of light in the night sky is not necessarily a dire one, but that greater attention needs to be given to system design, selection of appropriate equipment, and thoughtful operation (e.g., in terms of precisely how much light is needed for the given application and when). There is bright, carefully controlled light at the end of the tunnel.

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Loss of the Night Darkness by Artificial Light at Night (ALAN) – Is It a Loss of Ecosystem Services?

Themes: Biology & Ecology, Health

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Introduction

The many and varied benefits that we humans gain freely from the natural environment and from functioning ecosystems are known as ecosystem services, grouped into four categories. One of these categories is regulating, which among others will adjust functions of different systems within the organisms bodies to environmental changes, thus promising the best function with time of the day and season of the year. In ecology, much attention, given to spatial variables, but with the understanding of the biological-clock, which acts also as a calendar and the mechanism at its basis more attention is given to temporal variables. The main environmental signal for the entrainment of the biological cluck are the light/dark cycles emerging from the rotation of our planet earth, on its axis. A significant difference between the day and night apart of light intensity is the dominant wavelength. While during daytime the short wavelength (SWL) environmental light (450-500 nm) the dominant wave length at night is in the range of orange around 560 nm.

Throughout evolution, the cluck of terrestrial-organisms on our planet was adapted to such entrainment, where daytime characterized by dominant blue light and at nighttime no blue light. The blue light during daytime suppresses the production of the pineal neuro-hormone melatonin, involved in the regulation of physiological and immune functions in mammals. As at night this part of the spectrum is absent, under dark conditions the pineal gland produces and secrets Melatonin, which through the blood system and the brain and spinal fluid, transferred to the body cells. High levels of melatonin are the signal for night while low levels are the signal for daytime. Furthermore, a longer duration of high melatonin levels are the winter signal for body cells while a shorter duration are the signal for summer.

Humans as diurnal organisms looked for ways to extend photophase by using artificial light at night (ALAN) where the most dramatic success took place with the transformation of electrical energy into light. If in the first stage the Edison bulb, was inefficient as illumination production, accompanied by heat. Therefore, an attempt made to produce efficient illumination, based on SWL lighting including among others, florescent and light emitting diode LED. So what is the problem? The main problem is that the blue light suppresses melatonin at the natural time of its production, thus causing a double negative impact, interfering with the regulation of physiological and immune function as well as disrupting daily rhythms, thus the loss of the temporal organization. We suggest night darkness, which under natural conditions misses the blue part of the spectrum to be an ecosystem service. However, it seems that energy efficiency knockout out such a crucial service, which results with a negative impact on humans increasing health risks.

However, so far no economic analysis carried to assess the price we as societies are paying for this move. Treating the loss of darkness as an ecosystem service will help us in promoting such studies including external costs in the cost-benefit analysis methodology used by environmental economists. Adapting this methodology to studies of the negative impact of light pollution and mainly that of SWL energy efficient illumination will enable environmentalists to include economic values in their discussion.

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Hyperspectral study of the impact of private lighting on skyglow at the Asiago Observatory, Italy

Theme: Measurement & Modeling

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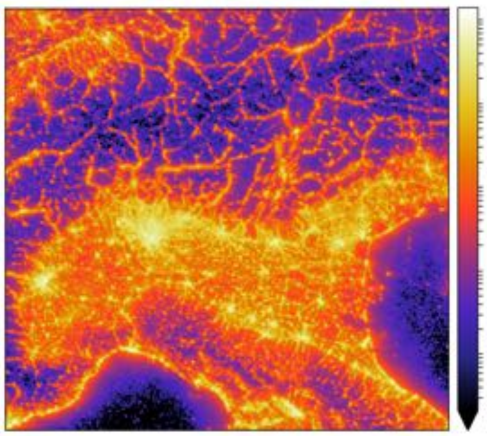
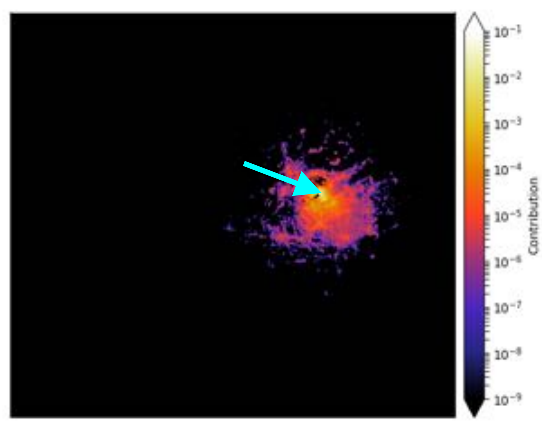


Intensity of the night lights for September 2017 as seen from the VIIRS-DNB sensor.

Introduction

Night protection has been a major concern for astronomers since the electrification of cities, and is beginning to be recognized as a major environmental problem. In recent years, regulations have been put in place through the establishment of Dark Sky Reserves that impose stringent constraints on lighting practices for cities in protected areas. Astronomers from the Asiago Observatory, located in the Veneto region of Italy, would like to create an area of this nature around their facilities to improve and protect the quality of their astronomical observations.

The present study assesses the current state of the sky in the region through numerical modeling using the latest improvements to the ILLUMINA model and aims to identify the main contributing sources of artificial light. The explicit calculation of the contribution of private lighting helps discerning origin of the light. Theses new improvements allow the simulation of the full spectrum of the skyglow in theoretical scenarios, thus widening the range of applications of the model by taking into account the spectral sensitivity of the detecting device. We also present a new approach for extracting the distribution of lamp technology in a region from images of astronauts taken from the International Space Station.



Provenance of the light seen at the zenith for an observatory in the region. The tip of the arrow points to the observatory.

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Globe at Night: An Awareness Campaign to Reduce Light Pollution

Themes: Society, Measurement, Technology, Health & Ecology

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Introduction

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. Globe at Night (GaN) encourages citizen-scientists worldwide to record the brightness of the night sky. During ten-days per month of moonless evenings, children and adults match the appearance of a specific constellation with 7 star maps of progressively fainter stars found at www.globeatnight.org. They then submit their choice of star map in-situ using the "webapp" on a smart device. In twelve years of the program, over 175,000 observations from 180 countries have been contributed to the campaign.

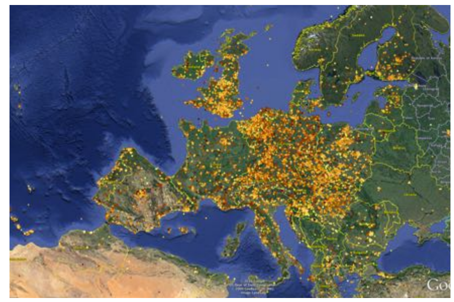

Fig 1: 10 years of Globe at Night data shown for Europe (2006-2015). Brighter data points mean brighter skies. (C. Walker, NOAO)

The Globe at Night (open) database is a source of research projects, even with other disciplines. For example, students conducted research to understand the lesser long-nosed bats' avoidance of city center at night. On-the-fly mapping enables citizen-scientists to see contributed observations immediately. The 12 campaigns per year accept 4 ways of taking measurements. The online app for data submission is in 28 languages. STEM activities for young children and problem-based learning activities for older students were created to experience real-life scenarios: role-playing sea turtles hatching (misdirected by lights on shore) or analyzing an ISS image of Houston to estimate the wasted energy, cost and carbon footprint. In-situ and on-line workshops have been given on using GaN in all its capacities, as well as for the activities. Our Facebook page exists to encourage dialogue and bring cutting edge news. To entice interest, we had monthly newsletters and serial podcasts starring the Dark Skies Crusader. GaN has been part of special campaigns like with the National Park Service, the National Geographic BioBlitz and Tucson in 2011. Partnerships also include SciStarter (working with participants through an online dashboard), STARS4ALL (working with light pollution initiatives), and Fieldscope (working with data analysis). We have built a community of practitioners worldwide and will continue to help reduce the effects of light pollution through awareness and action.

Globe at Night has provided the public with a variety of ways to be better stewards in minimizing the disappearance of our potentially starry night sky. Globe at Night is a flagship program of the National Optical Astronomy Observatory (NOAO). NOAO is the U.S. national observatory operated by the Association of Universities for Research in Astronomy, Inc. under cooperative agreement with the National Science Foundation.

Further information about the program can be found at www.globeatnight.org.

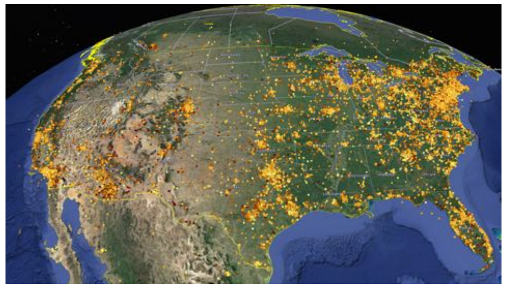

Fig 2: 10 years of Globe at Night data shown for the USA (2006-2015). Brighter data points mean brighter skies. (C. Walker, NOAO)

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Exposure to Screens of Digital Media Devices, Sleep and Concentration Abilities in Israeli Adults

Theme: Health

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Introduction: The last decade witnessed a dramatic growth in the availability and affordability of digital media devices such as televisions, desktop and laptop computers, tablets, video gaming consoles, and smartphones. These electronic devices have become more portable, multifunctional and useful for various everyday tasks, such as communication, reading, writing, working, playing, entertainment, and social media. In the "2011 Sleep in America" poll 97% of the participants reported that they had at least one electronic media device in their bedroom [1]. A major consequence of the invasion of digital media devices with screens equipped with light emitting diode (LED) into bedrooms exposes the users to ongoing short wavelength (SWL) lighting during the evening and at night, when under natural conditions long wavelength are dominant. Results of several studies reveal a negative physiological, behavioral and functional outcome of the exposure to SWL artificial light at night (ALAN) from digital media screens [2-5]. The aims of our study are to assess the relationships between digital media usage, sleep patterns, subjective sleepiness and attention abilities in adult Israeli citizens compared with Israeli adolescents.

Methods: We recruited 280 adult participants using convenience sample method, 49% males and 51% females with an age range of 18-82. The participants filled out self-reporting novel and original questionnaires as follow: demographic, general health evaluation, sleep habits and difficulties by the Pittsburgh Sleep Quality Index (PSQI) and the Karolinska Sleepiness Scale (KSS), prevalence and usage patterns of digital media devices.

Results: Smartphones were the most used digital media device in the evening and after bedtime (the time one gets to sleep in bed), followed by TV, computers, and tablets. Israeli adults used

smartphones for 30 min and TV for about 15 min after bedtime. Correlation analysis yielded significant negative correlation between subjective health evaluations and the use of smartphones in the evening ($r=-.141$, $p<0.05$) and after bedtime ($r=-.130$, $p<0.05$). We discovered a significant negative correlation between concentration in the morning and the usage time of computers in the evening ($r=-.149$, $p<0.05$) and watching TV in the evening ($r=-.266$, $p<0.01$). In addition, we found a significant negative correlation for using smartphones after bedtime and concentration in the morning ($r=-.156$, $p<0.05$). Correlation analysis revealed a significant positive correlation between time to fall asleep and the use of TV after bedtime ($r=.296$, $p<0.01$), using smartphones in the evening ($r=.159$, $p<0.05$) and after bedtime ($r=.172$, $p<0.05$). These findings indicate that excessive exposure to these devices is associated with longer sleep latency. We observed a significant negative correlation between the sleep complaint "Cannot get to sleep within 30 minutes" in the PSQI questionnaire and the usage time of smartphones in the evening ($r=.208$, $p<0.01$) and using smartphones after bedtime ($r=.193$, $p<0.01$). We noted a significant positive correlation, between subjective sleepiness with the following variables; TV watching after bedtime ($r=.171$, $p<0.05$), computer usage after bedtime ($r=.269$, $p<0.01$), smartphone use in the evening ($r=.270$, $p<0.01$).

Conclusion: To the best of our knowledge, this study is the first to explore the association between digital media screens usage, sleep, and concentration abilities in the Israeli adult. The prevalence of digital media screens into Israeli bedrooms (sleeping habitats) is high, and the exposure duration to SWL emitted from such screens in the Israeli adult population in the evening and at night is common, especially during the hours before bedtime or sleep. Our results suggest that using digital media devices in the evening and at night is associated with sleep difficulties and presumably as an outcome in the following morning greater sleepiness, attention and concentration dysfunction.

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Addressing the impact of light pollution on birds in Salt Lake City, Great Salt Lake and its Wetlands

Theme: Biology & Ecology

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Introduction

Light pollution from artificial light at night (ALAN) is a global and rapidly expanding environmental issue that is particularly detrimental to birds (Gauthreaux and Belser 2006). Although ALAN is concentrated in urban centers, its ecological impacts span the urban-rural gradient as sky glow bleeds into undeveloped areas outside of cities and towns. The geographic location of Salt Lake City, UT - situated in an important migratory flyway and adjacent to Great Salt Lake and its surrounding wetlands – amplifies the potential negative consequences of the city's light pollution. Tracy Aviary, National Audubon, and the Salt Lake Chapter of the International Dark Sky Association are working in partnership to understand and address the impact of ALAN on the birds of Salt Lake City and the adjacent Great Salt Lake and its wetlands.

Fig 1: A Wilson's warbler that had collided with a downtown Salt Lake City building was found as part of the Salt Lake Avian Collision Survey (SLACS). Photo by Cooper Farr

Approximately two-thirds of migratory birds migrate at night, and light pollution can cause these birds to become disoriented, be drawn off course, and collide with buildings and structures (Cusa et al. 2015). In 2017, Tracy Aviary launched the Salt Lake Avian Collision Survey (SLACS), a citizen science project to document bird-building collisions during spring and fall migration in Salt Lake City, UT. In 2017, citizen scientists found 44 birds representing 19 species that had collided with 21 out of 196 sampled buildings. We measured a suite of building and nighttime light-level characteristics at collision sites and an equal number of randomly selected buildings. We found that on average, collision sites were taller, had a larger surface area of glass, had more reflective glass in their windows, had a higher proportion of windows that were lighted at night, and had more nearby trees than buildings where bird collisions were not detected. Using information generated by SLACS, we launched Lights Out Salt Lake, an initiative to decrease light pollution and make Salt Lake City safer for migrating birds.

Great Salt Lake and its wetlands is considered North America's single most important interior wetland for birds. Annually, millions of shorebirds, waterfowl, wading birds, and other water-associated birds utilize Great Salt Lake for nesting and/or as a critical migration stopover. Great Salt Lake is designated as a Hemispheric Site within the Western Hemisphere Shorebird Reserve Network (the highest attainable category) and all five major bays have individually qualified as Globally Important Bird Areas based on criteria set by BirdLife International and National Audubon Society. The Great Salt Lake ecosystem is recognized as an important hemispheric site for large aggregations of birds because of its open saline water, large tracts of diverse wetland habitat, and abundant foraging opportunities for over 300 species of birds. For many species of birds, the majority of or a large percent of the world's population spend some part of their life cycle in Great Salt Lake habitats. Examples include the largest breeding population of Snowy Plover and American Avocet and a large percentage of migrating Marbled Godwit, Pintail and Tundra Swans.

American Avocets flock by the thousands at Great Salt Lake wetlands. Photo courtesy UDWR.

Great Salt Lake and its wetland habitat is situated next to a narrow strip of land along the western flank of the Wasatch Mountains, which harbors the most populous area in Utah, including Salt Lake City and its metropolitan municipalities. Along with a dense human population and its projected growth, pressures from environmental threats related to development and human activity on natural resources and birds continue to rise. One of the last remaining tracts of open land of Salt Lake City (9000 acres) is immediately adjacent to prime Great Salt Lake wetlands and is currently planned for development of an inland trade port and state prison. Attendant with the ensuing environmental threats of the port and prison is the assumed need for artificial light at night. In 2016, Audubon was contracted by the State of Utah to conduct a site assessment on local environmental threats of the prison to birds and other wildlife and provide recommendations to mitigate the threats including those from ALAN (Sorensen et al. 2016). We are currently working with city and state officials to bring environmental concerns into the planning dialogue for the port and associated facilities with the intent of lessening impacts that could have global implications on bird populations. Combined with the urban light pollution research and initiative in Salt Lake City, our efforts work in tandem to decrease the ecological impacts of ALAN and conserve birds throughout the region.

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Ecolinguistical analysis of knowledge transfer of the topic of artificial outdoor lighting

Theme: Society

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The question of this ecolinguistic analysis of knowledge transfer is, if there is evidence in the language, following the discourse held, that layman are underestimating the extent and impact of outdoor lighting. The question then is, if consequences of this are deriving for conservation and environment protection, if regularities were discovered.

For the discussion of consequences for conservation and environmental protection against the background of sustainability discussions, Einar von Haugen 1970 is describing ecolinguistic as the “interactions between any given language and its environment”. “The Ecology of Language”, Haugen (1972) is saying, was motivated socio-psychologically. The first, who included ecology in a biological sense, was Peter Finke in 1983 (Fill 1998, pp. 44). Wilhem Trampe (“ökologische Linguistik” 1990) was a doctorate student of him. Trampe wanted to ”look at ecological topics using linguistic and its methods, especially in order to analyse possible language based reasons and manifestations for the ‘ecological crisis’ (environment crisis), and by that, maybe even to contribute to a solution” (Fill 1996, p. 3). The latter is here to be seen as priority.

Fig 1: Title page of the publication (2003) for the conference (2002) of the BUND Berlin. It was argued for the installation of sodium vapor lamps instead of mercury vapor lamps.

Fig. 2: Photo of a street lamp in the shore area of the lake Muellrose in the east of Germany (2018/08/18). Linguistically, light is positively connoted. This is not true for insects, as far as one can compare, in this form.

In Berlin of the 1990s the BUND Berlin e.V. (Friends of the Earth) was critically watching the impact of the erection of a glass high rise building in the city centre. Motivated was this foremost by the aspect of invertebrate conservation, until the first mortalities of birds appeared at exactly this location. In 2002 the working group held an interdisciplinary symposium with the topic of insect friendly outdoor lighting.

The seriousness of the impact of outdoor lighting on nearly all other animal species on earth, especially on birds, was not known to that extent at the time. The symposium was one of the first of its kind, where artificial outdoor lighting was the main focus.

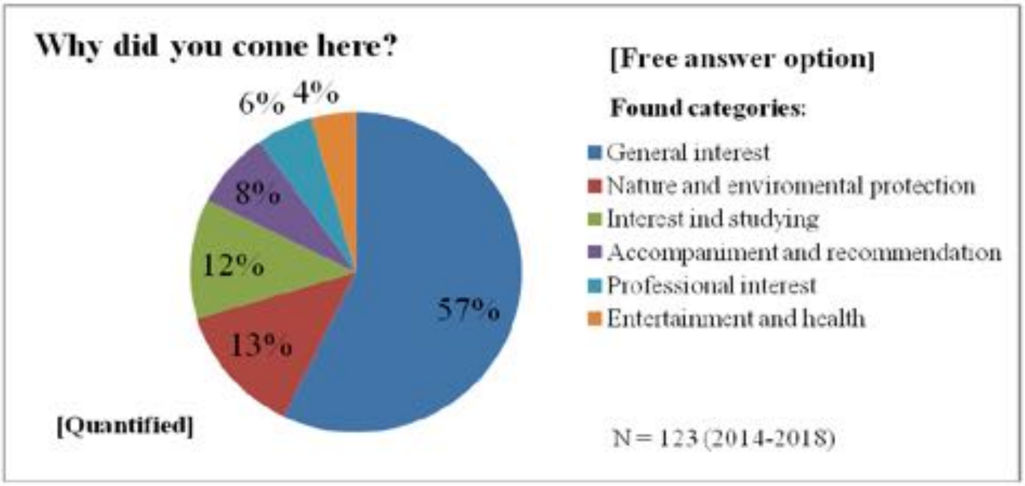

Fig 3: The quantified motives of the participants are shown why they have come to the guidance on the subject of light and ecology, as far as this results from the free answer possibilities. There were more participants than questionnaires filled out.

A discourse analysis was performed using an ecolinguistic evaluation of selected media. in the years 2014-2018 participants of guided tours during the “Langer Tag der Stadtnatur” were asked, using a written questionnaire, about their knowledge of the topic of outdoor lighting and they were also asked about their subjective attitude towards it. Fourteen questions had been chosen with experts in advance. More than 100 people participated in the survey over five years. The questions also included a quality component. The results are interesting with regard to the strategy formation of the communication of environmental organizations

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Do International Dark Sky Places Stay Dark After Accreditation?

Theme: Measurement and Modeling

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Introduction

The International Dark-Sky Association (IDA), a U.S.-based NGO, established the International Dark Sky Places Program in 2001 to recognize parks and protected lands that proactively manage use of outdoor light at night and educate visitors about the value of natural nighttime darkness. The program advances the IDA mission by encouraging the conservation of natural nighttime darkness where it still exists and promoting public policy interventions in cities and towns aimed at the reduction of light pollution. The program accredits International Dark Sky Communities (IDSCs), Parks (IDSPs), Reserves (IDSRs), Sanctuaries, and Dark Sky Friendly Developments of Distinction. As of mid-2018, over 100 IDSP designations have been made (Fig. 1).

Fig 1: World map showing the 100 designated IDA International Dark Sky Places as of mid-2018. The symbols are blue circles (Dark Sky Communities), purple crosses (Dark Sky Friendly Developments of Distinction), red squares (Dark Sky Parks), green diamonds (Dark Sky Reserves), and yellow stars (Dark Sky Sanctuaries).

For certain designation categories, sites seeking IDA accreditation must obtain and report a baseline set of night sky brightness measurements to establish their eligibility for participation in the program and allow IDA to determine the appropriate night sky quality ranking in a set of three tiers (Barentine 2017). After designation, all International Dark Sky Places are required to submit annual reports to IDA describing ongoing dark-skies conservation and rehabilitation efforts; these reports often include new measurements of night sky brightness. For purposes of consistent site characterization, these measurements are often obtained by the same individuals (or by means of fixed, automated sensors) with the same equipment and from the same locations, year after year. The most common means of characterizing night sky brightness involves broadband radiance measurements using version 'L' of the Unihedron Sky Quality Meter device. (SQM-L; Cinzano 2007)

Given the existence of these data sets, we asked whether the radiance of the night sky at the zenith over designated International Dark Sky Places tends to change over time after IDA accreditation is received. We hypothesized that the typically rural settings of designated places limit local development opportunities that would tend to bring more skyglow-forming light pollution. In International Dark Sky Communities, we expect ground light emission after accreditation to rise only at the rate of population growth due to improved outdoor lighting practices.

Method

We extracted SQM-L data from both publicly available International Dark Sky Places nomination documents and subsequent annual reports and examined the behavior of their

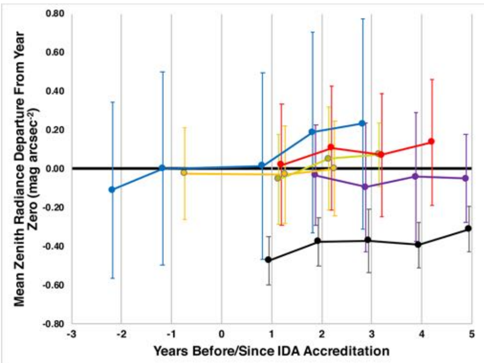

Fig 2: For years before and after the year in which IDA accreditation was received ('Year Zero'), mean departures from the mean zenith radiance value measured in Year Zero are shown. The traces shown are Westhavelland IDSR (blue); Aoraki Mackenzie IDSR (purple); NamibRand IDSR (black); Oracle IDSP (mustard); Enchanted Rock IDSP (red); and Westcliffe and Silver Cliff IDSC (orange).

distributions in the years following accreditation. Each data set was subjected to a number of cuts depending on the quality of the measurements, accounting for known contamination by twilight sky light, moonlight, zodiacal light, and atmospheric phenomena such as clouds and fog. We also discarded any measurements beyond an assumed night sky background threshold of 22 magnitudes per square arcsecond, taking this to be the lower radiance limit established by natural processes in the atmosphere (Garstang 1989; Leinart et al. 1997). From these data sets we calculated a variety of statistics, and computed frequency distributions to look for temporal trends. Where possible, we included data taken both before and after the year in which a given International Dark Sky Place received IDA accreditation. Six sites yielded sufficient data for this analysis.

Results

The radiance of the night sky at the zenith is largely unchanged in the several years both before and after a site receives IDA accreditation, implying relative short-term stability of night sky brightness over International Dark Sky Places. To the extent that zenith radiance is largely determined by light originating on the ground at relatively small radii from the measurement site (e.g., Aubé and Roby 2014), and given that International Dark Sky Places tend to be situated far from urban centers, the observed trends are consistent with our expectations. However, we also see year-on-year stability among the data from the one International Dark Sky Community we considered, while noting that population growth in this community over the survey period was very small. Further, we find no obvious evidence suggesting that sky quality improves measurably during the period in which aspiring International Dark Sky Places seek IDA accreditation.

Conclusion

Based on inconsistently sampled measurements of the radiance of the night sky at the zenith over a limited selection of International Dark Sky Places, we find no indication that night sky quality over these places changes with statistical significance in the years preceding and following IDA accreditation. We urge continued monitoring of these sites to search for evidence of long-term trends.

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Measuring European angular distribution of upwelling artificial light with the Suomi NPP VIIRS–DNB

Theme: Measurement and Modeling

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Introduction

Measurements of directionality of artificial light is necessary not only for light pollution modeling, but also for assessment of impacts to wildlife, since many kinds of disruptions to wildlife, for example disorientation of new-born sea turtles, occur with artificial light emission at particular angles. While not as refined as ground-based measurements using cameras and spectrometers, the recent availability of satellite-borne imaging sensors capable of measuring during the night time, for example, the VIIRS–DNB sensors on board the Suomi NPP and the NOAA–20 satellites, enables us to measure the angular distribution of artificial light over a wide area.

We downloaded night time images of Europe taken by the VIIRS–DNB sensor on board the Suomi NPP satellite. After gridding the data using an equal area projection grid, the EASE 2 grid, we calculated a quadratic fit for measured radiance with respect to the satellite zenith angle for each individual grid point. The quadratic term of the fit can be used to characterize the intensity of artificial light emitted nearer from the horizon relative to that at the nadir, whereas the slope can be used to determine the asymmetry of the emission, which mostly due to the change in the amount of artificial light emitted, but may sometimes also be attributed to highly unidirectional light sources.

Since the architecture of the VIIRS–DNB sensor on board the NOAA–20 satellite (and the other upcoming JPSS series satellites) is similar to that on the Suomi NPP (with the exception of the subpixel aggregation scheme at the scan edge), this analysis technique can also be applied to all VIIRS–DNB images by the future missions, and will allow long-term observations and ecological impact assessments.

Environmental Management Light Pollution Guidelines for Marine Turtles, Seabirds and Migratory Shorebirds

Theme: Society

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Introduction

Regulators have traditionally focused on light as tool to protect human health, safety and security. Consequently, light has not been considered as a pollutant in its own right and is rarely specifically recognised as an environmental pollutant in legislation. Regulators, industry and the public do not yet view light pollution as an environmental contaminant that requires management and monitoring along with all other forms of air, water, noise or soil pollution. This view is however slowly changing, being driven by a growing body of literature on the impacts of light pollution on humans, flora, fauna and ecosystems together with the documentation of the global increases in light emissions e.g. *The new world atlas of artificial night sky brightness* (Falchi et al 2017) and work by not for profit organizations promoting night sky protection (International Dark Sky Association, European Loss of the Night Network, Globe at Night etc.).

Light pollution was identified as a high-risk threat to marine turtles in the *Recovery Plan for Marine Turtles in Australia 2017,* because artificial light can disrupt critical behaviors such as adult nesting and hatchling orientation, sea finding and dispersal, and can reduce the reproductive viability of marine turtle stocks. A key action identified in the Recovery Plan was the development of guidelines for the management of light pollution in areas adjacent to biologically sensitive marine turtle habitat.

Artificial light can also disorient birds during flight, and subsequently cause death through collision with infrastructure. Birds may starve as a result of disruption to foraging, hampering their ability to replace used energy reserves to prepare for breeding or migration. High mortality of seabirds occurs through grounding of birds flying at night as a result of attraction to lights. The effect of artificial light on migratory shorebirds is less clear, particularly for nocturnally foraging shorebirds.

The Australian Commonwealth Department of the Environment and Energy has responsibility for protecting and conserving listed threatened and migratory species, under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and it is through this regulatory that vehicle these guidelines are being prepared.

The guidelines are intended to provide guidance to new and existing facilities. Recognizing the major changes facing councils, industry, ports, street lighting, airports, shipping, tourism developments and urban planners with the planned phasing out of High Intensity Discharge (HID) luminaires and the changeover to Light Emitting Diodes (LEDs). The guidelines address the recent literature on artificial light, the mechanisms by which it affects marine turtles, seabirds and migratory shorebirds and the associated impacts to individual and population fitness; summarizes current best practice lighting design principles and management objectives to minimize impacts; discusses project risk assessment in the context of competing priorities (human health and safety vs environmental values); assesses light monitoring techniques from the perspective of monitoring and measuring biologically meaningful light qualitatively and quantitatively; discusses the value of existing light engineering computer models to accurately represent the visibility of light to wildlife (radiometric vs photometric modelling); recommends methods for monitoring the biological impact of exposure to light on marine turtles, seabirds and migratory shorebirds, and the capacity of adaptive management to address failures in environmental management approaches as demonstrated by the biological monitoring results; and discusses the issues and limitations around setting numerical light emission values for sensitive environmental zones/ecosystems. Finally, the guidelines explore options and opportunities for encouraging behavioral changes to increase the voluntary uptake of light pollution measures and presents three case studies that describe situations where light has been successfully managed to avoid or minimize detrimental impact on turtles, seabirds and migratory shorebirds.

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Recovery Plan for Marine Turtles in Australia, Commonwealth of Australia (2017)

From HPS to LED: the plan for measuring changes in skyglow before and after a countywide lighting retrofit project

Theme: Measurement & Modeling

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Abstract

The US National Park Service (NPS) Night Skies Program is conducting a study to quantify changes in skyglow as a result of a countywide lighting retrofit project. Chelan County, located in Washington in the United State, is going to retrofit all their existing street lights to 3000 K full cut-off LEDs starting in the summer of 2018. The project is expected to be completed in two years. We have measured the skyglow level in Chelan County in May 2018, right before the start of the retrofit work, using the NPS night sky camera system in V and B bands. The images are photometrically calibrated and mosaicked together to provide a complete documentation of the skyglow condition in a panoramic view. The data we collected will be used as the reference for comparing to the skyglow level to be measured in the future after the completion of the lighting retrofit project.

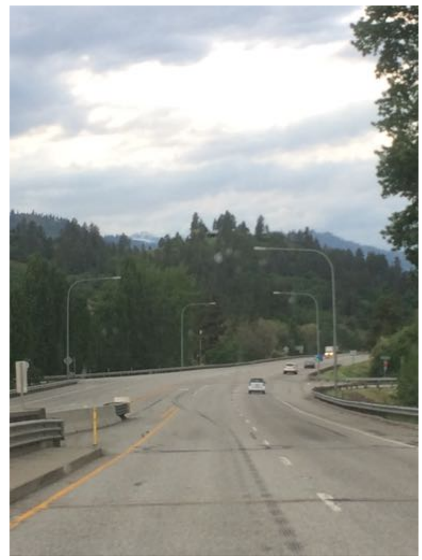

Fig 1: Street lights in Chelan County, Washington, USA in May 2018.

About Chelan County:

Chelan County is located in the US state of Washington, about three hours east of Seattle. Chelan County is a gateway community to the North Cascades National Park and Lake Chelan National Recreation Area. Their service territory includes the Stehekin community, which is within Lake Chelan National Recreation Area administered by the NPS. The largest city within the county boundary is Wenatchee.

The Lighting Retrofit Plan:

- The retrofit work is led by the Chelan County Public Utility District
- Chelan County is going to replace all 4000 county street lights, accounting for more than 60% of the total outdoor lights in the county.
- Current street lights: 200 W High Pressure Sodium cobra head light (majority).
- Planned replacement: full cut-off 3000 K LED ranging from 45 to 85 Watts.
- The retrofit is schedule to start in mid-2018 and will take about two years to complete.

Modelling and measurements of Light pollution at Malvern Hills AONB, for the effect of Herefordshire conversion to blue-rich LED lighting.

Theme: Modelling and Measurement

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Abstract

The first part of this work covers modelling the effect of different types of luminaires on the sky, especially with respect to the Malvern-Hills Area-of-Outstanding-Natural-Beauty (MHAONB), and the impact of the LED replacement of Low-Pressure-Sodium throughout Herefordshire. It was extended to include High-Pressure-Sodium and to LEDs at several CCTs, for the same Photopic ground illuminance. The introduction of blue rich Correlated-Colour-Temperature (CCT) 6000K road lighting could increase skyglow significantly compared with CCT 3000K types, if the blue content reaches the sky. Highways England have a policy for lighting specification on motorways advised by the author's work. This is a categorised environmental impact point system of summed brightness as a function of angle from vertically down to the cut off angle; but with no CCT limitation.

The second part describes the reassessment of a Dark-Sky Geographic Survey data for the MHAONB (2012), and then sequential measurements from the Mathon observatory location to 2018. Near-Zenith sky brightness photometry became continuous from 2016 at 2 minute intervals in all weathers, not just clear nights, with a networked calibrated Unihedron Lensed Sky Quality Meter (LSQM). For the original survey and ever since, samples were also taken of all-sky camera images, corrected for vignetting and near-Zenith calibrated with the LSQM. This has allowed detailed study of weather effects, Milky Way contribution, and the Herefordshire lighting conversion to blue-rich LEDs (2013-15), compared with the less converted Severn valley direction.

Time-plots and histogram analysis showed only slight reduction in brightness (2012-2018), 0.1 mag/arcsec2. Weather effects on the horizon dominate. Mist or low cloud on the horizon obscures light sources beyond, reducing local skyglow, while high cloud reflects from cities and towns beyond or on the horizon, increase clear sky brightness. The Milky Way is critically at 20% above background. Darkest periods near Zenith reach 21.1 mag/arcsec2, to 21.2 after rain or surrounding low-cloud or poor local visibility. Clear-sky brightness decreases into the early hours, but local dimming changes were not seen. The effect of the more distant blue rich LED lighting dominates on nights of less than good visibility or cloud, while more usually and on dark clear nights, the Worcestershire less converted lighting is prominent.

The Zenith brightness is still set by distant cities, while towards the horizon, commercial and private uncontrolled non-directional LED lighting is increasing, negating the improvements in road lighting.

Light pollution and faunal community effects on litter decomposition

Theme: Biology & Ecology

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Introduction

There is mounting evidence that light pollution has unintended consequences for ecological communities. However, very few studies have explored the ecosystem impacts of this anthropogenic pollutant. We conducted a field experiment to determine if light pollution affects decomposition, and if effects were similar across different decomposer class-sizes.

Ground-dwelling arthropods affect ecosystem dynamics primarily as primary consumers, secondary consumers, and detritivores. Previous works have found higher abundances of predatory and scavenger arthropods in light polluted areas (Holhzhauer et al. 2015, Davies et al. 2012, Davies et al. 2017). Given that ground-dwelling predatory invertebrates can initiate top-down trophic cascades (Moran et al. 1996, Schmitz 2007, Schmitz 2009, Hawlena et al. 2012), the possibility that light pollution may induce top-down trophic cascades affecting decomposition warrants investigation.

Our primary objective was to determine if light pollution affects the rate of decomposition driven by different size classes of soil fauna and microbes. Our hypothesis was that the effect of light pollution on decomposition will differ between decomposer communities. Additionally, we predicted decomposition would be reduced under light polluted conditions.

Methods

A field experiment using litterbags filled with uniform grass representative of the study area was conducted in the fall of 2017. Litterbags are used in decomposition studies and operate on the exclusion principle, the larger the mesh the more complex the invertebrate community represented within the litterbag. For this study, 3 mesh sizes were used for exclusion of some macrofauna (4 mm mesh size, most complex community), all macrofauna (2 mm mesh size), and all macro and meso-fauna (0.1 mm mesh size, least complex community). Litterbags were deployed in paired lit and unlit plots at Blandy Experimental Farm (Boyce, Virginia, USA) in

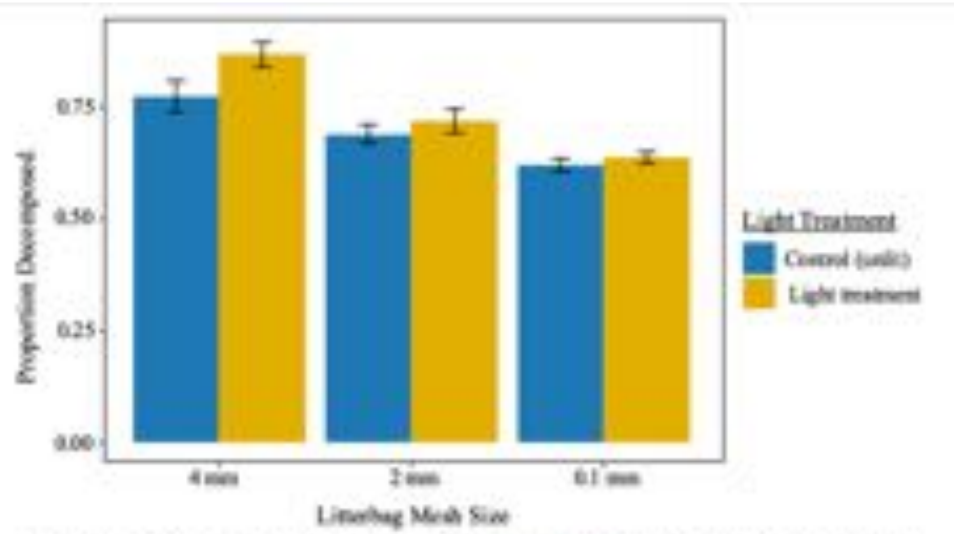

Figure 1. Light pollution effects on proportion of *P. virgatum* material decomposed based on community size class complexity. Proportion decomposed is shown (mean ± S.E.; 1 – final/initial, g) for macro (4 mm), meso (2 mm), and micro (0.1 mm) faunal communities after a 60 day incubation period in the field receiving either light pollution (yellow bars) or no light pollution (control, blue bars). Means and standard errors were calculated from log transformed data.

a native plant meadow, where dominant vegetation consists of warm season, C_4 grasses. The litterbags were filled and deployed concurrently with end of season senescence for the C_4 grasses. Upon retrieval (after 30 and 60-day field incubation times), arthropods were removed from all litterbags using Tulgren extraction and remaining plant material was dried and weighed to measure proportion of grass decomposed (1 – final/initial weight, g).

Results

We analyzed our data using a linear mixed effects model with presence of light pollution, community size-class complexity, and biomass in the plot as fixed effects, and pair, plot, and litterbag group as random effects. Contrary to our prediction that a trophic cascade would reduce decomposition under light polluted conditions, we found more grass litter was decomposed in the most complex community in lit plots after 60 days ($p = 0.0583$, Table 1). There were no significant differences in proportion decomposed between lit and unlit plots for the other two size-classes, though overall decomposition tended to be higher under lit conditions (Figure 1).

We found no evidence that top-down cascades slowing decomposition occurs in light polluted plots, but rather that decomposition rate increased. This could have been caused by greater influx of decomposer soil invertebrates as a phototactic response. It could also have been a result of increased activity levels among decomposers. Future work should investigate these possibilities. Decomposition is a critical part of both the carbon and nitrogen cycles, and this study presents novel findings that light pollution may affect nutrient cycling.

Table 1. Pairwise comparisons of proportion decomposed (1 – final/initial, g) by community size class complexity.

Contrast Group	Estimate	SE	df	t ratio	P value
Macro Lit - Unlit	0.067	0.0298	7.07	2.256	0.0583
Meso Lit - Unlit	0.0309	0.0298	7.07	1.037	0.3338
Micro Lit - Unlit	0.0248	0.0298	7.07	0.833	0.4321

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Using Astronomical CCD Imagery Techniques for the Study of Urban Light Domes at a Small College

Theme: Measurement and Modeling

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The National Park Service Night Skies Team has utilized charge-coupled device (CCD) imagery to create all-sky mosaics of the total and artificial (total minus natural) night sky-brightness at various sites within U.S. National Parks (e.g. Figure 1). This data, publicly available on Night Sky Monitoring Database via a Google Earth kml file, applies the imaging and analysis techniques commonly in the undergraduate astronomy curriculum, but in a new context. This method has been widely utilized to study dark skies in other locations (e.g. Falchi, 2011; Jechow, Kolláth, Lerner, et al., 2017; Jechow, Kolláth, Ribas, et al., 2017; Krisciunas et al., 2007; Rabaza, Aznar-Dols, Mercado-Vargas, & Espín-Estrella, 2014; Rabaza, Galadí-Enríquez, Estrella, & Dols, 2010)

Utah has become a national leader in both astrotourism and the protection of our nighttime dark skies in National and State Parks. Over one-third of our population, however, lives in the Salt Lake Valley, which is not protected by any dark skies regulations. There is currently little data characterizing the quantity or quality of light pollution in Salt Lake City. Such data are necessary to inform advocates and policy makers on methods to reduce the disruption of nighttime lighting to humans and wildlife (Falchi, Cinzano, Elvidge, Keith, & Haim, 2011)

This project aims to collect and disseminate critical measurements of the light pollution in the Salt Lake Valley to interested parties. We sought to reproduce the methods of Duriscoe, Luginbuhl, & Moore (2007) in the context of a burgeoning astronomy research program at a small liberal arts college. Our goals are to make datasets that can be utilized by policy makers and advocates of dark sky preservation in the Salt Lake Valley, and to create publicly available code and resources for similar projects to be reproduced by other astronomy students.

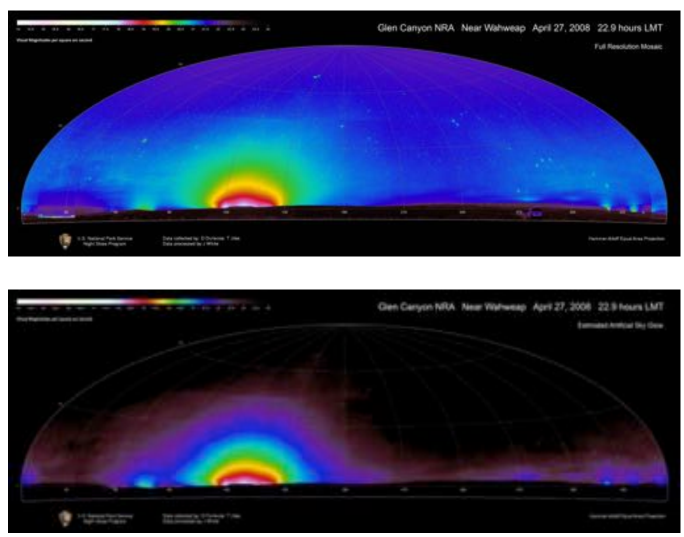

Fig 1: All-sky false-color panorama of the night sky in Glen Canyon National Recreation Area ("Night Sky Monitoring Database - Night Skies (U.S. National Park Service)"). Top: Total night sky brightness. Bottom: Estimated artificial sky glow after subtracting the natural sky background. The large light dome is Page, AZ.

We will use an astronomical CCD camera to image the entire night sky from locations near Salt Lake City, using typical equipment available to a small college astronomy program. After calibrating and aligning all of the images, we will create a panoramic view of the night sky, similar to that shown in Figure 1. This map can be used to determine a number of indices of sky quality: surface brightness at notable locations (zenith, brightest, darkest portions of the sky), total integrated sky background, and total integrated brightness of the city's light dome. Our procedures and Python scripts will be made publicly available for other small-college or amateur researchers to use. In the future, scripts for subtracting the natural sky brightness (Duriscoe, 2013) will also be created for use by other researchers. This procedure creates the bottom image of Figure 1 by subtracting the natural sky background from the top image.

By investigating the challenges faced by applying this technique to small college astronomy programs, we aim to make the study of night sky brightness easily accessible to other astronomical researchers.

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Interaction of clouds and fog with the measure of Night Sky Brightness

Theme: Measurements and Modelling

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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 Ribas et al 2016, Jechow et 2016, 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.

If it is well identified the effect of clouds and fog in NSB, it is possible to develop an inverse procedure to evaluate cloud coverage starting from simple NSB measurements and their evolution during the night. Some parameters can help to determine cloud coverage of the night sky with the only input of NSB.

Sky brightness and clouds data in dark and bright locations

The determination of the sky brightness has been done using Sky Quality Meter (SQM) devices of the Catalan Light Pollution Network (XCLCat). This network is a pilot plan of Parc Astronòmic Montsec in cooperation with the Government of Catalonia to evaluate NSB around the region (Ribas 2016). In this new updated study, data from TESS-W Stars4All project photometer have been included and an extended timeline is used in comparison with preliminary results (Ribas 2015, Ribas et al 2016).

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. In our studies we are using stations of XCLCat or TESS devices installed in areas with environmental studies. This is the case of Montsec mountains and the city of Barcelona, because both places have installed a ceilometer providing real time information of clouds and aerosols. Also TESS device as IR temperature cloud detector that can provide but with less accuracy cloud coverage data. So we have combined NSB measurements with independent cloud coverage data in dark and urban location.

The urban case of Barcelona showed us the expected amplification effect by clouds. In this case the NSB can be more than six times brighter with low clouds in comparison with clear skies. Opposite to this result is what is found in the same comparison applied to a protected area as

Montsec mountains. In this second case we found a darkening effect generated by clouds, mainly by low clouds that can lead to the highest values of magnitude measured by TESS and SQM (up to 24 mag/arcsec^2) so close to darkest possible values of these devices.

Evaluating cloud coverage using NSB data

When the effect of clouds and fog in NS is well identified, it could be possible to do the inverse possible and determine the cloud coverage status knowing how NSB is evolving. The starting point is the fact that NSB is almost stable in moonless and clear conditions but is very variable in moonless with cloudy conditions.

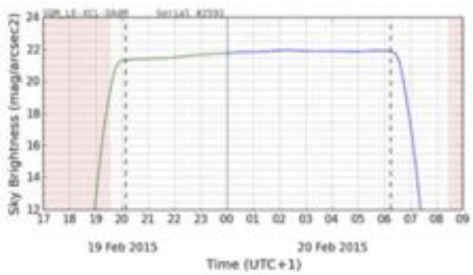

Fig 1: NSB evolution in a clear night, so after astronomical night starts there is high stability and only smooth changes happened

Fig 2: NSB evolution in a cloudy night. There are continuous and not smooth changes in the evolution of NSB.

Using the variation of NSB with time, we define a family of parameters called CSF (Clear Sky Factor) inspired by the proposal of SQM manufacturer (Unihedron) website. CSF parameters are higher as much as the change of the NSB is happening and in moonless conditions, this change can be only linked with weather conditions, mainly clouds.

We have evaluated the capacities of these CSF to determine cloud coverage using as test data ceilometer data from stations in Barcelona and Montsec. CSF factors can be good parameters for this purpose in urban areas where changes on NSB due to clouds are more extreme and easy to be detected. In dark sky areas, as Montsec, these parameters are less powerful specially in case when small variation of NSB is produced, this is the case of tiny clouds that are not generated changes in very dark places. The evaluation of the capacities of these different CSF in very different conditions will be discussed.

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The All-sky Light pollution Ratio (ALR) characterized using field data and modeled VIIRS data

Theme: Measurement & Modeling

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Introduction

One way to look at the impact of artificial light at night on parks is to compare measured all-sky night light to a modeled natural night sky including the Milky Way, zodiacal, and other natural phenomenon. The ratio between the artificial sky brightness and the natural sky is call the all-sky light pollution ratio (Dursico et al 2018). The Natural Sounds and Night Skies Division (NSNSD) of the National Park Service has been using this ratio to characterize the impact of artificial light on national parks. Over the last 15 years the NSNSD has been collecting ground based measurements (ie. field data gathered with using a hemispheric camera observation of the entire sky at specific locations within a variety of parks). These data have been used to calculate the ALR for these sites. More recently, the Suomi NPP VIIRS satellite has been acquiring nocturnal imagery (ie. day night band – DNB) covering the earth at night since 2012. This paper explores the statistical relationship between the camera and satellite representations of ALR (e.g. Figure 1). We hope to develop statistical methods to validate and enhance the modeled ALR values from VIIRS annual and monthly composites.

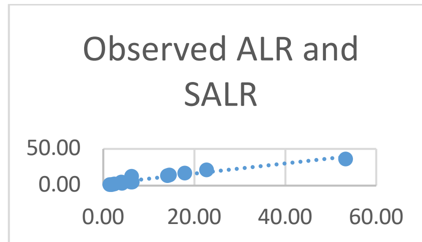

Fig 1: Graph of ALR calculated from the ground based data collection (observed from the ground) and the satellite modeled ALR using the SALR model.

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Artificial light at night increases survival of new neurons and suppresses melatonin in birds

Theme: Biology & Ecology

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Daily cycles of natural light affect many biological phenomena, however these patterns have been greatly disrupted through global urbanization. The introduction of artificial light at night (ALAN) from various sources (e.g. street, domestic, industrial) was found to have vast biological impacts, from the molecular to the ecosystem levels, including impacts on gene expression, physiology and behavior of organisms. ALAN is quite pervasive, in animals and humans, and findings suggest that it is associated with several physical and mental health problems. The few studies that exist on neuronal plasticity and cognitive functions in mammals indicate that the disruption of the circadian cycle induces learning and memory deficits and suppresses neurogenesis. However, nothing is known yet about the effect of ALAN on neuronal plasticity in birds.

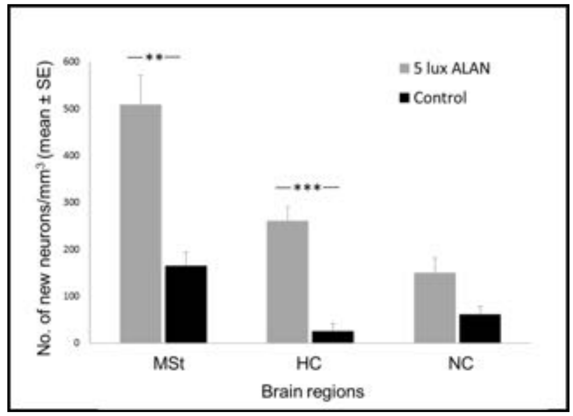

Fig 1: Densities of new neurons (numbers/mm^3 ± SE) in three brain regions: MSt (Medial Striatum), NC (Nidopallium Caudale) and HC (Hippocampus), in birds exposed to ALAN (5 lux) and controls that remained in dark nights.
**=p<0.05; ***= p<0.005. N=6 birds/group.

In a previous study we showed that in birds (zebra finches; *Taeniopygia guttata*), ALAN significantly increased neurogenesis, e.g. the birth of new neurons, in a dose-dependent manner. However, in that study we could not determine whether ALAN also affects the consequent survival of these new born neurons, when they migrate to their target regions in the brain and are being incorporated there. In the current study we aimed to answer this question.

To this end, we exposed birds to intensity of 5 lux ALAN, or to complete dark nights as controls. We chose 5 lux because we already found that this intensity affects neurogenesis, and because it is known to be ecologically relevant (e.g. comparable to levels of light pollution surrounding urban centers). Three weeks later we treated the birds with BrdU (a cell birth-date marker) to label new neurons in their brain. After additional four weeks we quantified the amount of new neurons that survived the migration from their place of birth and had been recruited in three brain regions: MSt (Medial Striatum; which is linked to visual perception and associative learning), NC (Nidopallium Caudale; which is known to contain auditory relays and is involved in vocal communication and in the integration of auditory information), and HC (Hippocampus; which is involved in the processing of spatial information). In both groups we also measured plasma melatonin levels during the day and during the night before and after exposure to ALAN.

In all the three investigated brain regions ALAN increased the survival of new neurons in comparison to the controls, and in HC and MSt this pattern was significant (Figure 1). We also found a significant reduction in nocturnal plasma melatonin levels in the experimental group, after the birds had been exposed to ALAN, while no differences were observed between the experimental and control groups in day time melatonin levels. Taken together, our study shows that in addition to the increase in production of new neurons (which we had already found in our previous study), ALAN also increases the consequent survival of these neurons, when they migrate to their final destinations in the brain and are being recruited there. Our data are novel because they contradict those reported in other species, mostly mice and rats. A major difference between our study and others is that we used a diurnal species, while most previous studies used nocturnal ones. This difference can explain our findings and emphasizes their importance, because our results support the hypothesis that although the circadian systems of nocturnal and diurnal animals function in a very similar way, they translate signals in opposite ways, according to the animal's lifestyle.

Effects of skyglow on physiology and diurnal rhythm of phytoplankton strains

Theme: Biology & Ecology

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Abstract

Since the invention of artificial light sources in the 19th century, anthropogenic light emissions on earth have greatly increased. The intense use of artificial light at night disrupts the natural photoperiod and has thus been regarded as light pollution. Effects on organisms can be manifold, because natural sunlight is not only an energy source, but also acts as a zeitgeber (Mittag 1996) that regulates diel changes in metabolic processes (Straub et al. 2011). Therefore, even low levels of light emitted to the atmosphere at night and backscattered to earth's surface by clouds and aerosols, a phenomenon referred to as artificial skyglow, can blur differences in the perception of day and night by organisms (Kyba & Hölker 2013). However, little is known about such effects of skyglow on aquatic primary producers (Grubisic et al. 2017a, 2017b, Poulin et al. 2014), which form the basis of freshwater and marine food webs.

The present study focused on assessing effects of skyglow on freshwater phytoplankton. To this end, we performed a laboratory experiment testing for the effect of low levels of artificial light at night on four strains of primary producers belonging to three main taxonomic groups: 2 strains of *Microcystis aeruginosa* (cyanobacteria), a *Cyclotella meneghiniana* (diatoms) strain and a *Mychonastes homosphaera* (chlorophytes) strain. After one week of acclimation to a 14:10 hour day:night cycle, we exposed the four strains in semicontinuous cultures either to low levels of artificial light at night (6 lux warm LED, simulating skyglow in megacities) or kept them in darkness at night (control). We measured cell abundances, photosystem II activity (photosynthetic yield), and concentrations of chlorophyll *a* and other pigments, and of particulate carbon, phosphorus and nitrogen before and one week after exposure to skyglow. Measurements were made twice at both occasions, each time just before switching to bright daylight, or to either darkness or skyglow conditions.

Responses of the algae to skyglow were strain-specific. Growth rates showed no significant differences between strains exposed to control or skyglow conditions, but indicated positive responses by chlorophytes and diatoms and negative responses by the cyanobacteria. The chlorophyte showed significantly higher chlorophyll-*a* fluorescence after exposure to skyglow (Fig.1), whereas the cyanobacteria and diatoms did not. Exposure to skyglow increased the photosynthetic yield of diatoms and of one but not the other strain of cyanobacteria, nor that of the chlorophytes. Furthermore, we found that not only responses at night (measured directly after exposure to skyglow), but also during day were affected by nighttime skyglow.

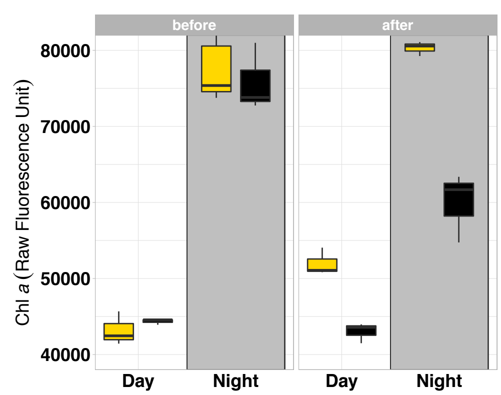

Fig 1: Chlorophyll *a* raw fluorescence of *Mychonastes homosphaera*, measured at day and night before and after switching on the artificial light.

Overall our results indicate that low levels of light pollution by skyglow can have direct effects on freshwater phytoplankton, although responses vary among strains and physiological traits. These varying effects could lead to shifts in natural phytoplankton communities experiencing skyglow and thus to repercussions for higher trophic levels such as zooplankton and fish.

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Coral reproduction and the timing of spawning in the era of rapid urbanization and ecological light pollution (ELP)

Theme: Biology & Ecology

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Introduction

Coral reefs represent the most diverse marine ecosystem on the planet, yet they are undergoing an unprecedented decline due to a combination of increasing global and local stressors. Despite the wealth of research investigating these stressors, "ecological light pollution" represents an emerging threat that has received extremely little attention in the context of coral reefs, despite the potential of disrupting the chronobiology of coral reef organisms. Scleractinian corals, the framework builders of coral reefs, depend on lunar illumination cues to synchronize their behavior, reproduction and physiology, while light pollution may mask and lead to disruption or a-synchronization of these bloggable process. In the recent years we aimed to understand the broader impacts of light pollution on the reproductive ecology of scleractinian corals, and more specifically assess how light pollution affects both ecological (spawning synchrony, recruitment and connectivity) and organismal (reproductive phenology, physiology and gene expression) responses in scleractinian corals. The success of coral reefs and the persistence and recovery of healthy reefs is highly dependent on successful gamete production, fertilization, development of viable offspring and survival of new recruits. In scleractinian corals, "broadcast spawning" is the dominant form of sexual reproduction. Broadcast spawners are either gonochoric or hermaphroditic and can release their gametes independently or simultaneously. Representatives of the alternative reproductive mode, "brooders", can also be gonochoric or hermaphroditic, however their oocytes are fertilized inside the coral polyp prior to development into a swimming larvae. Both reproductive modes are dependent on a particular phenology, with a cycle that can occur yearly, seasonally or monthly. The reproductive phenology depends on the species and environmental condition, with repeated yearly episodes associated with broadcast and brooder spawning representing a classic example of a periodic biological rhythm. This rhythm that leads to spawning in synchrony, is thought to be controlled by both an exogenous (i.e. environmental) and endogenous (i.e. biological/circadian) clock. For circadian clock oscillations to function, an animal should be able to perceive geophysical cycle information from its surrounding environment and adapt to its biorhythm. For corals, the moon phase and moonlight are key imperative cues with biophysical evidence showing that corals exhibit photoreception in the blue region of the light spectrum and are extraordinarily sensitive to blue spectra matching blue moonlight irradiance levels. Spawning behavior appears to be modulated by a complex series of cellular changes, involving G-protein coupled photoreceptors and cytoplasmic second messengers, and changes in protein abundance. Spawning behavior and reproductive phenology can differ between different geographical regions (e.g. with different climate conditions) and reef environments (e.g. different depths).

Our studies in the last few years show how light pollution can mask moonlight signals and can impact the synchronization and the timing of spawning in coral reefs. Our results show that light pollution is effecting coral spawning from the behavioral, physiology and molecular aspects. Overall, our research shed light on the emerging threat of light pollution and the impacts on the chronobiology and ecology of scleractinian corals, and we hope that our data will help us formulate specific management implementations to mitigate its potential harmful impacts.

The Island of Saint Helena as an example of Metrics Based Legislation to Address Artificial Light at Night Problems and to Promote Dark-sky Tourism

Theme: Society

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Introduction

The legal regulation of artificial light at night has many benefits: the reduction in energy (and carbon emission) wastage, benefits to human and ecological health, as well as the protection of the night time environment and sky. All of which may boost safety, security and local economies with dark-sky tourism. The goal of any law must be to promote and balance the positive advantages of the use of light at night against the problems it may cause. As such it must be based upon a full understanding of the issues.

Such legislation may be based upon objective metrics or subjective judgment. It may take the form of binding (hard) law, or soft (non-binding) law in the form of guidance or a "lighting management plan", it may even be composed of both. Ultimately it must be workable on all sides- light users (consumer and commercial) and enforcement.

The Island of Saint Helena, due to its remoteness and dark location intends to promote dark-sky tourism with IDA accreditation. This has offered an opportunity for the author to help draft a binding law that aims to address the combined problems with artificial light at night and to boost the local economy via IDA dark-sky status. This paper will assess the policy drivers for the drafting of the law including the challenges and solutions using metrics over a subjective system. It will demonstrate how such legislation can be re-enforced by soft law in the form of a well drafted lighting management plan. As well as underscore the importance and value of the IDA's guidance in providing established wisdom and the promotion of harmony and good practice. It is hoped that the Saint Helena law can offer a good example for other areas considering either IDA dark-sky status or tackling the broader problems caused by artificial light at night.

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Winter (and arctic) light pollution: a new frontier?

Theme: Measurements and Modeling

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Introduction

Artificial light at night (ALAN) can have diverse negative effects on flora and fauna (Rich&Longcore2006) and is growing continuously (Kyba2017). Especially skyglow, ALAN scattered within the atmosphere, can be sensed at large distances and therefore is suspected to have long range effects (Kyba2013). It is well known that clouds can amplify skyglow (Kyba2011, Jechow2017) and that the ground reflectance changes dramatically with snow. However, very few studies on snow at the ground (Falchi2011) or ice in the atmosphere on skyglow exist and satellite imagery is challenging for these conditions. This knowledge gap is problematic, as in winter the effects of ALAN are particularly severe for different reasons. First, nights are longer, ultimately stretching 24 h a day during polar night. Furthermore, the use of ALAN is increased particularly in polar regions due to its necessity for human activity. Additionally, permanent snow cover and peculiar atmospheric effects due to the presence of ice crystals are correlated with the elongated dark periods. Animals adapted to long stretches of darkness within polar nights are therefore particularly affected by ALAN. Due to harsh conditions for humans, winter ecology is notoriously understudied, with polar regions just gaining more attention recently. See for example studies on zooplankton during polar night (Last2016, Ludvigsen2018).

Snowglow - skyglow meets snow

Here we report results regarding skyglow, clouds and snow. Fig. 1 shows a set of night sky brightness (NSB) measurements obtained with a DSLR camera taken in the town Ludwigsfelde, 20 km south of Berlin for a) clear sky without snow, b) cloudy sky without snow and c) cloudy sky with snow cover. While the clear sky NSB is almost at 1.3 mcd/m² about five times brighter than natural, the cloudy sky is about six times brighter than that (7.3 mcd/m²). With clouds and snow however, the NSB is three orders of magnitude brighter than natural, giving a combined amplification by clouds and snow of 200 times compared to the clear night (* note that compared to a cloudy night without ALAN this should be even more).

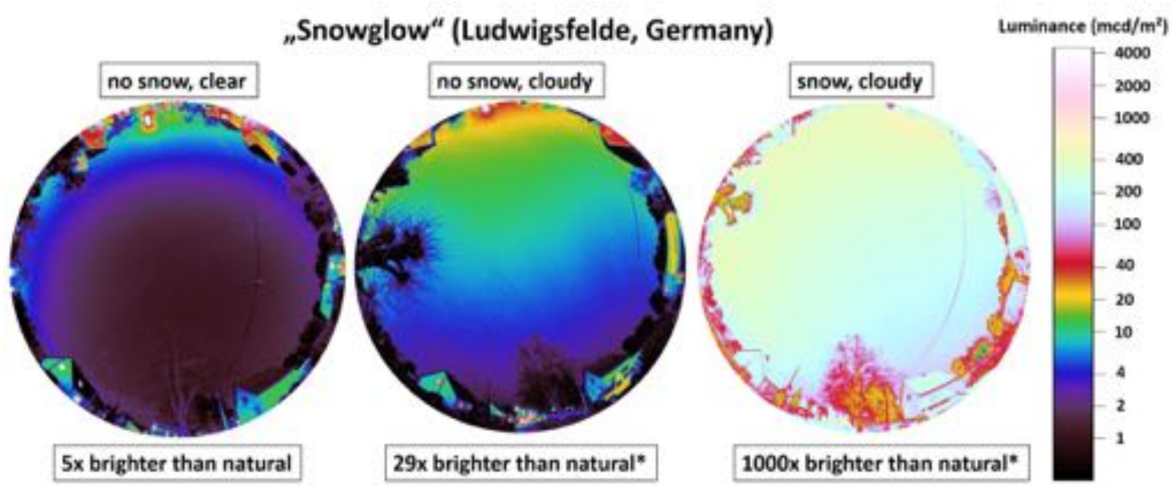

Fig 1: Snowglow – combined influence of snow and clouds on the night sky brightness.

The 2018 Darkness4all Lapland survey

As part of a light pollution initiative of the Stars4all project, we performed a survey in Lapland in January 2018 covering more than 1000 km on icy roads taking NSB measurements with different instruments (TESS, SQM, DSLR) on different terrain, near settlements and in remote places including on frozen lakes. The survey started in Kiruna, Sweden and was conducted via Tromsø, Norway to Kilpisjärvi, Finland and back to Kiruna. Permanent snow cover, cloud cover, fog and ice crystals enhance the effects of ALAN dramatically in places. Fig 2 shows a combined ice-pillar and cloud scattering pattern originating from a small border control station between Finland and Norway. Fig. 3 shows an SQM deployed on a frozen lake. We will present and discus a large variety of results, ranging from NSB with and without aurora borealis, transect measurements with cameras and SQMs (Jechow2017) and as luxmeter measurements taken during day and night.

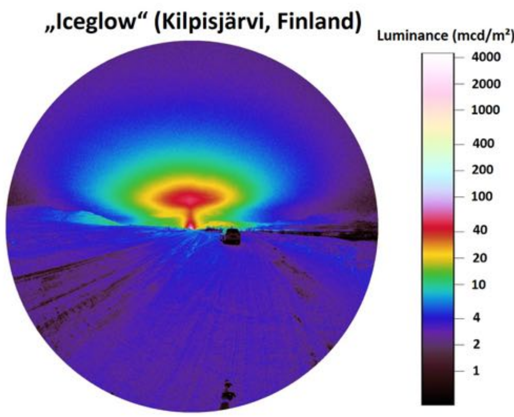

Fig 2: Light pillar and cloud backscatter pattern induced by ALAN from a single border station in a remote polar region. Fig 3. SQM installed on frozen lake Kilpisjärvi in Lapland, Finland.

Acknowledgements

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Legal restrictions on artificial light at night

Theme: Society

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Introduction

Artificial light at night (ALAN) is a trending research topic that receives most attention from natural sciences. After significant progress has been made to examine the extent and consequences of ALAN, the questions of how to mitigate and adapt to the – still increasing – illumination arise (Kyba et al., 2017, 2).

ALAN can cause severe adverse ecological effects. Affected by artificial lighting are especially animals. Illuminated buildings attract birds and increase the risk of bird strikes (Herrmann et al., 2006, 115). Artificial light emitted by outdoor lighting attract insects which perish at the light source due to exhaustion, heat or exposure to predators (MacGregor, 2015, 191). By attracting insects outdoor lighting might also hinder insect migration, particularly in the case of street lamps along a road (Eisenbeis, 2013, 53). Additionally, outdoor lighting can affect certain bat species that avoid lit areas forcing them to change their flight and foraging patterns (Stone et al., 2015, 214). Furthermore, ALAN can change conditions in natural habitats causing consequences yet to be determined.

Though, measures to avoid or minimize these adverse ecological effects have been identified, questions about legal restrictions remain unanswered: Which legal provisions exist to mitigate adverse ecological impacts of artificial light? Under which circumstances is one obligated to implement avoiding or minimizing measures? If so, who is addressed and compelled to act? Also, which mechanism secure the implementation of avoiding and minimizing measures?

Environmental law, particularly conservation law, construction and planning law are areas of law worth considering. However, the legal obligations vary depending on the respective national laws and its provisions.

The European Union (EU) has used its competence in environmental matters to impose legislation on European member states in order to establish a coherent European system of environmental protection (Calliess, Ruffert, 2016, art. 191 rec. 1). One is the council directive 92/43/EEC on the conservation of natural habitats and of wild life fauna and flora (FFH-directive). Another is the directive 2009/147/EC on the conversation of wild birds (wild birds directive). Both directives contain requirements compelling member states to implement national laws that shall not fall short of the level of environmental protection set forth in the directive. Hence, the examination of these directives provides an understanding of the legal obligations regarding ALAN that is applicable in all European member states.

Art. 12 para. 1 FFH-directive states that member states shall prohibit

a) All forms of deliberate capture or killing of specimen of protected species in the wild;
b) Deliberate disturbance of these species, particularly during the period of breeding, rearing, hibernation and migration; […]
d) Deterioration or destruction of breeding sites and resting places.

Similarly, art. 5 wild birds directive prohibits the killing of protected birds by any method. According to art. 1 wild birds directive all bird species occurring naturally in the wild state in European territory are protected. Both directives and their legal requirements address member states. They are obliged to implement laws that prohibit conducts as described above.

The use of artificial outdoor lighting can cause the death of animals, e.g. a streetlamp or skybeamer that attract and kill protected specimen. Considering the Caretta-Caretta-decision of the European Court of Justice (ECJ) (Lütkes, 2008, 600), the installation and operation of outdoor lighting can be classified as a deliberate conduct. Therefore, the installation and operation of outdoor lighting could violate art. 12 para. 1 FFH-directive and art. 5 wild birds directive.

Nevertheless, a violation does not occur, if measures to prevent or reduce the risk of the killing of protected specimen (preventive and minimizing measures) are put in place (Bick, Wulfert, 2017, 347). That raises the question, when, which and to what extend preventive and minimizing measures are required by both directives. Under which circumstances does the application of minimizing measures by reducing the risks of a killing result in the interpretation, that the specific installation and operation of outdoor lighting cannot be understood as a 'deliberate' killing of protected specimen?

By the example of and comparison to the German act of transposition of both statutes (§ 44 para. 1 BNatSchG) it can be shown that the question set forth above require (a) a nature conservation evaluation, (b) a comparison between risks caused by artificial lighting and natural mortality, which (c) includes an assessment whether the risks of artificial light are an inevitable consequence of human environment.

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LED Lighting: Fighting the brightening on turtle nesting beaches

Theme: Biology and Ecology

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Introduction

The Australian coastline is currently undergoing rapid development, particularly along the Queensland coast. Artificial light at night (ALAN) is an emerging threat to a wide range of taxa and specifically to adult and hatchling marine turtles. The beaches of the Sunshine Coast support nesting by loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) turtles. The Sunshine Coast Council (SCC) has endorsed an Urban Public Lighting Master Plan (ULMP) (September 2016). The ULMP is consistent with United Nations Environment Program (UNEP) Action Plan targets for *C. Caretta* and the International Dark Sky Association (IDA) conventions for the protection of the night sky.

Light Emitting Diodes (LEDs) provide cost-efficiencies from reduced energy consumption due to longer-lasting bulbs and brighter light. Using LEDS to meet sustainability targets, councils across Australia are rapidly replacing incandescent bulbs, with over 300,000 bulbs replaced to date.

There is a growing body of research, providing evidence of directly related impairment of human, wildlife and ecosystem health resulting from artificial light and which is amplified in the case of LEDs, which is becoming harder to ignore. White LEDs are enriched in blue light, the wavelength turtles are most sensitive to.

Sky42™ gathered light images over three nights at each of 27 monitoring sites on 16 nesting beaches covering a 60 km stretch of the Queensland coastline between South Bribie Island in the south and Coolum Beach in the north. Images were analysed using custom written software to quantify brightness at zenith, on the horizon and for the whole of sky in astronomical units of magnitude/arcsec^2.

In its first year the program: quantified and described the existing night sky horizon, identified primary sources of sky-glow and problematic point sources of light, designed a targeted emissions management approach and quantified the contribution of LED carpark lighting measured at an adjacent nesting beach.

In the current and repeat annual surveys, the program will establish benchmark light emission levels in each survey area, describing the night sky horizon and measuring lighting from marine turtle nesting beaches, providing data to address concerns regarding LED lighting and the understand cumulative impacts of light on turtles. This information will inform strategic planning decisions and support effective management of light emissions on nesting marine turtle populations on Queensland's ever brighter nesting beaches. There is potential for rapid uptake of the program among Australia's coastal councils and scope to measure monitor and manage impacts to a broader range of biological receptors, including turtles.

10 years of social engagement: lessons from Mont-Megantic's International Dark-Sky Reserve

Theme: Society

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Introduction

By essence, a dark sky reserve has to be rooted in its social environment. Strong political and community leveraging is needed in order to create it, and sustained efforts must be done in order to preserve it. Here we present the highlights of Mont-Megantic's International Dark Sky Reserve sociopolitical actions since its creation. Challenges were met on three fronts: regulation, luminaire conversion and outreach.

The region around mount Mégantic was recognized in 2007 as the first IDA International Dark-Sky Reserve (IDSR), following the adoption of three county wide lighting ordinances, and the conversion of 3000+ light fixtures. Centered around an astronomical observatory and a national park, it is encompassing 34 municipalities, a 250 000 population, and is covering a 5 300 km^2 area in southern Quebec, Canada. Cited by some as a model of balance between outdoor lighting needs and mitigation of ALAN impacts, it is currently undergoing one the most important PC-Amber LED exterior lighting conversion worldwide.

On the regulation front, two issues stood out most during this first decade: regulatory expertise/enforcement and adaptation to blue rich LED's arrival on the market. In order to tackle theses challenges, political efforts were made to stimulate regulations updates, with simplified tools and better control over the CCT. Regional dark sky preservation committees were put in place to better inform/educate partners, to share expertise and solutions, and to maintain and strengthen networks. A new large scale geolocalized database of street lighting was created, giving greater knowledge of the situation, allowing more precise light pollution modeling, and better planning of future efforts. Mont-Mégantic IDSR expertise also played an important role in the creation of a provincial exterior lighting standard, aimed to better control light pollution in Quebec.

In such a large protected territory, most of the initial light sources conversions took place inside the core zone, within a radius of approximately 25 km around mount Mégantic. Meanwhile, municipalities in the peripheral area adopted lighting ordinances, and proceeded with gradual conversion of existing installations. Recognizing the advent of blue-rich LED fixtures as a vital threat to the future of the reserve, focus was quickly shifted to address this new challenge. Following requests and discussions with the industry, PC-Amber LED's luminaires were made available by some manufacturers, on special orders at first. Up to date, 15 towns and villages in the reserve are undergoing a gradual conversion from HPS to PC-Amber LED's, including the city of Sherbrooke (170 000 population). Availability and prices are still an issue, but the warm LED market is now growing, and other light sources like 2000K LED and filtered-LED are also becoming more available.

While it is vital to provide political and municipal staff with adequate tools and training to understand and enforce lighting ordinances, there is also a strong belief in the importance of outreach in the population, to increase awareness, sentiment of belonging, and pride of living inside a Dark-Sky Reserve. Numerous communication efforts were made and activities held on the territory over the years. The ASTROLab, the observatory's visitors center, is a region's central attraction, being visited by 25 000 people each year. The national park itself receives over 100 000 visitors annually.

Over the years, the Mont-Megantic National Park has taken increased responsibilities in the management of the reserve. From an initial partner, it has become the main leader in coordinating and funding efforts. It has also integrated nocturnal habitat protection as its main conservation issue, reflecting the general widening of a project initially aimed at saving the starry sky, that has now evolved to encompass the nighttime environment as a whole.

A citizen science approach to quantify illuminance levels of sea turtle habitat in Gulf Islands National Seashore

Theme: Measurement and Modeling

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Introduction

Gulf Islands National Seashore (GUIS) spans 160 miles along the Gulf Coast from Mississippi to Florida and provides nesting habitat for several threatened and endangered sea turtle species. Proximity to the highly developed Florida gulf coast has contributed to zenith light pollution levels between 2-15 times brighter than natural conditions (Falchi et al. 2016). It is well known that anthropogenic light disrupts sea turtle phenology (Salmon 1995, Tuxbury 2005, Cruz 2018), and park biologists believe the intensity of anthropogenic light levels along with several other factors contribute to high disorientation rates among hatchling sea turtles within the park. In an effort to understand the distribution of light pollution throughout the seashore and how it may affect sea turtles, GUIS developed Turtle T.H.i.S, a citizen science campaign to engage volunteers and local middle school and high school students in measuring night-time light levels across the seashore.

Fig 1: A local high school student measures light pollution using the SQM-L multi point system atop a sand dune in Gulf Islands National Seashore. Photo by: Jeremy White

GUIS partnered with the National Park Service Night Skies Program, Colorado State University, and US Geological Survey to develop a portable measurement system to rapidly assess all-sky conditions along the seashore. Using a panoramic mount and paired Unihedron SQM-L units, with one modified with a 470 nm bandpass filter, luminance was systematically measured at 53 points creating hemispheric sky luminance maps. These maps generated a suite of metrics about the photic environment including horizontal and vertical illuminance, providing biologically relevant information about the distribution of light at each monitoring position.

From 2014 to 2017 students, volunteers, and park staff collected data at 116 locations across the seashore at three positions: mean high tide, dune toe, and dune top. Data were collected during both clear and cloudy nights to assess the amplification impact of cloud cover within sea turtle habitat. Results from dune top locations across GUIS show zenith light pollution levels between 1.5 - 25 times brighter than average natural conditions during clear moonless nights similar to conditions used by Falchi et. al. Average horizontal and vertical illuminance levels were 36 and 57 times brighter than average natural conditions, respectively. During nights with high cloud cover these metrics nearly doubled. While vertical illuminance was brighter than natural conditions in all directions, measures which included the developed coastline were significantly greater than those towards the gulf.

Here we discuss the success of the Turtle T.H.i.S. citizen science campaign at GUIS and the implementation of the multi-point SQM system. We take a preliminary look at the results of the campaign and compare these with other measurement techniques such as all-sky mosaics from calibrated CCD cameras (Duriscoe et al. 2007), and satellite imagery, and address the advantages and limitations of each. Finally, we discuss how these data will be used by Gulf Islands National Seashore in their efforts to manage the natural resources of the park.

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Helping Communities Develop a Lighting Ordinance

Theme: Society

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Introduction

Since the introduction of the International Dark Sky Association (IDA) and the Illuminating Engineering Society (IES) joint Model Lighting Ordinance (MLO) (IDA, 2011), several communities are using the MLO as the basis of their outdoor lighting ordinances. As a model, the MLO presents many choices to the communities to customize it to meet citizen's expectations. There are also MLO exclusions and/or options that communities may want to include such as sports lighting, streetlighting, light source spectrum and electronic sign brightness (luminance). City of Plymouth, Minnesota Zoning Ordinance (2018, p. 21105-3) is one of the longest standing ordinances using the MLO and now has added electronic sign luminance. The current City of Plymouth Zoning Ordinance (2018) states:

Fig 1: Softball field in Fort Collins, CO (A. Stevenson, Clanton & Associates, Inc.)

Signs using an LED (Light Emitting Diode) light source shall not exceed a luminance level of 350 candela per square meter (nits) between sunset and sunrise, and shall not exceed a luminance level of 4,500 candela per square meter between sunrise and sunset. *(Amended by Ord. No. 2013-27, 10/22/13).* (p. 21155-3)

City of Fort Collins, Colorado is currently developing an ordinance that includes both sports lighting and Correlated Color Temperature (CCT).

The first step to successful ordinances is to explore with the community their priorities. Gathering community and stakeholder expectations is the key to successful ordinances. Expectations may range from dark skies, minimal melatonin disruption, minimal ecological disruption, walkable safe environments, outdoor sales, evening sports activities, ease of understanding, and ease of enforcing. Stakeholder and community feedback on public lighting regulation is critical, especially when the lighting is located in residential neighborhoods.

Establishing Lighting Zones (LZ) that overlay on land use zones takes coordination with the planning department. Lighting Zones range from LZ0 to LZ4. LZ0 is a zone where outdoor lighting is not expected. LZ4 should not be used in 99.9% of the communities. City of Plymouth

Minnesota assigned lighting zones during the development of their outdoor lighting ordinance and have continued to refine them as they receive more community feedback. Typically, LZ0 or LZ1 is assigned to single family residential neighborhoods and LZ1 or LZ2 to multi-family residential, smaller retail areas, and office parks. Successful lighting zones are assigned to established land use zoning.

There are two compliance methods in the MLO. One is prescriptive, assigning initial lumens per square foot of hardscape and setting luminaire photometric criteria for allowable backlight, uplight and glare (BUG) (IES TM-15, 2011). The second is performance, which dictates the amount of light that is escaping the site (glass box approach). In our experience, the prescriptive method works well. The performance method still needs refinement.

Curfews, which include lighting level schedules, are another component. These can be assigned to lighting zones and/or applications. For instance, public parking lighting may need to turn off or dim in a parking lot one hour after the retail establishments are closed. Lighting that is still energized may be controlled by motion sensing to allow for deliveries and night shift staff.

Sports lighting can also be regulated. Working with the parks and recreation departments on light trespass, glare restrictions, uplight, lighting zones, adjacency to residential neighborhoods, lighting levels (as determined by play classification), and curfew, the sports lighting can meet the community's expectations for nighttime recreation with minimal neighborhood disruption.

Street lighting can be regulated for backlight, uplight, glare, CCT, and controls per lighting zone locations.

Finally, other goals can be identified and included such as limitation on spectral distribution and CCT. Establishing the non-compliance period where existing lighting is exempt is another challenge. City of Boulder, Colorado Title 9 Land Use Code (2018) used the IRS Tax Depreciation schedule to enforce compliance of all existing outdoor lighting 15 years after the ordinance adoption.

Educating the compliance personnel in planning departments and code enforcement officers is a very important step to establish consistency. Getting measurements and data before the regulation is developed, and then several years after the regulation will measure the ordinance's success.

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Contentious Lighting: Understanding Lighting Conflicts

Theme: Society

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Abstract

Views on artificial outdoor lighting can differ dramatically – and with them, opinions on its fair usage: One and the same element of lighting may, for example, equally be judged as a necessary basic amenity or as a superfluous source of costs and pollution. In contrast to most other types of emissions, lighting can be seen as "good" and "bad" at once. This ambiguity is a significant challenge for the development of sustainable lighting policies, which must ultimately balance the benefits and costs artificial lighting can bring.

Conflicts that revolve around artificial lighting offer a possibility to gain a deeper understanding of such ambiguous interpretations: In them, actors publicly take positions and exchange arguments, thereby opening windows on their views and the interests and rationales behind them. My presentation will tap this resource to provide a first overview of the landscape of lighting conflicts. Based on a broad analysis of contemporary conflict cases, its focus will be on the types of actors engaging in these disputes as conflict parties, and on the range and clashes of perspectives that become visible in regard to different types of lighting.

From Research to Practice: ALAN in Star Parks in Germany

Theme: Society

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Introduction

The impact of artificial light at night (ALAN) has generated an increasing number of research papers during the last years (e.g. Gaston et al., 2015). A variety of results was derived for the - mostly negative - impact on wildlife, human beings, on nocturnal landscape, and the sky brightness. Often general recommendations for reducing the influence of ALAN are given, while upper limiting values for the measurement methods used are seldom specified. However these limits would be essential to derive regulations or laws.

Fig 1: Demonstration road of RhönEnergie in Fulda with full cut-off and low blue content lighting. Photo: A. Hänel

Artificial light at night can be characterized by

- the luminous flux,
- energy efficiency of the lamps,
- the light directionality,
- the exposure time of ALAN,
- the spectral characteristics

Regulations exist for minimum values for illuminance or luminance for public lighting (e.g. EN 13201 or ANSI/IES RP-8) and illuminance for outdoor working places. These values could be optimized to reduce the luminous flux (and therefore energy use) through energy efficient lamps and directionality. Energy efficiency is regulated in many countries to reduce CO_2 emissions. Some upper limits to reduce the effects of obtrusive light are only defined in the CIE Technical Report CIE 150:2017, and help to reduce light pollution mainly through directionality.

Best Practice in Star Parks

A solution to reduce light pollution by applying modern research results (like Kinzey et al., 2007) is through voluntary action in dark sky protected areas. This implies information and discussion with local residents, administration and politicians. By this way protected star places could become best practices for reducing light pollution and using not only energy efficient but also sustainable lighting that protects nature und humans from the adverse influence of ALAN. Guidelines for dark sky places as defined by the Starlight Foundation or the International Dark Sky Association IDA are another approach to protect nocturnal darkness. Besides optimizing the directionality of light, as defined in CIE 150, the other aspects should also be addressed:

Luminous flux: New installations or refurbishments should not have higher luminous power as before. This may help to reduce a rebound effect. If lighting shall fulfill the norms, which are not legislative, the lowest possible luminous intensity class of the European norm should be applied.

Reducing exposure: Light should be reduced by at least 70% later in the night as reducing just by 50% is not visible to the human eye without having a comparison.

Spectral characteristics of light: Many studies have shown that higher amounts of shorter wavelengths are harmful for nature, humans and the visibility of stars. Sodium high pressure lamps are often used as reference, they have typically 7% of light with wavelengths up to 500 nm compared to the whole (for humans) visible spectrum from 360 – 700 nm. Corresponding values are the scotopic/photopic S/P ratio (about 0.7) or the correlated color temperature cct (about 2000 K).

Nature Park Westhavelland

When in 2012 preparing the application for the Nature Park Westhavelland west of Berlin to become an IDA Dark Sky Park or Reserve, the blue content of lamps was not explicitly limited in the IDA guidelines (2008). But as research showed already at this time that the blue content should be limited, an explicit upper limit of 2000 K in the core zones and 3000 K (13 % blue content) in the buffer zones was given in the lighting guidelines for the Nature Park. In the IDA guidelines revision of 2013 a maximal cct of 3100 K was introduced.

Many communities in Westhavelland have no money for the complete replacements of the street lighting. Therefore they can finance just LED retrofit lamps in the luminaires, which is very cost efficient for the old mercury high pressure lamps with cct 4200 K). The decision is mostly for white light with 3000 K and higher relative blue content than high pressure sodium. But often a lower luminance is chosen that the absolute blue content is reduced. Furtheron solutions with LED retrofits e.g. with asymmetric directed light and low cct of 2200 K are chosen. In many villages street lighting is reduced during the night to 20 – 50 %, in some villages even switched off.

UNESCO Biosphere Reserve Rhön and City of Fulda

Similar methods were used in the UNESCO biosphere reserve Rhön in the center of Germany, where in several communities street lighting was halved and replacements from 4000 K fluorescent tubes to 3000 K LED tubes or new 3000 K LED full cut-off luminaires were installed. Several villages even decided for pc amber LED lighting. The main success story of the Rhön is that more and more communities want to accept the lighting guidelines as an example of sustainable lighting and become a member of the IDSReserve. And the city of Fulda with about 70 000 inhabitants plans to become an IDA Dark Sky community.

Winkmoosalm

The IDSPark Winklmoosalm in the Alps of Southern Germany is a traditional seasonal mountain pasture at an altitude of 1200 m. There is no public but only private lighting and the owners of the 36 houses including 2 large hotels have been motivated to replace their lighting according to the dark sky park guidelines. Simple and cheap solutions were chosen to reduce the luminous flux to less than 500 lumens especially for not full cut-off luminaires, to incline flood lights that they only emit under the horizontal line and changes to cct less than 3000 K. Further on, most lighting on the Alm is used only occasionally and only switched on when really needed.

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Best Management Practices for Mitigating Social and Ecological Impacts of Artificial Lighting at Night on BLM-Administered Lands

Theme: Technology & Design

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Introduction

The United States Department of the Interior Bureau of Land Management (BLM) manages approximately 1,001,000 km2 (247.3 million acres) of publicly owned land, primarily desert and open rangeland in the western U.S., about one eighth of total landmass of the U.S. BLM-administered lands include the darkest skies in the U.S., and much of the land managed by BLM has very dark skies and abundant natural darkness. BLM lands also surround or are directly adjacent to many U.S. national parks, monuments, and historic sites, as well as sensitive tribal lands and major and minor population centers.

Preserving Night Skies and Darkness within a Multiple Use Mission

BLM is a multiple use agency. It manages the public lands for recreation and conservation, but also mining, grazing, and energy production. BLM faces increasing interest in the use of BLM-administered public lands for differing types of activities, developments, and visitor services. The increase in development activity has led to an increase in outdoor artificial lighting at night (ALAN). The increase in nighttime lighting can contribute to light pollution that impairs the visible clarity of starlit skies, negatively impacts wildlife, and can also affect human health and wellbeing. Development on BLM-managed lands can also affect the biological resources and human uses on neighboring publicly and privately owned lands. These lands include many major tourist destinations, some heavily used for astro-tourism and other night time recreation, but also include important cultural, religious, and historic sites, and they provide critical habitat for many types of wildlife, including many sensitive to ALAN.

The BLM must ensure that development projects and activities on BLM-managed lands meet all applicable environmental laws and regulations, including the Federal Land Policy and Management Act of 1976 (FLPMA) and the National Environmental Policy Act of 1969 (NEPA) (Title 42, Sections 4321–4327 of the *United States Code* [42 USC 4321–4327]). Because night skies and darkness are considered scientific, scenic, cultural, and recreation resources, and are subject to the BLM's management authority under FLPMA. A stated goal of NEPA is to "assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings" and to "preserve important historic, cultural, and natural aspects of our national heritage." Night skies and darkness are an integral component of aesthetically and culturally pleasing surroundings on the public lands, and constitute important historic, cultural, and natural aspects of our national heritage.

Best Management Practices Publication

In response to the increasing public concern over potential impacts associated with ALAN on BLM-administered lands, the BLM will soon publish *Best Management Practices for Reducing Impacts of Outdoor Artificial Lighting at Night on BLM-Administered Lands* (hereafter referred to as the "ALAN BMPs publication"). Best management practices (BMPs) are state-of-the-art mitigation measures designed to provide for safe and efficient operations while minimizing undesirable impacts to the environment.

In addition to extended discussions of night sky/darkness values, light pollution, ALAN impact mechanisms and impacts, the ALAN BMPs publication presents more than 60 BMPs to avoid or reduce potential impacts associated with the use of ALAN for facilities or activities located on the public lands. The ALAN BMPs publication is intended to:

- Improve understanding of the full range of night sky and darkness resource values and importance in the context of BLM land use management activities;
- Improve understanding of impacts of ALAN and the basic mechanisms by which ALAN causes adverse impacts to ecological, cultural, historic, and recreation resources found on or near BLM-administered lands, as well as the economic benefits provided by dark skies and natural darkness; and
- Influence better outdoor lighting design and management practices for facilities developed on BLM-administered lands, and for any other type of land use activities that have artificial lighting that affects night skies and dark environments.

ALAN BMPs Publication Intended Uses and Users

The ALAN BMPs publication is intended for ecologists, recreational planners, landscape architects, project managers, realty specialists, and cultural resource specialists as a comprehensive information source to learn about night sky/darkness values, ecological and human impacts of ALAN, and strategies to mitigate those impacts. It will provide agency staff, industry, and other stakeholders with proven, effective, and vetted BMPs to address a wide range of potential impacts from outdoor lighting. The BMPs were compiled from a variety of sources, including guidance documents developed by various government agencies and non-governmental organizations; professional practice literature; consultations with subject matter experts, including federal agency staff, lighting engineers, ecologists, cultural resource specialists, astronomers, landscape architects, and energy professionals. The publication has received extensive peer review. The expected publication date is late 2018 or early 2019.

Representing the Night Sky: Examining the Roles of 'Lay Experts' and Sensory Experiences in Dark Sky Preservation

Theme: Society

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Abstract

Weber (1946), one of the "founding fathers" of social theory, asserted that the process of rationalization strips the world of mystery, leaving it disenchanted. Via astronomy, an entire field of science seeks to uncover the night sky's secrets, yet a dark night sky continues to evoke awe, humility, aesthetic appreciation, and numinous experiences (Bogard, 2013). Night sky preservation presents a rich space to explore intersections between the material facts that define environmental quality and the experiences, emotions, and beliefs that make natural objects meaningful.

As Boström and Uggla (2016) noted, "The environment or 'nature' cannot plead its own case but must be represented." The night sky's representatives include non-profit organizations, such as the International Dark-Sky Association, staff of parks and protected areas, and the astronomy community—both amateurs and professionals. Representations, however, are not neutral (Carolan, 2009), and these groups have different interests at stake. For example, professional astronomers seek to protect their jobs and the continuation of their discipline, whereas park administrators seek to sustainably manage their natural resources. We know little about the effects of organizational affiliation on environmental representation (Boström and Uggla 2016). Utilizing qualitative social science methods, including participant observation, semi-structured interviews, content analysis, and an online survey, I examined how dark sky advocates 'represent' the night sky.

Two decades of social science research have demonstrated that the categories of 'expert' and 'layperson' are better conceptualized as two ends of a continuum, rather than a dichotomy. Filling the middle are "lay experts"—members of the public who have amassed sufficient knowledge about a topic to be a credible participant, despite lacking the professional employment and academic credentials of an expert (Epstein, 1995). Within the realm of dark sky preservation, there are two primary groups of lay experts: amateur astronomers and nature interpreters.

Latour (1987, p. 72) noted that representatives—or 'spokespersons,' as he often called them—are most compelling "when they do not talk by and for themselves but *in the presence of* what they represent." In addition to giving informal talks about light pollution, both amateur astronomers and nature interpreters host outdoor, nighttime events that introduce the public to the night sky. In these "tactile spaces" (Carolan, 2007), visitors accumulate embodied knowledge of the night sky via sensory experiences in informal, recreational programs.

On the continuum of night sky representation, with the professional scientist's detached observations at one end and the radical environmentalist's passionate pleas at the other, amateur astronomers and nature interpreters permeate the middle. Their significant knowledge base earns them credibility, while their position as something other than a formal scientist grants them greater liberty to express emotion, emphasize beauty, or perhaps even mention God while maintaining that

credibility. In other words, they can (sometimes) earn and maintain credibility as science 'experts' without disenchanting the natural world. Despite possessing this unusual persuasive potential, I show how their fears of appearing "too political" frequently cause them to privilege science and material facts in their representations of the night sky.

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Monitoring public lighting in Ireland: using space imagery and lighting inventories

Theme: Measurement and Modeling

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Introduction

During the Celtic Tiger years, there has been a large increase in light production in Ireland, amounting to an annual cost of €56 million currently. Across the Republic, roughly 95% of public lighting is provided by sodium discharge luminaires, either of low pressure (LPS) or high pressure (HPS) types. Most lighting is unmetered, and can cost up to 70% of a local council's budget. Due to the low overall efficiency of these types in terms of lumens on the ground to overall electric power, there is now a drive to replace older lighting with newer and more efficient full cut-off LED lighting, and there is also a campaign to switch to "trimming & dimming" across the Irish Republic in 2019. To monitor the effect of such changes, we have commenced the first stage of a campaign to monitor light production and changes over time, and also to monitor the relative contributions from public and commercial/retail lighting.

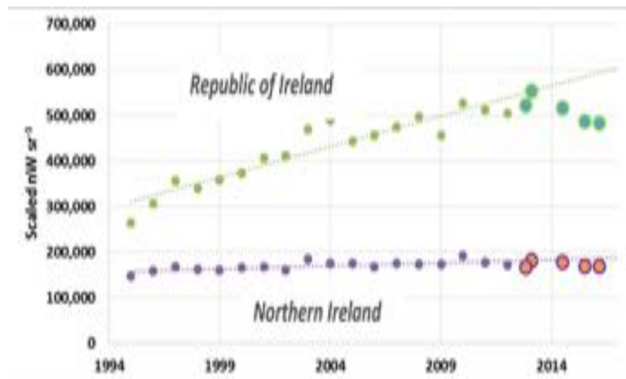

Fig 1: Growth of light emitted by Republic of Ireland showing the ~80% increase in light over 1995-2014, compared with relatively constant output from Northern Ireland. Measurements were obtained from the Defense Meteorological Program (DMSP) satellites, with newer data from NASA's SUOMI VIIRS instrument.

Monitoring from Space

The SUOMI/VIIRS mission has revolutionised the study of light at night due to the higher sensitivity and resolution of the Day/Night Band (DNB) imager compared with the older DMSP/OLS data. However, a downside of these new data is their relatively modest spatial resolution and lack of colour information, in particular the lack of spectral response in the blue portion of the spectrum. This is an issue as more blue-rich white light sources – particularly those using LED technology – have significant emission in this part of the spectrum. On the other hand, higher resolution colour imagery is available via astronaut photos from the International Space Station but these are not intensity uncalibrated by default.

We will present results of a new approach to combining these space imagery datasets to estimate power output at a resolution down to approximately 10m, or roughly 30-50 times better than the basic VIIRS resolution for Ireland. We assess the quality of our calibration by making use of the Irish national public lighting inventory to provide ground truth estimates of energy use and lumen output for a range of lamp types in different environments, from small towns to large cities. This is an important first step in monitoring the introduction of new lamp types and practices in Ireland.

Artificial light at night increases neurogenesis and suppresses melatonin in birds in a dose-dependent manner

Theme: Biology & Ecology

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Daily cycles of natural light affect many biological phenomena. However, these patterns have been greatly disrupted through global urbanization. The introduction of artificial light at night (ALAN) from various sources (e.g. street, domestic, industrial) was found to have vast biological impacts, from the molecular to the ecosystem levels, including impacts on gene expression, physiology and behavior of organisms. ALAN is quite pervasive, in animals and humans, and findings suggest that it is associated with several physical and mental health problems. The few studies that exist on neurogenesis and cognitive functions in mammals indicate that the disruption of the circadian cycle induces learning and memory deficits and suppresses neurogenesis. However, nothing is known yet about the effect of ALAN on neurogenesis (i.e. the birth of new neurons) in birds.

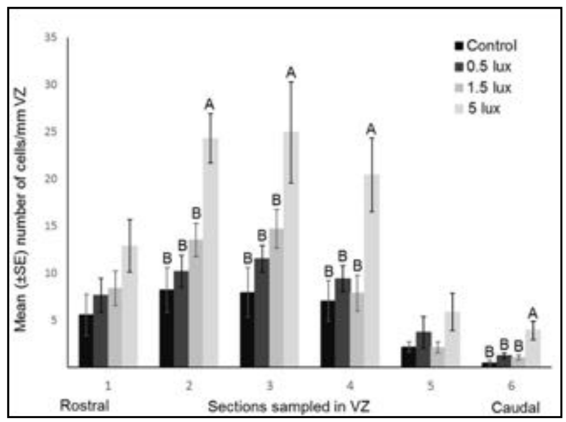

Fig. 1: Cell proliferation (# of cells/mm; mean ± SE) in the ventral wall of the VZ in brains of birds exposed to ALAN (0.5, 1.5, & 5 lux), and controls that remained in dark nights. Six sections were sampled along the rostral-caudal axis of the VZ. Different letters indicate significant differences ($p<0.05$) within each section. N = 6 birds / group.

To this end zebra finches (*Taeniopygia guttata*) were exposed during three weeks to varying intesities of ALAN that are known to be ecologically relevant (0.5, 1.5, and 5 lux). Then, the birds were treated with BrdU (a cell birth-date marker) to quantify neurogenesis in the ventricular zone (VZ) in their brains, and compared to control birds that were kept in complete dark nights. We found that ALAN significantly increased neurogenesis in specific parts of the VZ (**Fig. 1**), and suppressed melatonin production (**Fig. 2**), both in a dose-dependent manner. Our study is the first report that ALAN affects neurogenesis in birds, and adds to the growing body of compelling evidence that ALAN alters basic biological processes. Moreover, our data show that in contrast to nocturnal species, in which it had been found that ALAN negatively affects neurogenesis and neuronal survival, in diurnal animals neurogenesis is augmented by ALAN. We believe that our study lays the ground for a broader investigation of possible relations between ALAN, neuronal plasticity, and melatonin. In addition, our data further support the hypothesis that although the circadian systems of nocturnal and diurnal animals function in a very similar way, they translate signals in opposite ways, according to the animal's lifestyle.

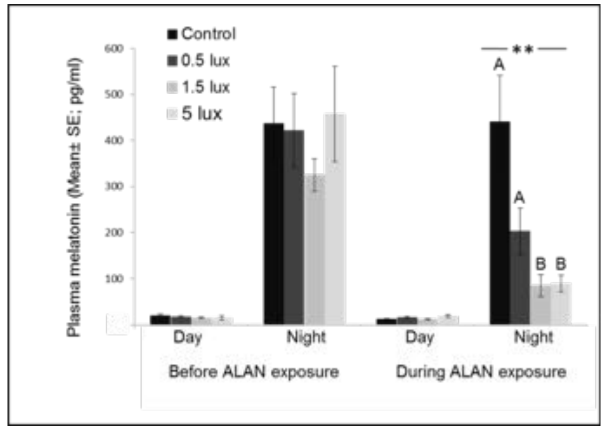

Fig. 2: Day and night plasma melatonin levels (pg/ml; mean ± SE) before and after ALAN exposure (0.5, 1.5, 5 lux), compared with controls that remained under dark nights. N=6 birds/group. Letters indicate significant differences ($p<0.05$).

NITELITE: a High-Altitude Balloon (HAB) framework for angularly dependent temporal sensing of light pollution

Theme: Measurement and Modeling

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Introduction

Approximately 99% of the populations of the United States and European Union reside in areas where the ambient light surpasses the International Astronomical Union threshold for light-polluted status (Chepesiuk, 2009). As lighting technology advances, many civic organizations (such as Chicago Smart Lighting Project, 2017), seek affordable techniques to measure the effects of lighting infrastructure changes. The NITELITE program is a series of high altitude balloon (HAB) missions with a payload designed for nighttime imaging of light pollution from approximately 25 km. HAB surveys provide comparable imaging quality to other techniques such as aerial surveys (Kuechly, 2012), satellite imaging, and ISS imaging, while significantly reducing cost. Additionally, NITELITE provides unique benefits such as repeatable imaging, identification of moving light sources, and measurement of angular dependence of light pollution from permanent light fixtures. In this paper, we discuss the data analysis techniques necessary to extract such information from the NITELITE system.

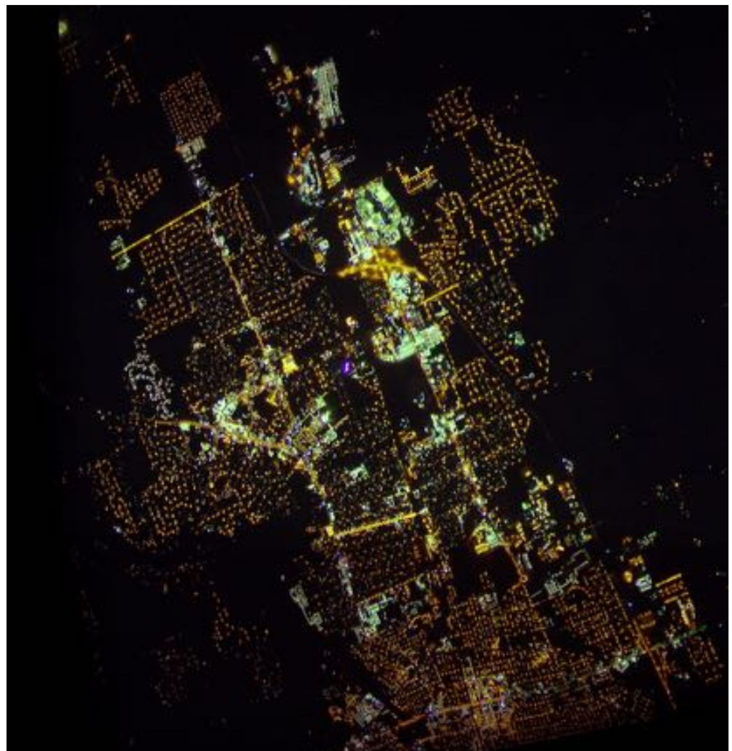

Fig. 1: Kankakee, IL as imaged by the NITELITE system. This composite image is a stack of five 50ms exposures from one off-axis camera taken at an altitude of 24 km.

Experimental Design

The primary payload for NITELITE consists of imaging equipment, dynamics sensors, transmitters, and tracking beacons. The imaging system consists of three Basler acA1920 – 40uc cameras with a 1920x1200px resolution in standard Bayer RGB format. The three cameras are mounted to the payload - one nadir pointing and two off-axis at opposite a 21 degree angles creating a single 35x10km imaging footprint at altitude. Additionally, an On-Board Computer (OBC) is used to log GPS, accelerometer, gyroscope, and magnetometer data associated with each image. These two systems provide the raw image data and dynamical metadata necessary to perform our analysis.

Image Post-Processing and Light Source Identification

Unlike a typical aerial flyover, the altitude and orientation of the cameras varies with the trajectory of the HAB system. For each 3D position and orientation, we use the OBC's accelerometer, gyro, and GPS data to do an approximate orthorectification/geolocation of the image. We then correct the estimated location using landmark registration provided by a dedicated Citizen Science (Zooniverse) project. The orthorectification/geolocation is then repeated with these precise values. This process is inherently noisy, since errors in the OBC sensors and GPS coordinates propagate throughout this pipeline. However, unlike aerial flyovers, NITELITE generates a large number of overlapping images for a single location. Borrowing from astrophotography techniques, we stack and cross-register images of the same region in the ground plane to reduce both photometric and geometric noise. Individual light sources are extracted from stacked images by selecting discontiguous regions after removing pixels below a certain threshold. These sources, separated into transient and permanent sources and indexed by location and time are the fundamental results of our data pipeline.

Statistical Analysis

Analysis of the light sources is performed in a variety of ways.

Lamp Type: Following the work of (Hale, 2013), we can identify individual light sources by their lamp type based on color and geometry These identifications are verified using ground observations.

Angular Dependence (AD): Compared to traditional aerial surveys, NITELITE provides a wider field of view for tracking light sources over a range of angles. This allows us to calculate the AD of light emission, an often overlooked aspect of light pollution sensing. Given the stacked images, we can produce AD curves for each individual light source; one flight can yield thousands of such curves. These curves can then be correlated with light types using models from existing literature.

Temporal: NITELITE offers uniquely dense temporal coverage, both at short and long scales. At short scales, NITELITE enables minute to hour scale tracking of light sources, which can be used to track moving light artifacts such as car headlights. Additionally, due its low cost, NITELITE can support multiple flights per year, enabling tracking of seasonal and infrastructural changes in lighting.

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Migratory birds' exposure to artificial light at night at the continental scale

Theme: Biology and Ecology

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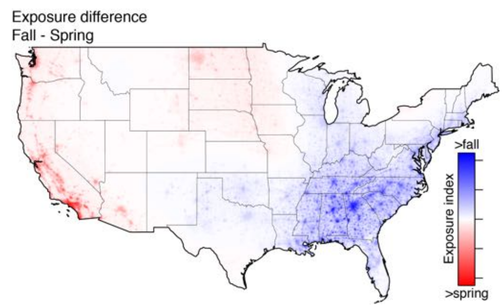

Fig 1: Seasonal differences in exposure to ALAN. Magnitude of spring and fall cumulative movements is standardized to highlight seasonal differences in migratory routes.

Introduction: Artificial light at night (ALAN), including from streets, tall structures, and stadia, can disturb wildlife in a multitude of different ways (e.g. Rodríguez *et al.* 2017; Hoffmann *et al.* 2018). For nocturnally migrating birds, ALAN can disorient actively migrating birds, alter stopover locations, and at worst, result in mortality (e.g. Lebbin et al. 2005; Gauthreaux & Belser 2006; Hölker *et al.* 2010; Van Doren et al. 2017). Mitigating actions to reduce impacts of artificial light on nocturnal migrants may ease these disturbances, and can include directed efforts at specific sites that range from informing the public to reducing excess lights (Evans Ogden 2002) and periodically turning high intensity lights off (Van Doren *et al.* 2017). Although avian migrants regularly travel over heavily photo polluted areas (Cabrera-Cruz *et al.* 2018), risks posed by artificial light on nocturnal migration may not be spatially or temporally uniform. There may be considerable variation in risk that necessitates mitigation and conservation plans that are spatially and temporally specific. Furthermore, the potential is high for heavy casualties from ALAN related collisions and behavioral alterations. Here, we combine a long-term remote sensing data set of where and when the highest numbers of migrants pass over ALAN in the continental US, to identify the areas and times of year when the highest number of migrants are exposed to ALAN. We map the exposure across the continental US and over the 125 most populated urban areas, highlighting 10 cities with the highest exposure factors.

Methods: We use weather surveillance radar data from 143 stations during spring (March 1st to May 31st) and fall (August 15th to November 15th) from 1995 to spring 2017 to characterize the cumulative migration intensity across the continental United States. We use Visible Infrared Imaging Radiometer Suite (VIIRS) data to quantify the magnitude of artificial light at night (source: Earth Observation Group, NOAA National Geophysical Data Center). We calculated exposure as the product of cumulative migration intensity and radiance. Within urban areas we calculated exposure as the product of cumulative migration intensity and the sum of radiance.

Results: Almost all areas of the continental US showed an increased migratory activity during fall, resulting in 58.0% higher sum of migrants exposed to ALAN. After standardizing for differences in total migration intensity between seasons, we observed 12.6% higher sum of exposure in the fall. This means that more migrants moved through photo-polluted airspaces in fall, especially in the eastern half of the United States, although in some areas in the west exposure was higher during spring. Not surprising, the strongest reflectance values were observed in urban areas. Examining city-level exposure, the top-10 most populous cities were not always the worst photo-polluters, and did not always show the highest levels of exposure of migrants to ALAN. However, of the top-10 most populous cities, 6 of 10 were in the top-10 for highest levels of exposure across the United States during the spring, and 5 of 10 in the fall. Regardless of season, Chicago, Dallas, and Houston in descending order showed the highest levels of exposure of migrants to anthropogenic light at night. Of the 125 largest cities, the top-10 greatest changes in seasonal rankings occurred in the western half of the country (e.g. San Diego, CA, Riverside, CA, San Jose, CA).

Conclusion: We provide the first quantification of exposure to nocturnally migrating birds at a continental scale. Our analysis highlights the importance of considering spatial and temporal variation in developing action plans. Furthermore, for the first time we can potentially evaluate the relative contributions of urban centers across a wide latitudinal and longitudinal gradient with respect to ALAN effects on migrants. This information can facilitate new research on migrant bird populations that can inform both biological investigation of how birds respond at multiple spatial and temporal scales to ALAN and conservation action for where and when to implement mitigation plans to ease potential hazards.

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Characterizing local properties of artificial light at night

Theme: Measurement & Modeling

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Introduction

The public lighting will be replaced in two Hungarian settlements, one close to the Zselic Starry Sky Park in southwestern Hungary, and another one inside the Bükk Starry Sky Park near the city Eger in northeastern Hungary. The new system provides possibilities for interdisciplinary light pollution research. Both the flux and the spectral distribution of the new LED-based luminaires can be controlled within a specific range. We will monitor the differences in lighting by standard light pollution measurement techniques, and also perform biomonitoring at the respective locations. We refer to this whole system as Living Environmental Lab for Lighting (LELL).

The goal of this system is to provide local and detailed assessments of the environmental impacts of ALAN. To achieve this, we are developing a high-resolution mapping method which gives the complete information of the local light field, in order to help to understand the results from biomonitoring. Although there are methods to analyse digital camera images for sky radiance and luminance measurements (see, e.g. Jechow et al. 2017), close to light sources these methods usually fail due to the very high dynamic range of the scene. Therefore we provide a new procedure for such measurements.

First, we obtain a high-resolution and high-density-range luminance/radiance map of the whole sphere at a possible observer or specific living creature by measurements with a robotic panorama head and a calibrated digital camera. From the spherical mapping, the irradiance or illuminance on all the possible planes can be calculated. Then we downsample the high-resolution radiance map to a lower resolution mapping to filter out localised sources of noise. Afterwards, we further reduce the measurement data by spherical harmonics fitting. With these simplified parameters representing the angular and spectral distribution of radiance, the search for the correlations between the night sky pattern and ecological impacts for different locations can be facilitated.

Acknowledgements

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Reproductive and Body Mass Responses of Australian Budgerigars (Melopsittacus Undulatus) to Short Wavelength Artificial Light at Night (ALAN) Exposure: Is it an exceptional Avian Model?

Theme: Biology & Ecology

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Introduction

Objective and methods: We assessed the reproductive and body-mass (Wb) responses of 24 adult pairs of Australian budgerigars (Melopsittacus Undulatus), to short-wavelength (SWL) artificial light at night (ALAN) exposure. We divided the budgerigars into four experimental groups consisting of six pairs each placed in separate cages: 1) control group with no ALAN exposure. 2) Exposure for 30 min to SWL-ALAN. 3) Exposure for 60 min to SWL-ALAN, and 4) exposure for 90 min to SWL-ALAN, following a habituation period of 30 days during the season of increasing photophase from April until June. During the study, we measured Wb, the number of eggs laid, chick hatches and levels of the pineal neuro-hormone melatonin secretion assessed from its metabolite collected from the droppings.

Results: We revealed differences between the numbers of eggs laid by the control group (an average of four), compared with those under 90 min of exposure (n=0) ($p<0.01$), during the entire experimental period. We also noted a significant ($p<0.01$) difference in the number of hatching chicks (mean=3.6 for controls vs. mean=0 for budgerigars, exposed for 60 or 90 min to ALAN). In addition, we observed differences in Wb gains between control and test groups: while Wb at the beginning of the study was similar for all individuals of all groups, during the experiment (four months), differences in Wb developed and only the SWL-ALAN exposed groups gained Wb. We also noted a positive correlation ($p<0.01$) between melatonin levels and the number of eggs laid but a negative correlation ($p<0.05$) between Wb and number of eggs laid.

Conclusion: We conclude that SWL-ALAN exposure has a negative impact on the reproductive system of Australian budgerigars and this impact presumably related to the duration of exposure.

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Spectral survey of sky quality

Theme: Measurement & Modeling

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Introduction

Sky quality measurements by digital cameras have become a routine procedure in protected areas (Kolláth & Dömény 2017); however, these observations lack the wavelength dependence of sky radiance. We have started a spectral sky quality survey in the Zselic Starry Sky Park. Our mobile laboratory consists of a Konica-Minolta CS–2000A spectroradiometer and a digital camera-based measurement system. We calibrated the spectral sensitivity of the digital cameras using the spectroradiometer. Our initial tests show that the spectroradiometer can measure spectral radiance in 4 minutes with a low noise level and high accuracy even at pristine sky conditions. The digital camera-based system calibrated by the spectroradiometer further enables measurements at remote locations.

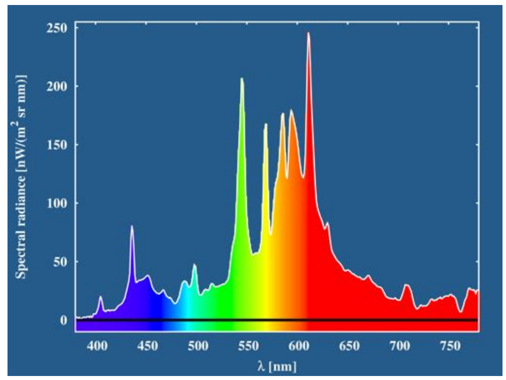

Fig 1: The spectral radiance of the light-dome of Kaposvár. This spectral distribution can be decomposed to a mixture of Sodium lamp, LED and CFL sources.

Examples of how the spectral radiance distribution varies as a function of the location on the sky will be given. The spectral radiance distribution is decomposed by templates based on the measurements of the given area, which allows mapping of the whole hemisphere. We will also discuss how the standard observations are affected by the different spectral sensitivities of the devices.

Another potential use of the measurements is the variation of the spectral radiance as a function of the distance from the source, for example, major cities or towns, or industrial areas with a high emission of artificial light. The relative brightness of the sky at the different wavelength ranges depends on the spectral extinction coefficient of the atmosphere. Thus, the measurements provide information also on the aerosol content of the air and other essential properties. These data provide substantial input data for radiative transfer modelling.

Acknowledgements

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Rhythms in the dark: direct and systemic impact of light at night on temporal organization of activity

Theme: Biology & Ecology

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Evidence showing negative impact of artificial light at night on species and ecosystems is accumulating. Effects vary from direct mortality to disruption of species' natural behaviour. A frequently reported consequence of light at night are changes in the daily timing of activity of species. The occurrence of such changes may be expected, as the natural light/dark cycle is for most species the most powerful cue for time of day. It modulates activity patterns directly by light intensity, and indirectly by entraining the endogenous circadian system of species.

In the field, there are several examples of changes in daily timing of activity as a result of artificial light at night. Several bird species substantially advance their dawn song activity in the presence of artificial light at night. Another example are birds that search for food by visual cues at locations that normally serve as foraging grounds during daytime. Although the latter may be a clear example of a direct response to light, in many other cases it is not clear whether effects relate to a direct effect of light, or to a changed phase of the endogenous circadian clock. In addition, for many other species groups, examples of temporal changes in activity are limited at all. Here, we present 1) the results of measurements of temporal activity of birds in the laboratory, and terrestrial mammals and bats in the field, in both cases with and without experimental light at night. Subsequently we 2) evaluate whether observed changes in the temporal organization of behaviour here and elsewhere may be caused by a direct response to light, or by changes to the endogenous circadian clock.

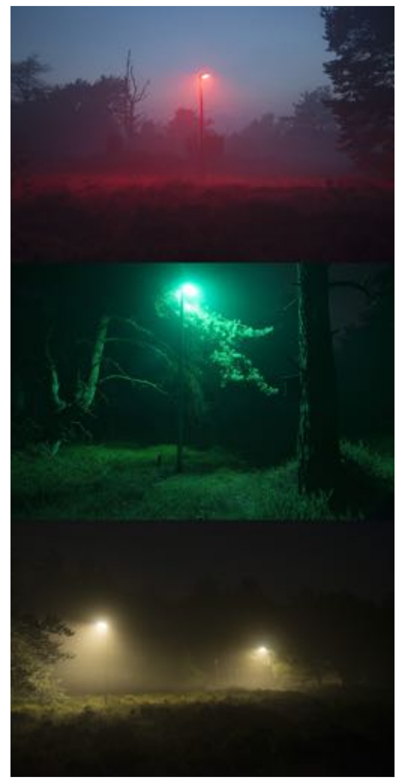

Fig 1: Three colors of light at one of the eight experimental sites.
Images by Kamiel Spoelstra / NIOO-KNAW.

1) In a unique field experiment, at each of eight study sites, we experimentally illuminated previously dark natural habitat with white, green and red light with light levels commonly used for countryside infrastructure (fig.1). We measured activity of small mammals and bats at these field sites with and without the presence of light. Simultaneously, we ran assays with birds for which we continuously measured activity with and without light at night in the laboratory.

2) We tested for a direct response in 'daily' timing of activity of small mammals and bats by switching lighting on- and off at the experimental sites in the field. For birds, we studied whether changes in activity patterns by (dim) light at night were caused by a direct response to light by subjecting great tits to a light schedule, which revealed possible changes to the endogenous circadian rhythm.

The results of these studies reveal moderate to strong changes in the temporal organization of activity. However, these changes appear to be a direct response to light, and in case of the great tits in the laboratory, these changes clearly do not relate to changes in the circadian system. These direct responses imply that species are rather flexible in their response to light at night. Indirect responses, including those involving changes to the circadian system, may certainly occur for certain species in specific circumstances. However, it is good to realize that changes in daily activity patterns do not necessarily reflect changes in the circadian system.

The results raise many new questions with respect to changes in activity by light at night for different species groups in natural habitat. Research on whether these changes affect the circadian organization and other physiological can be challenging, but novel techniques and specific assays may provide effective solutions.

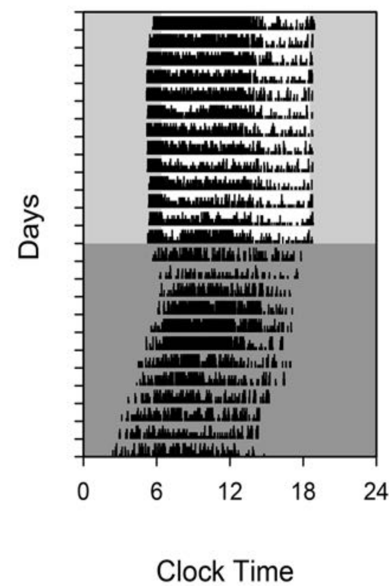

Fig 2: Activity pattern of a great tit (*Parus major*). Each line contains 24 hour of activity (indicated in black). When an organism is deprived of time cues, the endogenous circadian system regulates the expression of activity (lower half of the actogram). The initial timing of activity directly after the switch from a light/dark cycle to continuous darkness (halfway the actogram) reveals the phase of the master circadian clock. In case light at night has an effect on the circadian system, it will change this phase.

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Sky42 - Measuring light with autonomously operated DSLR cameras: Generation II

Theme: Measurement and Modelling

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Introduction

10 years ago, we began development of our Sky42 cameras to capture and measure artificial light at night predominantly on Australian turtle nesting beaches. The cameras needed to be rugged and able to withstand a range of conditions, including rain, high humidity, wind, sand and heat for 10 – 12 hours. We achieved this using Canon Powershot G12 cameras encased in a custom-built housing powered by lithium ion batteries and controlled by an Arduino microprocessor.

In 2017 we began development of a second generation set of cameras, with a new design building upon our experiences with the first generation and including a wide range of improvements that result in better quality images and higher reliability. This presentation outlines the differences in design between each generation and how this has resulted in the capture of higher quality data.

Evaluating Artificial light at night (ALAN) risk exposures in gastroesophageal cancer and chronic lymphocytic leukemia in Spain (MCC-Spain study)

Theme: Health

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Abstract

Background. The increase of artificial light-at-night (ALAN) in cities has altered the natural light levels in the nocturnal environment and extended human activities into the usually dark hours (Falchi et al. 2016). Different studies have established significant associations between prolonged exposure to ALAN and several adverse health effects, including sleep disturbance (Ohayon et al. 2016), obesity (Rybnikova et al. 2016) and elevated risks of hormone-dependent cancers in general population i.e. non-shift workers (Garcia-Saenz et al. 2018). However, regarding non hormone-dependent cancers, limited studies have evaluated this association and with little evidence and exposure information.

The present study attempts to investigate the relationships between ALAN exposure and the risk of two non-hormone dependent cancers i.e. gastroesophageal cancer and chronic lymphocytic leukemia (CLL), within the context of a multicase-control study in Spain (MCC-Spain). We examined individual residential information on ALAN focusing on blue light spectrum exposure.

Methods. We enrolled 81 incident histologically verified gastroesophageal cancer cases and 155 CLL cases, with age, sex and region-matched population controls, from Barcelona and Madrid, between 2008 and 2013(Castano-Vinyals et al, 2015). All subjects were interviewed and residences geocoded. Outdoor-ALAN was analyzed using images from the International Space Station (ISS) available for Barcelona and Madrid, including data of remotely sensed upward light intensity and

blue light spectrum information for each geocoded longest residence of each MCC-Spain subject. Images were downloaded from the Earth Science and Remote Sensing Unit, NASA Johnson Space Centre (url: https://eol.jsc.nasa.gov). and calibrated applying the procedure described in Sánchez de Miguel (2015), by using existing databases of standard typical emission spectra of known types of outdoor lighting and inferring the observed lighting type from the RGB signature. We also calculated an index of outdoor blue light spectrum using an approach described in Aubé et al. (2013) to calculate the melatonin suppression index (MSI) at each pixel of the image.

Results. We found no clear evidence concerning an association between ALAN blue light spectrum exposures and gastroesophageal cancer (adjusted Odds Ratio (OR) = 1.31, 95%confidence interval (CI) 0.71, 2.42) not either with chronic lymphocytic leukemia (OR=1.05, 95% CI 0.66,1.67). ORs were adjusted for age, sex, center, education and a score indicating adherence to cancer preventive policies (World Cancer Research Fund score including smoking, physical activity, red meat consumption and other) and further adjusted for area based socioeconomic status (urban vulnerability index) and family history of gastroesophageal cancer or lymphoproliferative disorders. In a sensitivity analysis we included subjects who reported having worked in night shift and this resulted in very similar estimates for gastroesophageal cancer (OR=1.00, 95%CI 0.60,1.67) and CLL (OR=1.08, 95%CI 0.68,1.70).

Conclusion. Outdoor ALAN and particularly blue enriched light spectrum, was not associated with an increased risk of gastroesophageal cancer and chronic lymphocytic leukemia in the general population.

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Call for features: New light pollution model
Theme: Measurement & Modeling

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Introduction

The numerical simulation of artificial skyglow is a type of tool that has been around for many decades since the Garstang model was introduced in 1986 for astronomical purposes. Since then, models have gotten more complex and allow for very diverse usage in various fields of study. However, current models have been mainly developed for astronomy and are not very versatile. A need has also been identified for applications in health and ecology.

The Sherbrooke Light Pollution research group is starting the development of a model that aims to be simple to use for everyone, to provide relevant data for a varied range on application in multiple field of research including the traditional astronomical applications and that doesn’t require a lot of computing resources. With this in mind, we would like the input of the scientific community on the kinds of tools and features they would like to see implemented in such a model (such as output units, wavelength ranges, spectral sensitivity and field of view), as well as any other relevant suggestions.

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“Dark Skies for All”: Public Engagement on Light Pollution

Themes: Society, Measurement, Technology, Health & Ecology

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Introduction

The “Dark Skies for All” project is part of the IAU100 flagship theme on Astronomy Natural and Cultural Heritage, in celebration of 100 years of the IAU in 2019. The Dark Skies for All project has two parts. One is about education on light pollution, which will be accomplished with the Quality Lighting Teaching (QLT) Kit and online trainings for schools and organizations worldwide. The other is about public engagement on light pollution protection actions, including government lobbying actions, making the term “light pollution” a household term.

The Quality Lighting Teaching Kit

For the International Year of Light in 2015, the National Optical Astronomy Observatory’s Education and Public Outreach group was funded by the International Astronomical Union and the Optical Society to produce a Quality Lighting Teaching Kit. The goal of the Quality Lighting Teaching (QLT) Kit program is to raise awareness of the importance of preserving our dark, starry night skies and learn ways to mitigate the effects of artificial light at night. Through use of the QLT Kit, practitioners learn how to inspire the public (mainly students) to take an active part in implementing solutions to light pollution. During Fall2018, the kit will be manufactured through laserclassroom.org and available worldwide in Spanish and English.

Fig 1: Shown are the contents of all 6 activities of the Quality Lighting Teaching Kit. [P. Marenfeld, NOAO]

The Kit Activities

The kit is designed around problem-based learning scenarios. The kit’s six activities allow students to address real lighting problems that relate to wildlife, sky glow, aging eyes, energy consumption, safety, and light trespass. The activities are optimized for 11-14 year olds but can be expanded to younger and older. Most of the activities can be done within in a few minutes during class or after-school and as stations or as stand-alones. Everything you need for the six activities is included in the kit. Tutorial videos on how to do the activities can be found at www.noao.edu/education/qltkit.php.

Our Partners

NOAO’s partners were the Optical Society (OSA), the International Commission on Illumination (CIE), the International Society for Optics and Photonics (SPIE), the International Dark-Sky Association (IDA), the Office of Astronomy for Development (OAD) and the International Astronomical Union (IAU). Their networks disseminated nearly 100 kits to formal and informal audiences worldwide. The impact sought is a change in knowledge, attitude, and behavior in each community by learning how to light responsibly, improving the quality of life in "illuminating" ways.

The Dark Skies Ambassadors Program and Resources

The second part of the Dark Skies for All will be accomplished by creating a dark sky ambassadors program with resources on a webpage which will have brochures and posters on why and how to protect the night sky, a tool kit to lobby with governments, a press kit to communicate with media, and a dark sky protection declaration signup form. The aim will be to use materials in many languages when they exist and to create them where needed.

To accomplish this, we welcome partnering with a variety of networks:

- IAU groups (C.B7, C1, OAO, OAD, World Heritage, etc)
- Light pollution affiliated organizations (ALAN, LPTMM, IDA, etc)
- astronomical observatories
- amateur and professional astronomy associations
- library associations
- science centers
- environmental organizations and national parks
- health organizations
- illumination and optical engineering societies

Fig 2: Walker engages a community of astrotourism officials, teachers, and amateur and professional astronomers from the Canary Islands in learning about the QLT Kit. [V. Grigore, SARM]

Through these networks, we intend to reach schools, astronomical communities, science centers, libraries, national parks, media, the general public, city councils and municipalities, city planners, illumination and optical engineering societies and more.

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Using broadband CCD photometry and spectroscopy to identify sources of sky glow

Theme: Measurement and Modeling

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Abstract

The brightness and spectral power distribution of artificial sky glow affects the dark adapted human eye's ability to detect astronomical features of the night sky. Models have been used to predict the impacts of outdoor lighting designs on the night sky quality of relatively remote sensitive areas, such as observatories and wilderness. Observations which include both the intensity and color of sky glow over the hemisphere are needed for the verification of models and for continuous environmental monitoring, which will reveal a range of impact under a variety of conditions.

We investigate the use of a wide angle monochromatic CCD camera equipped with broadband filters supplemented by observations of selected areas of the sky with a spectrometer as a means of obtaining information required to identify sources and amount of sky glow, either artificial or natural. Examples include observations at a variety of distances from isolated small and large cities. The results are interpreted in terms of the impact to night sky quality throughout the observable hemisphere. The natural airglow, zodiacal light, and light scattered from artificial sources are identified and relative quantities of each component are calculated for the observation points. Sources of error in the measurements are identified and discussed. Recommendations for long term monitoring programs are also presented.

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Dual ecological trap of the night-swarming mayfly *Ephoron virgo* at lamp-lit bridges in Europe

Theme: Biology & Ecology

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Introduction

Ephoron virgo is a river-dwelling mayfly species inhabited in the river Danube and can be found in several countries in Europe, Turkey and North Africa. This species was absent from the Hungarian Danube-section in the last 50 years and reappeared only after 2010 due to the improvement of water quality. Today, *E. virgo* is protected in Hungary, with a conservation value of about 33 Euros per specimen.

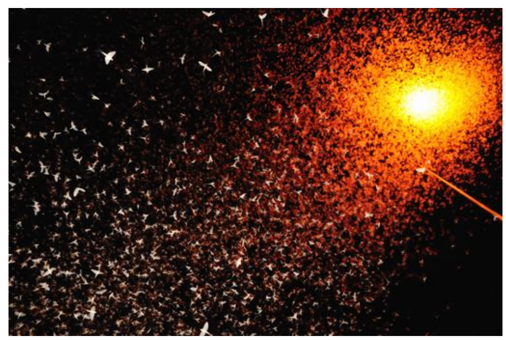

Fig 1: Mass swarming of *E. virgo* mayflies attracted to a bridge-lamp in Tahitótfalu, Hungary.
This photograph was taken by Imre Potyó and was used with the permission of the photographer.

The swarming period of this mayfly ranges from the middle of July to the end of August depending on the river-section. Females and males start to swarm after sunset and after copulation, female mayflies start their compensatory flight, flying several kilometers upstream the river, then they lay egg batches on the water surface en masse and perish soon after.

During this compensatory flight, *E. virgo* females encounter illuminated bridges, the high-intensity traffic lights of which can elicit positive phototaxis and attract them to the bridge-lamps, where they start to swarm around the light sources. Additionally, the asphalt road running on the bridge can reflect strongly and horizontally polarized light that induces positive polarotaxis in these insects, keeping them on the asphalt road. Thus, a dual ecological trap forms in which the conventional ecological light pollution (elicited by the intensity of lamplight) and the polarized light pollution (elicited by the horizontal polarization of asphalt-reflected light) are simultaneously involved with synergistic effects. Consequently, the mayflies lay their eggs on the asphalt road which perish because of dehydration. During one night, at a single bridge, the population loss can be several millions of mayflies and egg clutches.

This problematic issue cannot be solved easily, since the bridge-lights cannot be switched off due to safety regulations in Hungary and some other countries. We have worked out a method for the conservation of these mayflies exploiting their positive phototaxis. With downstream-facing light-emitting diode beacon lights above two tributaries of the river Danube, we managed to guide egg-laying female mayflies to the river surface and prevent them from perishing outside the river near urban lights. By means of measuring the mayfly outflow from the river as functions of time and the on/off state of the beacons, we have showed that the number of mayflies exiting the river's area was practically zero while our beacons were operating. Tributaries could be the sources of mayfly recolonization in the case of water quality degradation of large rivers. The protection of mayfly populations in small rivers and safeguarding their aggregation and oviposition sites are therefore important.

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Pyrenees La Nuit: Pyrenean strategy for the protection and improvement of the nocturnal environment

Theme: Society / Measurement and Modelling / Biology and Ecology

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Introduction

Pyrenees la Nuit (PLN) is a European project focused on the Pyrenean area that aims to study, disseminate and protect the natural darkness of the night in these mountains. Six institutions from both sides of the Pyrenees are taking part of this project. Planetario de Pamplona, Parc Astronòmic Montsec and Gestion Ambiental de Navarra from Spain and Observatoire du Pic du Midi, Association A Ciel Ouvert and CPIE65 from France.

This project has been co-financed at 65% by the European Regional Development Fund (FEDER) through the Interreg POCTEFA V-A Spain-France-Andorra Program (POCTEFA 2014-2020). The activities of this project started in July 2017 with the organization of LPTMM2017 conference in Montsec and intend to finish in June 2020 with a final event in Lleida, Spain. The project covers three major areas of interest: Science, Outreach and Strategies with many activities being under development within every of them.

PLN Science

In order to protect the natural darkness of the Pyrenees night we must first know the current state of it. Scientific activities of PLN are covering different aspects related to this issue, measuring the sky, study the effects of ALAN in different species and modeling the behavior of light in the Pyrenees. Parc Astronòmic Montsec is leading the Science of PLN.

- To Measure the brightness of the sky we are using three different approaches:
    - ✓ Continuous measuring. A set of photometers connected to the internet distributed throughout the Pyrenees will be used. These devices will be continuously measuring the brightness of the sky at the zenith. Data will be accessible online for everyone.
    - ✓ Punctual measuring. We are planning some special campaigns to measure in several locations the sky brightness in different directions and bands using all-sky detectors.
    - ✓ Participative measuring. Taking advantage of the star parties scheduled during the project, we will promote the use of apps among the participants to measure the darkness of the sky with their own smartphones.
- Affections to local species. Some studies on how the ALAN affects to endemic species of the Pyrenees are currently in progress, including moths, bats and other mammals. These studies are carried on by the Spanish public company GAN-NIK in Navarra, and by the French association CPIE65, who are working in a coordinately manner sharing their methods, techniques and results.
- Modeling. A PhD on light pollution is currently progressing in cooperation between Parc Astronòmic Montsec and Universitat de Barcelona. First results have been obtained analyzing from Montsec the effects of Lleida (Linares et al 2018). The final aim is to apply

the model ILLUMINA (Aubé et al 2005) to the entire mountain range of Pyrenees including light coming from the big cities around like Barcelona, Toulouse or Zaragoza.

The conclusions of these studies are intended to be presented in a final event around mid-2020 in a location inside PLN area. It could be an important and strategic impact to present these scientific studies and conclusions close to the area that is being researched, and close to the people who are in charge of the administration of the lighting systems. It would be the best way to show them the importance of preserving the natural conditions of the night.

PLN Outreach

We are organizing a set of activities focused on the popularization of the importance of preserving the natural darkness of the night, especially within the wild areas. We highlight three actions over the rest:

- The permanent exhibition in Parc Astronòmic Montsec focused on Dark Sky evaluation and protection. This will be part of the dark sky experience of every visitor of this center.
- A planetarium show in fulldome 4k 3D about the night and specifically about the night at the Pyrenees. It is being produced by Planetarium of Pamplona team and will include many sequences shot in the very heart of these beautiful mountains.
- The creation of La Maison de la Nuit (The House of the Night) in the village of Bagnères de Bigorre, with permanent exhibitions, A/V items and many other things designed to valorize the night, and its natural darkness. Pic du Midi team, with the collaboration of A Ciel Ouvert, is in charge of the building remodeling and the design of the exhibition elements.

And of course, an important number of star parties, conferences, workshops, courses, concerts under the starry sky, promenades in the wild night and this kind of traditional activities around the night and the dark sky are also on Pyrenees La Nuit agenda.

PLN Strategy

The main objective, and the natural conclusion of the project, is the elaboration of the Pyrenean Strategy to protect the night. A set of documents which will include a manual of good practices in outdoor lighting, a proposal of compromise of the municipalities in order to defend the natural darkness of the night, etc. will be elaborated. We will focus on the presentation of a proposal for the Working Community of the Pyrenees in order to create administrative structures dedicated to achieve the main conclusions of the scientific studies of this project. This will be the starting point of a new culture of light that will be enforced due to the creation of new territories with two international dark sky certifications: IDA and Starlight. The areas selected are: The RICE around Pic du Midi in France, the area of Montsec mountains and the Valley of Roncal in Spain.

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The Sky of Montsec: How a Dark Sky is Impacting the Economy of a Rural Area in Catalonia

Theme: Society

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Montsec is a calcareous mountain range more than 40 kilometers long in the regions of Catalunya and Aragon in the north-east of the Iberian Peninsula. The Catalonian part includes around 20 municipalities in the counties of Pallars Jussà and La Noguera.

This area showed excellent parameters to develop activities around astronomy and dark skies. For this reason the Government of Catalonia promoted the creation and development of Parc Astronòmic Montsec as a tool to help in the economic development of the region. This development gives the chance to stop the loss of population and the creation and upgrading of new touristic facilities related to dark skies and astronomical activities.

In 2013, more than 1700 km2 were declared as Starlight Touristic Destination, and part of this area became Starlight Reserve thanks to its wonderful parameters of the night sky and the actions taken in the area to preserve it.

Since 2012, the first analyses of the economic and social impact have been done in the area. For example, the results shown by the evaluation process for the development of the 'Pla de Desenvolupament Sostenible del Turisme Montsec 2020' [SomMontsec 2012] as strategic plan for tourism in the area. In 2014 a new study was done studying the visitors of Parc Astronòmic Montsec and how they participate in the local economy and in alternative activities in Montsec area. This 2014 study has been updated with 2017 visitors and economy data available.

These studies give us important results in the improvement of Montsec area. For example the number of accommodation facilities has been doubled in the last decade, the stop of the loss of population in the area or the estimation of close to 2.0M Euros of economic activity generated in the area by the visitors of Parc Astronòmic Montsec.

The effect of ecological light pollution on the physiology and recruitment on coral reefs from Eilat Red Sea

Theme: Biology & Ecology

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Introduction

Coral reefs are one of the most diverse and important marine ecosystems, providing homes to hundreds of thousands of species, Coral reefs support more species per unit area than any other marine ecosystem, making them an important reservoir for biological diversity and complexity. Many people around the world depend on coral reefs for their livelihood and about 15% of the world's population live within 100 km of coral reef ecosystems. The importance of coral reefs for tourism, fishing, building materials, coastal protection and drug discovery cannot be underestimated. Coral reefs have had a crucial role in shaping tropical oceans over the past 200 million years, but still appear to be highly vulnerable to environmental stress in general, and specifically to anthropogenic factors including climate change.

The coral reefs of in the Gulf of Eilat/Aqaba (GOE/A) have not suffered any mass bleaching events or other natural large-scale catastrophes, however during the last four decades degradation is apparent. The reefs are threatened by increased anthropogenic perturbations such as pollution from commercial ports, tourism, intensive development of the shoreline and rapid urban expansion of Eilat and Aqaba cities at the north tip of the Gulf and more recently from "light pollution". Despite the understanding of coral reefs' importance and unique role in the Red Sea history, knowledge on their reproduction, recruitment, genetic connectivity remains extremely limited. Since approximately 22% of coastlines and 35% (20% across their entire area) of marine-protected areas around the world experience artificial light at night, suggesting that many intertidal and marine ecosystems are exposed to some potential impacts of altering natural day–night cycles that inform the behavior of many marine species. Therefore, light pollution is, likely altering the structure and functioning of marine ecosystems in many other ways that have yet to be explored.

In this work we show that artificial light pollution in Eilat is affecting coral physiology, and coral recruitment phylogeny and gene connectivity along the shoreline of the GOE/A from north to south which exposed from high to low gradient of light pollution. We have conducted a long term experiment exposing two corals species *Acropora eurystoma* and *Pocillopora damicornis* to light pollution simulating Eilat city night light levels. After 8 months of comparison between ambient to light polluted colonies, we saw differences in the chlorophyll fluorescence, algae concentration, protein levels and quantum yield. Additionally, settlements plates placed in 6 stations along Eilat shoreline from north to south representing different levels of light pollutions were studied mainly on the coral *Stylophora pistillata* recruitments. The plates during a given period (every two months), were removed and analyzed in a lab. The number of coral larvae (coral spat) showed a clear negative impact on the phylogenetic and recruitment of the coral *Stylophora pistillata* under light pollution.

Combining radar technology and all-sky imagery to study flight to light behavior of moths

Theme: Biology and Ecology

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The use of artificial light at night (ALAN) is growing continuously in area and extent (Kyba et al. 2017) and diverse effects of ALAN have been discovered within the last decades (Rich & Loncore 2006) including effects on important ecosystem functioning like pollination (Knop et al. 2017). Moths are, among other, important nocturnal pollinators and several studies on ALAN and moths exist (van Langevelde et al. 2011, Degen et al. 2016). Nevertheless, a comprehensive understanding of flight to light behavior of moths regarding natural light, for example moonlight, and artificial light, including direct light and skyglow, is still missing.

We will use the harmonic radar technique to record the flight paths of individual moths. Since it is still unclear how the moon phase influences their behavior, moths will be released each day in presence or absence of artificial light sources in the course of two moon phases. The artificial light sources correspond to common street lighting to get representative results for their impact on orientation and behavior. One main objective will be to determine the attraction radius and to answer the question whether it changes in dependence on the moon phase. The characterization of the light environment, including both natural and artificial light sources, will be critical for the evaluation of the recorded data as moths are highly sensitive to light. It is therefore likely that their behavior relates to different light environments in a specific manner. We will use multiple approaches to characterize the light environment including all-sky imagery using DSLR cameras (Fig. 1, Jechow et al. 2017). This will allow to disentangle the individual light sources for attraction of moths.

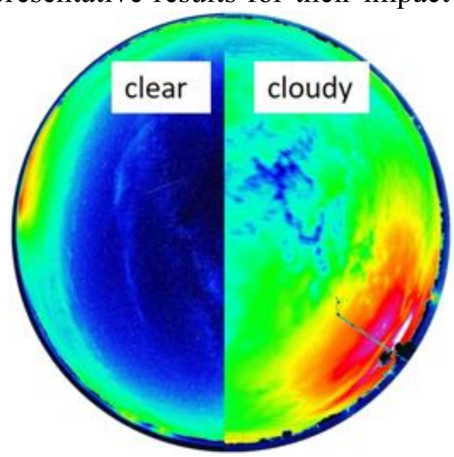

Fig 1: All-sky image taken at the field site for clear and cloudy conditions.

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Growth and development of African Clawed Frog (*Xenopus laevis)* larvae reared under different intensities of LED light at night

Theme: Biology & Ecology

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Amphibian populations are declining globally due to several anthropogenic changes to natural ecosystems including habitat loss, climate change, introduced species, pollution, and disease (Blaustein et al., 2014). Most amphibians are nocturnal so the global increase in light pollution (Artificial Light At Night, ALAN) and its disruption of natural, dark nights has the potential to affect negatively amphibians that are reliant upon distinct light-and-dark-dependent circadian cues and dark nocturnal illuminations (Buchanan, 2006). Previous research in our lab has examined the effects of fluorescent ALAN on development of frogs and found that ALAN causes accelerated growth but delayed development in African Clawed Frog (*Xenopus laevis*) larvae. However, little is known about the effects of ALAN from LED (Light-Emitting Diode) lamps on frog growth and development. Understanding the impact of LED lighting is particularly important because of the recent, rapid replacement of incandescent, halogen, and fluorescent lamp technologies with more energy-efficient LED lamps. We hypothesized that ALAN from LEDs would enhance growth and delay development of clawed frog larvae in the same way that fluorescent lighting does. To test this hypothesis, we exposed larvae of *X. laevis* (24 h post-fertilization) to four lighting treatments throughout their larval period. All larvae were exposed to a 12L:12D photoperiod with 100 lx day lighting and were randomly assigned to one of four different nocturnal light treatments (0.0001 lx, 0.01 lx, 1 lx, 100 lx). We then measured body length (using ImageJ, NIH) and developmental stage from digital photographs of tadpoles in the different night-lighting treatments. Comparison of growth and development in the different LED lighting treatments and a comparison of the impact of fluorescent and LEDs will be discussed.

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Use of Live Sky Quality Meters for Outreach and Public Awareness

Theme: Measurement & Modeling

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We compare dark and light polluted skies at two locations in Utah to enhance public awareness of dark skies. We have setup two identical sky quality meters (SQMs) in discrepant locations. One SQM is setup at the rooftop observatory on the South Physics Building on the University of Utah's urban campus; the other will be located at Dead Horse State Park in eastern Utah. In both cases, a Unihedron SQM-LU-DL was mounted on a tripod and attached to an Internet connected computer housed in a utility box (Figure 1).

The measurement of sky quality, in magnitudes per square arcsecond, is recorded every five minutes. Each measurement updates a file in a shared OneDrive folder. We seek to make a web widget which would include a live reading of the night sky quality, which when clicked, would direct the user to information about night sky preservation. Such a widget could be included on the websites of local weather stations, along with air quality and other measurements. In addition to this widget, we will present possible uses of the simple SQM data reports for incorporation into secondary science and introductory college classrooms. This data can also be used to fill a void in the measurements of sky quality in the state of Utah on the Globe at Night database. The public availability of this data will allow researchers to understand trends in the sky brightness over extended periods of time as Salt Lake City continues to grow.

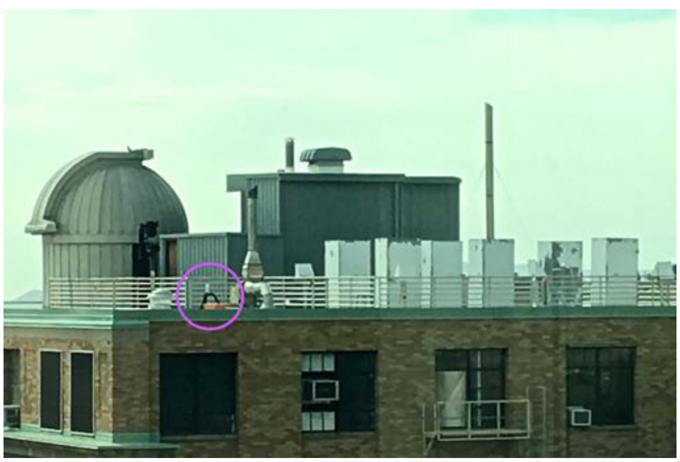

Fig 1: Image of rooftop observatory of the South Physics building at the University of Utah, taken from a nearby building. The SQM housing is circled. Picture by Anil Seth.

NITELITE: An Open Source Stratospheric Light Pollution Imaging System

Theme: Measurement and Modeling

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Introduction

Much of our understanding of light pollution (LP) comes from datasets generated by remote sensing such as from the ISS, VIIRS instrument and aerial surveys. Each of these platforms has its own limitations for research, such as prohibitive cost (aerial surveys), or limited resolution from orbital data. The NITELITE system provides an option for acquiring high-quality light pollution data at a relatively low cost from a High Altitude Balloon (HAB). NITELITE is a self-contained, automated light pollution imaging system flown to altitudes between 25-30 km. The goal of the system is to image large areas (100s km^2) in multiple color bands with high resolution (5m/px) for a relatively low startup cost (<$3000). Additionally, subsequent flights should be relatively inexpensive (<$1000/flight), to afford researchers opportunities to study light pollution in a wide range of time-dependent settings. All the software and hardware designs used in NITELITE will be available as open source resources, as we encourage other researchers to use our tools to collect their own light pollution data.

System Components

The NITELITE system consists of three main elements within a single payload: the imaging system, On Board Computer (OBC) and Altitude Control System (ACS).

The imaging system consists of three Basler acA1920–40uc RGB cameras each with a 1920x1200 pixel resolution and a 25mm f/1.4 lens giving a 22°x 14° field of view. For our test system one camera is nadir pointing and two are pointed symmetric off-axis. This equates to a 35x10 km footprint at altitude. In our use case - imaging Chicago - this multiple camera configuration is required to capture the entire city which has a roughly 3:1 N/S to E/W orientation. For most surveys a single camera would be sufficient. The cameras are controlled by an ODROID-XU4 single-board computer, which triggers the image acquisition sequence and records the RAW images.

The OBC is a Teensy 3.5 microcontroller that provides instantaneous state data to the imaging system from a GPS and a 9DoF IMU. State data is logged to the ODROID as images are taken.

HAB platforms are notoriously unstable. To obtain the highest quality data the payload must be as

Fig. 2: Launch of a NITELITE test mission showing the configuration of the flight elements.

stable as possible during image acquisition. As the balloon rises, airflow over the highly elastic balloon excites vibrational and rotational modes in the balloon/payload system. To reduce this instability, the NITELITE system is equipped with an Altitude Control System. The ACS automatically vents helium from the balloon as the payload approaches the target altitude. Once the HAB reaches neutral buoyancy, the vent is closed. Without the turbulent airflow encountered with ascent the platform becomes stable enough for quality LP imaging.

The NITELITE system is flown as part of a standard HAB experimental setup seen in Figure 1. Aside from the NITELITE specific components described above, we use HAM radio APRS transmitters for tracking, location-finding beacons, a radar reflector, parachute, and ground equipment for balloon fill and tracking.

Results and Further Work

We have tested the fully integrated system over multiple flights and have obtained results matching our mission goals. Figure 2 shows a sample result from a test flight which acquired over 600 km^2 of imagery with an average resolution of 5m/pixel. Flights to image the city of Chicago are scheduled for the summer of 2018.

Improvements, simplifications and documentation of the system are ongoing with a goal of providing interested researchers the ability to reproduce this mission for their own research surveys.

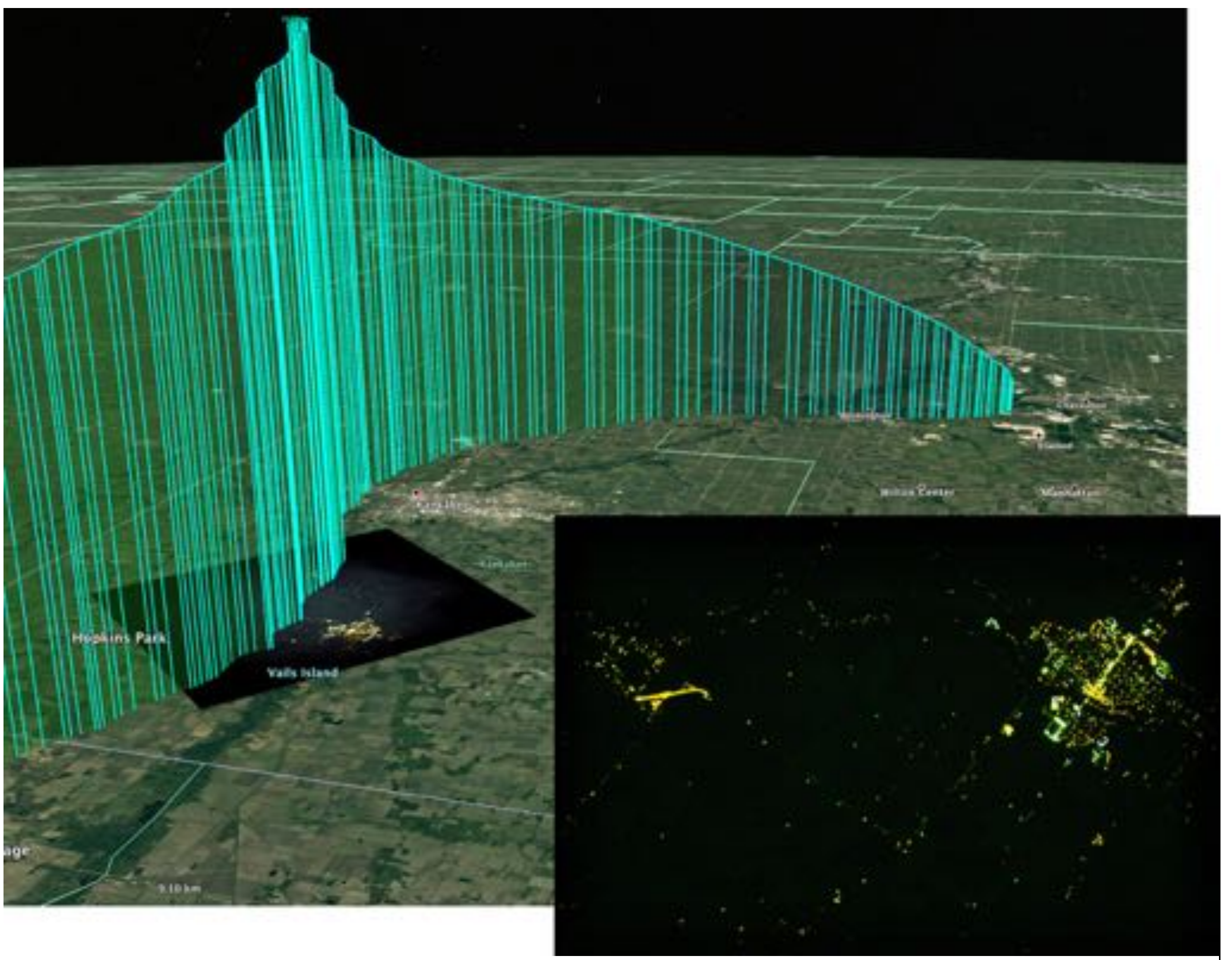

Fig. 3: Path of a NITELITE test flight. Inset: Sample flight image of the town of Momence, IL and surrounding area. Map Data: Google, Landsat/Copernicus 2018

Monitoring the night sky at Lake Balaton

Theme: Measurement & Modeling

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Introduction

Observation of clouds and visibility are essential in routine meteorological applications. Complementing conventional instruments and methods, like satellite images, cloud-base ceilometers and human observations, applying ground-based sky cameras became increasingly popular. However photometric analysis of its images is challenging especially at night (Dev et al. 2017, Shields et al. 2013). Compared to daytime problems are raised at night not only because of longer exposure times and higher noise but the different relationship between the colour channels (ratio of red and blue). Clear sky is predominantly blue during daytime which is no longer valid during nighttime.

Nevertheless, artificial lights provide also an opportunity for meteorological observation. The clouds could dramatically increase the luminance of the sky and change its colour even from considerable distances from urban areas (Jechow et al. 2017). The height of a homogeneous stratiform cloud sheet could be estimated with triangulation method (Kolláth 2016).

Our idea is that sky cameras should be principally applied to light pollution research and weather observation in parallel so that they can enhance each other.

Observation site

We installed a sky camera at a meteorological station situated on the south coast of Lake Balaton, Hungary. It is a computer controlled DSLR camera with a wide-angle lens directed to the north. The north coast is about 9-14 km distance. The coast of Lake Balaton is generally light polluted, but there are two dominant sources: Balatonfüred with 13.000 and Veszprém with 60.000 inhabitants (Fig. 1-2.). In Balatonfüred the public lightings are installed dominantly with white LED.

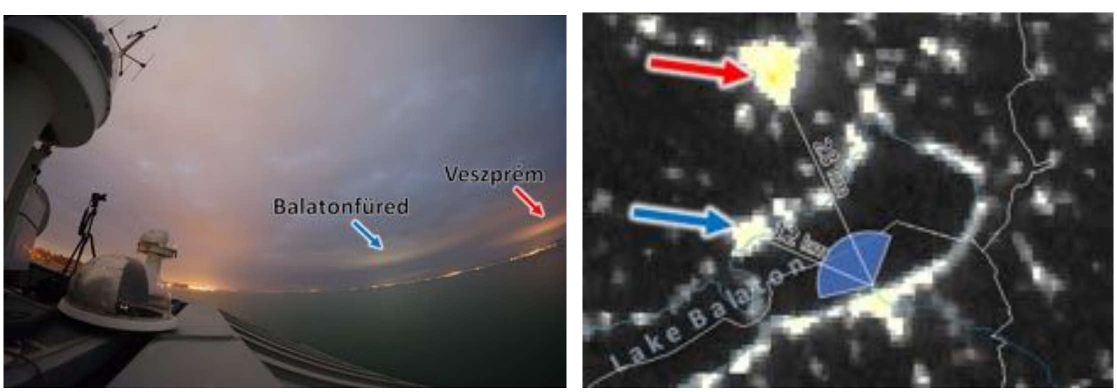

Fig 1-2. Observation site where the sky camera is installed on the coast of Lake Balaton. The map shows a monthly averaged VIIRS DNB satellite image (source: Earth Observation Group, NOAA).

Data and image processing

We processed the collection of unaltered RAW images from the DSLR camera. Images were taken in every 15 minutes in the night periods from December 2017. The green channel was converted to luminance values in natural sky unit (NSU) performed using the software, DiCaLum (Kolláth Z, 2017). Red and blue channels were also available for further processing. A typical scenario is shown in Fig 3., with a middle level (Altocumulus) cloud sheet with good visibility. Note the different red/blue ratio above Veszprém and Balatonfüred with white LED public lightings.

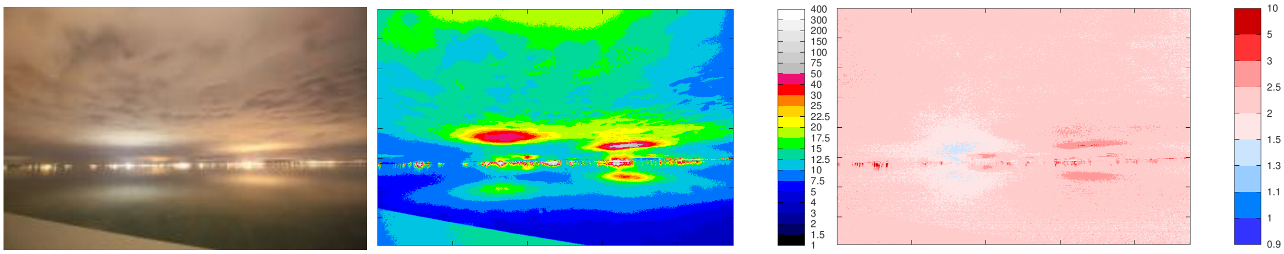

Fig 3. a) JPEG picture from the site with clouds and calm water.
Fig 3. b) Processed RAW image converted to NSU units based on the green channel.
Fig 3. c) Ratio of red and blue (R/B) pixel values from the RAW image.

We present our experience with the following challenges:

- Monitoring variations and trends of the light pollution
- Detect clouds and estimating its amount, types and base height
- Categorizing visibility range and detect haze/mist or fog
- Investigate the relation and added value compared to other available routine meteorological observations

The Project is supported by the European Union and co-financed by the European Social Fund (Grant no. EFOP-3.6.2-16-201-00014; Development of international research environment for light pollution studies)

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Major Errors in Research on Lighting and Public Safety

Theme: Society

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Abstract

Exterior lighting can certainly help people to see at night, and so avoid problems such as trip hazards. However, lighting is also claimed to have major benefits in increasing public safety by reducing crime and road traffic collisions. Such claims are used to justify and indeed encourage increases in exterior lighting, involving either brightening existing lighting or installing additional lamps. An earlier paper (Marchant 2017) gives some reasons why errors can and do occur.

This image by Paul R Marchant is in the public domain

This presentation will extend the material presented in that paper by examining several recent papers and reports, which may be used to encourage the installation of more lighting. The specific grave errors made will be laid bare. These errors are sufficiently serious to nullify the claimed findings of large public safety benefits attributed to lighting, in these publications.

For example, the study (Chaffin et al, 2017) into lighting and crime in public housing was, commendably, designed as a Randomised Controlled Trial. However, it regrettably was not analysed appropriately; that means on the difference between treatment and control groups. The study of Jackett and Frith (2013) groups and averages data, thereby masking the inherent uncertainty and variation in the data, which perhaps accounts for the impressively high R^2 of 0.99 displayed. In neither of these studies is the data offered so that others, having written a protocol, might be able to check and extend the results

These and analyses in other publications will be the subject of 'meta-research' into lighting and public safety.

The issue of faulty lighting research is just one aspect of wider concerns around research integrity, The Research Integrity Inquiry of the UK Parliament's House of Commons Science and Technology Committee is one manifestation of such concerns. The Inquiry originally commenced in the previous Parliament, but has been continuing in the new one and took more evidence in May

2018. It has had 6 evidence sessions and over 100 written submissions and the scale perhaps indicates the depth of the concern and size of the problem. The presentation will offer some solutions to the problems exhibited. Engagement with professional statisticians would certainly help deliver better research.

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including, http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/science-and-technology-committee/research-integrity/written/77124.html

Keywords

Exterior lighting, Security, Public safety, Crime, Road traffic collisions, Research integrity, Erroneous statistical conduct.

Integrated study of Sky Glow, Calgary, Alberta, Canada

Theme: Measurement & Modeling

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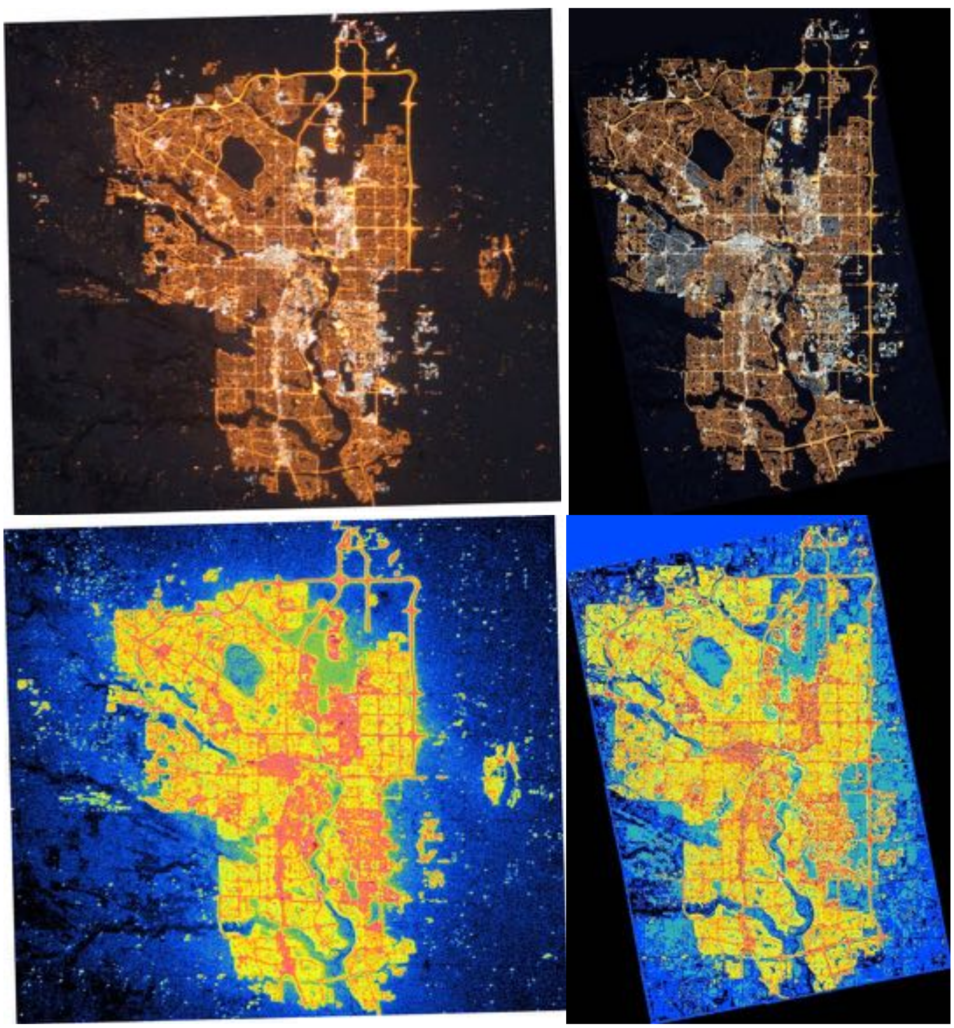
Using orthorectified photos taken from the International Space Station, ground-based Unihedron Sky Quality Meter data, and visual star count data collected over time, ground level and sky glow brightnesses were measured throughout the City of Calgary to characterize the effect of changing from HPS to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

Disruption of Endogenous Circadian Rhythms by Exposure to Light at Night Accelerates Pancreatic Tumor Growth in Mice

Theme: Health

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Introduction

Intact circadian rhythms are critical for optimal physiological and behavioral functions. The widespread adoption of electric lighting worldwide has led to significant exposure to artificial light at night (LAN), which results in disruption of circadian rhythms. Exposure to LAN is strongly correlated with increased prevalence of obesity, metabolic disorders, and certain types of cancer. Pancreatic ductal adenocarcinoma (PDAC) is among the most aggressive cancers with poor prognosis and short post diagnosis survival rates in which K-Ras mutations account for ~90-95% of cases. The objective of this study was to explore whether dysregulation of circadian rhythms by LAN accelerates PDAC development in high-risk patients using PDAC mouse models bearing K-Ras-G12D (KC) or K-Ras-G12D-P53−R270H (KPC) mutated alleles. We hypothesized that exposure to LAN accelerates tumorigenesis by dampening the expression of the circadian gene, Period-2 (Per2) in the pancreas, thereby disinhibiting cellular proliferation and exacerbating inflammatory responses to tumor formation. Six-week old male KPC and KC mice and littermate controls were randomly assigned to either dark nights (LD group: 14 h light-150 lux/10 h dark-0 lux) or to dim light at night (LAN) (14 h light-150 lux/10 h dim white light-40 lux) for either 8 weeks (n=10-11 per KPC group) or 16

Cancer type	Completely sightless	Severe visually impaired	Amish/Ohio
Tobacco-related	0.67	1.04	0.37
Non-tobacco	0.69	0.94	0.72
Breast	0.82	1.06	0.58
Prostate	0.71	0.98	0.62
Colon	0.36	1.0	0.7

Fig. 1: Summary of cancer incidence among different populations exposed to dark nights vs. light at night.

weeks (n=6-7 per KC group). LAN caused both KPC and KC mice to display elevated rates of neoplastic transformation and increased incidence of PDAC; specifically, ~90% of KPC mice developed tumors in LAN, of which (73% were PDAC and 18% were mucinous cystic neoplasms (MCNs), whereas 66% of KC mice developed intraductal PDAC.

These results were accompanied by reduced expression of *Per2* in the brain and dysregulated expression of Per2, Per1, Bmal1 and Cry1 in the pancreata of KPC and KC mice exposed to LAN. Furthermore, LAN increased expression of the cell cycle gene Cyclin D as well as the proliferative genes c-myc, Notch and insulin growth factor signaling in pancreata of KPC mice with invasive PDAC. LAN also induced metabolic, but not inflammation, changes in KPC mice. In conclusion, LAN disrupts circadian clock function resulting in a sequence of events that promotes cell proliferation and enhances tumorigenesis, tumor growth, and early onset PDAC. Considering LAN an environmental risk factor and targeting the problem by using low cost lighting technology may be useful for PDAC prevention among high risk individuals.

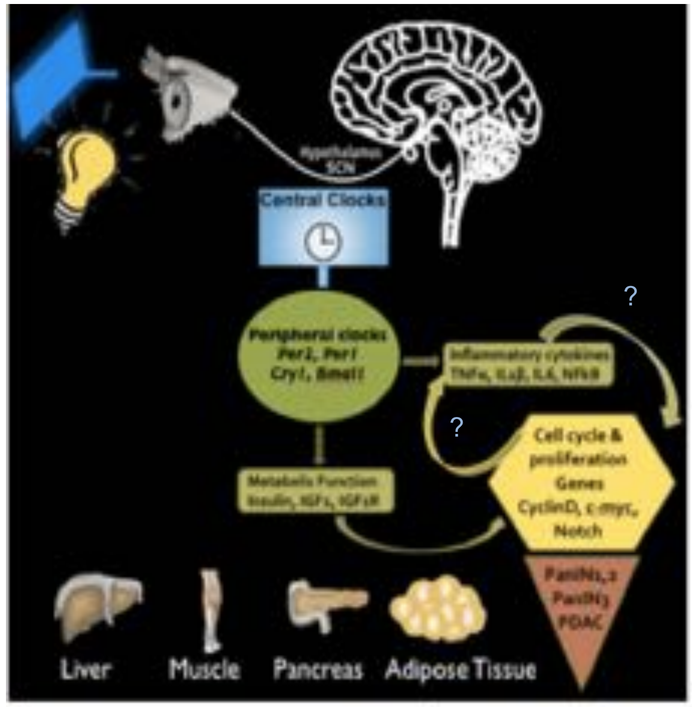

Fig.2: Schematic representation of LAN-induced chain of events that result in accelerated neoplastic transformation and tumor growth in PDAC mouse models.

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The effect of artificial light at night (ALAN) on activity patterns of a nocturnal salamander

Theme: Biology and Ecology

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Many organisms exhibit a circadian rhythm that uses external environmental light stimuli to regulate their internal physiological processes. ALAN (artificial light at night) has the potential to disrupt circadian rhythms and adversely affect circadian-dependent physiological and behavioral responses (Fonken and Nelson, 2014). Most amphibians are nocturnal with daily activity commencing as light levels drop and night begins. The eastern red-backed salamander (*Plethodon cinereus*) is a nocturnal amphibian that shelters under rocks and logs during the day and then emerges after dusk under moist conditions to forage until dawn (Perry et al., 2008). We hypothesized that darkness is used as a cue for nightly emergence from refugia and that ALAN should delay emergence and reduce above-ground nocturnal activity in these salamanders. We tested this hypothesis by exposing 16 salamanders to four nocturnal lighting treatments in a randomized order. Salamanders were housed in square plastic test chambers with round, opaque refugia in the center of each chamber. All salamanders were exposed to each lighting treatment for 4 days followed by re-habituation to natural (control) night lighting. The salamanders were exposed to a 12L:12D photoperiod, with daylight intensities of 100 lx and one of four different intensities of light at night in each round of a repeated measures design. Night lighting intensities were: 0.0001 lx (natural, dark control), 0.01 lx (low levels of light pollution), 1 lx (moderate level of light pollution), and 100 lx (continuous daylight, control). Infrared video cameras were used to record salamander movements constantly for 4 days and nights. Animal movements in these recordings were then tracked using Ethovision XT7 software to determine when animals emerged from refugia and how much they moved per hour outside their refugia. Preliminary analysis suggests that small amounts of ALAN have the potential to reduce nocturnal activity and that large amounts of ALAN can completely eliminate circadian rhythmicity in activity; however, analysis of these recordings is still in progress and more detailed results will be presented and discussed.

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From Brighter than the Moon to Dimmer than the Stars:
Hemispherical Photography of Nighttime Illumination Across the American West

Theme: Measurement and Modeling

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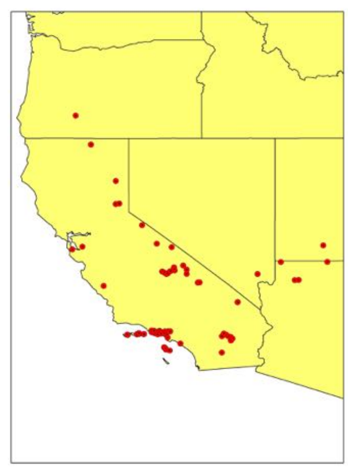
Introduction

Light pollution is a significant problem for natural lands and its extent and intensity has only worsened over the past several decades. Affordable measurement techniques to describe metrics artificial light intensity at a fine scale that would be relevant for studies of ecological and astronomical visibility impacts are not well developed. Existing methods are very expensive and require high levels of technical skill or are inexpensive and yield limited data. This study was the first extensive trial in the US of an emerging method for light pollution monitoring. We used a consumer digital camera with a hemispherical fisheye lens to capture the entire night sky in a single long-exposure image (Jechow et al. 2017, Jechow et al. 2018) and processed the images with Sky Quality Camera (a commercial light pollution monitoring software calibrated to specific hardware). We documented the range of illumination conditions under different weather conditions and analyzed the effect of clouds on night sky brightness, exploring which areas are made darker by cloud cover and which experience amplified illumination under cloud cover (Kyba et al. 2011).

Methods

We (BVB) sampled 104 sites from six states in the American West, at 0–4,400 m elevation, including locations that required boat travel or days of foot access (Fig. 1) and focused on units of the National Park Service or other federal land. One sampling zone included a gradient of night sky brightness as predicted by the World Atlas of Artificial Night Sky Brightness from the urbanized Los Angeles basin to the California Channel Islands over 150 km away.



F
ig. 3: Map of sampling locations, excluding Big Bend National Park in Texas.

Photographs were taken with a Canon Rebel T6S DSLR camera and Sigma 4.5mm f2.8 circular fisheye lens mounted on a tripod. Exposures ranged from 1 second to 120 seconds depending on background illumination levels to provide the optimal signal to noise ratio and eliminate overexposure. Image collection occurred after astronomical twilight and the moon was below the horizon to ensure no contributions from the moon or sun. Images were processed with Sky Quality Camera (Euromix Ltd., Ljubljana, Slovenia). Automatic rotation was applied, stars were removed, and data were smoothed for sky brightness and color temperature. We focused on scalar illuminance (Duriscoe 2016) as the measure most likely to influence wildlife behavior from sky glow (e.g., influence on foraging and predator-prey relations) in wildlands. Further analysis and visualization was produced with JMP® software (SAS Institute, Cary, NC).

Results and Discussion

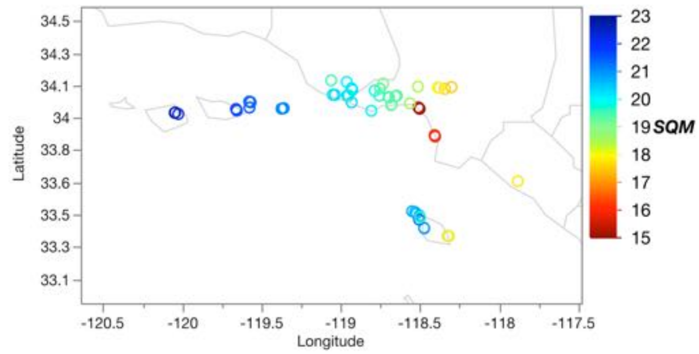


Fig. 4: Transect of light pollution conditions from Los Angeles to the California Channel Islands.

Sites ranged from perpetually brighter than the full moon in Griffith Park near downtown Los Angeles (497 mlux) to dimmer than a starry sky (0.217 mlx) (both cosine-adjusted horizontal illuminance; see Kyba et al. 2017). Equivalent SQM values ranged from 14.7 to 22.8 (e.g., Fig. 2). Scalar illuminance ranged upwards to 1.1 lux at the brightest sites, from sky glow alone. Cloud cover resulted in increased illuminance and sky brightness near urban areas, but a decrease at sites far from lighting sources (Fig. 3), indicating a transition of clouds from acting as reflectors to acting as shields across gradients of light pollution.

Whether taking photos in the light-polluted Santa Monica Mountains or deep in the Death Valley National Park backcountry, the tested equipment returned results of an accuracy comparable to systems that cost three times as much and with a far simpler user interface. This study demonstrates the value of a basic DSLR camera for providing high quality images to assess nighttime lighting levels in remote, natural environments. The portability and flexibility of this system makes it a promising method for government agencies and other landowners who are committed to monitoring light pollution levels in protected lands.

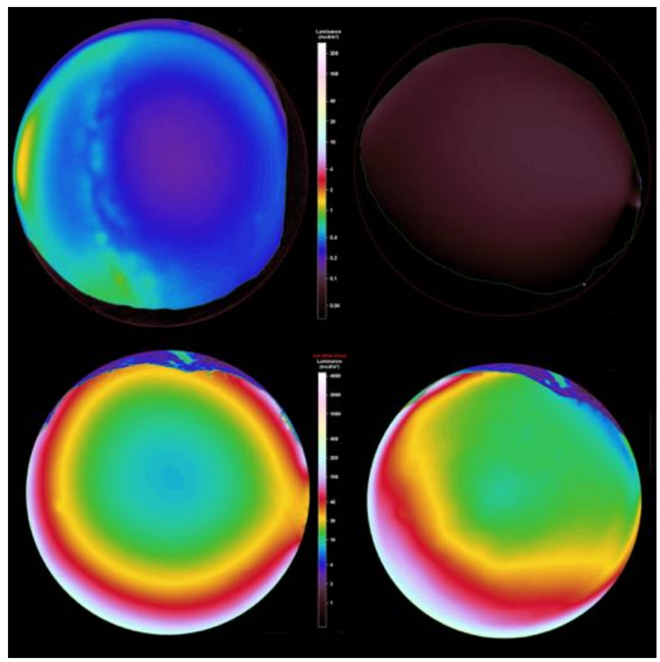


Fig. 5: Influence of cloud cover on scalar illuminance. Top: Santa Rosa Island, L: cloudless 2.005 mlx (21.64 SQM), R: 100% clouds: 0.35 mlx (22.83 SQM). Bottom: Griffith Park, L: cloudless, 168.0 mlx (17.55 SQM), R: 100% clouds: 192.1 mlx (17.2 SQM).

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Illuminating lakes: assessing skyglow effects in ecosystem-scale experiments

Theme: Biology & Ecology

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Light is key in structuring ecosystems and their biological communities. Since the introduction of the electric bulb in the late 19th century and the subsequent dramatic increase of artificial lighting, the natural light regime on earth has changed substantially. During the last decades the global average light emission has increased by 2 to 6 percent per year (Hölker et al. 2010, Kyba et al. 2017).


Fig 1: Skyglow near Berlin, Germany , Photo: A. Jechow.

Aquatic ecosystems can be disturbed by light pollution – the riparian areas through direct lighting, the open water of lakes primarily by a diffuse illuminated night sky. This phenomenon, known as artificial skyglow, mostly occurs during cloudy weather above areas with strong artificial lighting (e.g. cities, harbors, greenhouses): The light emitted upwards is scattered back to the earth's surface by molecules and aerosols within the atmosphere so that a glowing dome appears in the sky (Fig. 1, Kyba et al. 2015).

Biological impacts of direct lighting have been demonstrated for a wide range of biological processes in aquatic ecosystems, from gene expression patterns to land-water interactions and ecosystem functioning (Hölker et al. 2015, Manfrin et al. 2017, Brüning et al. 2018). However, the influence of skyglow is largely unknown (Kyba & Hölker 2013). Although the light intensity of skyglow is low compared to direct light, it could arguably be significant and affect lakes and aquatic organisms beyond densely populated urban centres over very large areas (Kyba et al. 2017). In lakes, zooplankton typically reside in deeper and darker water layers during the day to avoid predation by visual predators. At night, they migrate towards the water surface to feed on microorganisms that typically occur at highest densities in the upper layers such as phytoplankton. Skyglow can dramatically reduce this diel vertical migration (Moore et al. 2000) and may thus reduce the grazing pressure on phytoplankton. However, the extent to which such behavioral changes of zooplankton affect planktonic food-web interactions and the productivity of freshwaters is completely unclear.


Fig 2: Simulated skyglow at the IGB LakeLab in Lake Stechlin, Photo: A. Jechow.

To fill this critical gap we assess the ecological consequences of skyglow and the underlying mechanisms under highly realistic field conditions using a recently developed ecosystem-scale experimental facility installed directly in a deep clear-water lake, Lake Stechlin, in north-eastern Germany. The site is located 70 km north of Berlin in a rural area belonging to one of the darkest regions in Germany (Jechow et al. 2016), thus providing excellent dark control conditions. The experimental facility, the IGB LakeLab, has 24 very large enclosures (1270 m^3 each) equipped with real time *in situ* water sensors (Fig. 2; Giling et al. 2017) and is situated next to a well-equipped laboratory. The LakeLab has a specifically developed artificial light system creating realistic skyglow scenarios (http://www.lake-lab.de/index.php/iles.html). With its unique features and size it allows realistic, highly replicated skyglow-studies on lake ecosystems encompassing all trophic levels up to fish, a feature presently unique in the world (see http://mesocosm.eu for an international overview).

The overall objective of the large-scale *in-situ* experiments is to elucidate the community and ecosystem consequences of night-time changes in light regimes of lakes caused by skyglow. We expect that the new lighting conditions will influence the physiology and behavior of key species and result in multiple indirect effects mediated by species interactions. Consequently, the lake food web and biogeochemical fluxes could be markedly altered. Our results will provide fundamentally new insights into lake ecosystems and offer important information for future lake management in the face of rapidly spreading light pollution.

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Youth Organization for Lights Out: Engaging Chicago Youth in Light Pollution Research and Activism

Theme: Measurement and Modeling

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Introduction

The Adler Planetarium's Youth Organization for Lights Out (YOLO) is a light pollution awareness and civic action program in working-class neighborhoods of color for high school students in and out of the classroom. YOLO's goals are:

1. Youth will participate in the scientific inquiry process as they collect, analyze, and share results of their light pollution investigations.
2. Youth will engage in community advocacy by developing prototype solutions and action plans to increase awareness of light pollution's local effects in Chicago.

Fig 1: YOLO logo

The program is a partnership between the Adler Planetarium and World Language High School, a predominately Mexican-American neighborhood known as Little Village, in the West Side of Chicago. The collaboration intends to increase minority representation in science, technology, engineering and math (STEM) with active engagement centered on the local impact of light pollution within their community. According to a report from the Little Village Education Collaborative, "some students said that the instructors/teachers/supervisors of these programs/experiences not only motivated them to continue pursuing their newfound interest, they also provided resources for them to do so." YOLO has ten consistent students who are engaged and have committed to meeting after school to discuss upcoming research projects to educate the Little Village community.

Light Pollution Education

The program model begins in a classroom setting where participants learn about the causes and effects of light pollution, take a night field trip to collect data on darkness levels, talk to a light pollution researcher and biology professor from Northeastern Illinois University, and ends with the students hosting a share-out event at their school and for guests who visit the Adler Planetarium. As students collect and analyze data using a luminance measurement device, Sky Quality Meters (SQMs), and the Loss of the Night (LON) phone app that allows citizen scientists to be a part of a worldwide project, the measurements allow them to connect with Far Horizon's NITELITE (high altitude balloon LP imaging missions) and NITESat (the Night Imaging and Tracking Experiment Satellite) program that will capture night light images from space. The idea is to get as many students and community members to assist in the data collection.

Students attend a dark sky field trip to the nearest national park, Indiana Dunes, during a clear and moonless night. At the Indiana Dunes, students use the SQMs and the LON app to compare the difference between Chicago's night sky and the national park night sky. Adler telescope volunteers attend the event and set up their telescopes positioned to have the students view constellations and planets. Many of the students who attend the dark sky field trip have never left their urban neighborhood and have never been in a location so dark they are able to see a sky full of stars. This experience provides them the energy and excitement to explain to others, during Adler's annual Earth Day fest, why it is important to reduce light pollution and save our environment, particularly the impact of bird night migration.

One of the biggest challenges YOLO is currently facing is the recruitment of other students. The consistent ten participants are going to begin their junior year of high school, the year college preparation becomes rigorous. They are creating a legacy in their school that will encourage others continue the environmental justice work currently being created. In the upcoming school year, YOLO will not only be an after-school program but it will also go back into the classroom setting with high school freshmen. This is intended to expand our data collection with the SQM and LON along with recruiting for the after-school program.

Community Advocacy and Outreach

The city of Chicago has implemented changing the street lights through the Chicago Smart Lighting Program. Some of the changes began in the Little Village neighborhoods. YOLO students noticed the difference in the light bulbs going from HPS to LED but also took note that the shielding has not changed in some areas and not in others.

For 2018 school year, the students' goals are to continue to do share-outs, in English and Spanish, attend elementary school events and inform the students and their families ways they can reduce light pollution in Little Village. They want to inform elementary students how to use a telescope and have hands-on activities for the young students while educating the parents on how to properly use the Loss of the Night app.

Outcomes

YOLO is designed to motivate and empower youth by exposing them to more in-depth knowledge about light pollution and learn to become environmental activists within their own community. The students will collect and analyze data, bring awareness to their neighborhood and become youth activists.

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Melatonin concentrations are decreased by very low intensities of artificial light at night in European perch (*Perca fluviatilis*)

Theme: Biology and Ecology

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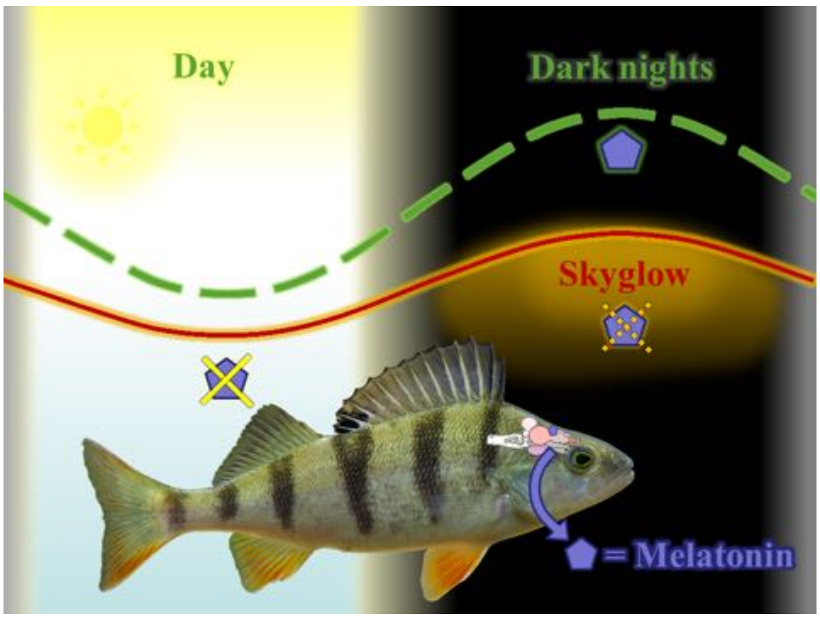

Fig 1: Circadian rhythm of melatonin production in European perch under natural day and night scenario and under artificial light at night at intensities resembling skyglow. During the day melatonin production in the brain is naturally suppressed by light (> 3000lux) and is produced in darkness (< 0.0001 lux) (green dotted line). Under low intensity ALAN (0.01 lux, e.g. skyglow) melatonin production is partially suppressed (red solid line).

Our study aimed for a better understanding concerning the dose-response relationship between artificial light at night (ALAN) and melatonin production at night. This is necessary to better assess the impacts that ALAN causes in different geographical regions (Gaston et al. 2015). Especially low intensities of ALAN (< 1 lux) have often been neglected in controlled lab experiments so far. Ecologically, low intensity ALAN affects large geographical areas in the form of skyglow, which is created when direct ALAN from cities is scattered in the atmosphere and illuminates the night sky over regions up to many kilometers away from the cities (Kyba et al. 2015).

Melatonin rhythms are found in most organisms and provide important information to optimize the physiological energy allocation on a daily as well as a seasonal basis (Navara and Nelson 2007). ALAN alters the information about the natural light and besides inducing behavioral changes it also impairs melatonin production at night in many animal groups such as mammals, birds, insects as well as fish (Jones et al. 2015, Ouyang et al. 2018). The disturbance of melatonin rhythmicity by ALAN can thereby lead to an imbalance in energy allocation and might lead to decreased physiological performance, may it be growth, reproduction, immune function or other physiological traits (Navara and Nelson 2007, Ouyang et al. 2018).

The current study investigated the melatonin rhythm of European perch (*Perca fluviatilis*) under ALAN at intensities of 0.01, 0.1 and 1 lux after an exposure period of 10 days with high light intensities during the day (> 3000 lux) and a simulated dusk and dawn period. Each treatment plus a control treatment with complete darkness (< 0.0001 lux) at night were replicated six times with 30 European perch in each aquarium. Melatonin concentrations of the rearing water were measured every three hours. Earlier studies on European perch and roach using the same setup, found a strong suppression of melatonin at night with light intensities down to 1 lux (Brüning et al. 2015, 2017). From these studies it remained unclear which light intensity of ALAN might be the threshold for an impact on melatonin. The aim of our study, hence, was to investigate the dose-response relationship between nocturnal light intensities below 1 lux and melatonin suppression at night and in order to at best define a minimal threshold where ALAN starts to have an impact.

Surprisingly, melatonin production at night was still strongly and significantly decreased by 50% even at the lowest intensity of 0.01 lux at the water surface (Fig. 1). Average melatonin concentrations during the night were 40 or 25% of the concentrations at control conditions at 0.1 or 1 lux, respectively. Even though a “no observed effect level” (NOEL) of ALAN could not be realized in this study, our results together with the previous study (Brüning et al. 2015) allow a quite detailed description of a dose-response curve. A cosine analysis for rhythmicity revealed significant rhythms in all treatments except the 1 lux treatment and the amplitude was significantly lowered in a dose-response manner.

On top of an increased understanding of the dose-response function, the results are important to estimate the potential threat of low intensity ALAN. Especially the lower light intensities of our experiment emulate realistic skyglow scenarios in Europe and other industrially developed countries. Therefore, we can draw the conclusion from our results that skyglow can alter physiological rhythms in European perch and the current study highlights the importance of studying the effects of low intensity ALAN in fish.

This work is part of the ILES project (Illuminating Lake Ecosystems) funded by the Leibniz Association, Germany (SAW-2015-IGB-1 415).

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STARS4ALL – citizen science to save European nightscapes

Theme: Society

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An awareness project for social and sustainable innovation

The STARS4ALL project is a European initiative to build an awareness platform for strengthening forces against the globally increasing effects of light pollution. The project is part of the social digital network CAPSSI (https://capssi.eu/), which is is offering support in creating awareness of sustainability problems and developing collaborative solutions based on innovative networks of people.

Partners in the STARS4ALL projects are the Universidad Politécnica Madrid, the Universidad Complutense Madrid, the European Business School Madrid, the European Crowdfunding Network, the Southampton University, the Astrophysical Institute of Canary and the Leibniz Institute of Freshwater Ecology and Inland Fisheries Berlin.

STARS4ALL has developed several tools like a photometer measurement network (Zamorano et al., 2017), gamification of citizen science approaches to engage in urban life and scientific data (Celino et al., 2016), data management for light pollution measurements and other citizen science databases as well as a crowdfunding platform (Brüntje & Gajda, 2016) for actions and initiatives against light pollution. Today 23 initiatives, involving projects from architectural lighting to exhibitions into the darkest areas of Europe, have joined the STARS4ALL platform (http://stars4all.eu/lpi/). To support the sustainability of the network the project has developed methods and metrics to assess and ensure the quality of the human generated output produced by the users in citizen science initiatives and a foundation will financially support the actions of the project upon funding time (2016-18). At the moment, two further tools are being developed, first a petition for the protection of European dark skies and second a label to be granted by citizens to the private sector, villages or companies that have invested into solutions to protect the environment from light pollution.

Citizen science and engagement against light pollution

In this talk we will discuss the impact citizen science has on the research of light pollution and the various scientific backgrounds the citizen actions provide. Citizen science projects around the globe collect data of artificial light measurements perceived from the ground as well as from remote, and data about effects the light has on the environment (Schroer et al., 2016; 2018). We will present the tools STARS4ALL offers to the community and further discuss the expected success by both the petition for stronger regulation policy and the development of a label for the certification of investment in reducing light pollution in the private sector.

European legislation is often disregarded concerning the emission of light. Light emission into sensitive habitat of ecosystems can interfere with ecosystems and biodiversity (e.g. Schroer and Hölker, 2016; Bennie et al., 2015; Manfrin et al., 2017). Thus, light installations that do not consider sustainable technological solutions to reduce the emission into sensitive habitat can violate the European law for the protection of the environment. Furthermore, light emissions in living areas are regulated by national law (e.g. LAI in Germany), but often such regulations are disregarded or not demanded by concerned persons due to lack of knowledge. Expected changes by the intended petition are a stronger enforcement of national regulations and a European standard for the protection of the environment from light emission at night.

For the development of a citizen's label for companies and villages, terms and regulation need to be provided and certification criteria presented in a transparent and comprehensible way. These criteria include measures for the regulation of (a) light intensity, (b) light emission into non-target areas, (c) reduction of blue light content of the light emission, and (d) awareness campaigns on the issue of light pollution. The intention of the label is to promote the investment into sustainable illumination by areas, village or companies, to visitors and to empower citizens' arguments for more sustainable lighting in their communities.

The measures for public awareness of the problem of light pollution and the public knowledge how to enforce regulations to avoid the mismanagement of lighting are of urgent need to save what is left of Europeans natural nightscapes (Kyba et al., 2014; 2017).

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Street lamps disrupt flower-visitor interactions beyond the illuminated area

Theme: Biology & Ecology

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Introduction

Light pollution from street lighting has been shown to negatively affect biodiversity and ecosystem functioning, such as interactions between plants and flower-visitors. However, the spatial extent of such disruptive effects is currently unknown.

We therefore investigated the effect of a light intensity gradient on flower-visitor interactions. For doing so, we selected 8 ruderal and unmanaged meadows in the Bernese pre-alps which still present low levels of light emission. Half of the sites was illuminated by a LED street lamp, the others were kept in the dark as control sites. During summer 2017, potted phytometers (*Silene latifolia*) were placed in the control sites as well as in the illuminated sites at different distances from the lamp to expose them to a gradient of light intensity from about 40 lux to the darkness on to control sites. *Silene latifolia* forms a nursery pollination mutualism with one of its main flower-visitors *Hadena bicruris,* i.e. while pollinating the moths oviposit on the ovaries inside the flowers. During the experiment we assessed nocturnal pollinator abundance along the light intensity gradient and, after flowering, we quantified reproductive success and parasitism rate of the phytometers. For understanding the underlying mechanism, in a controlled indoor experiment, we offered flowers of *S. latifolia* at different light intensity levels to specimens of *H. bicruris* and recorded oviposition and visitation rates.

The proportion of parasitized flowers was significantly increased on illuminated sites. Within illuminated sites proportion of parasitized flowers was negatively related to light intensity, with highest parasitism rates beyond the edge of the illuminated area, where light intensity levels were similar to dark sites. The latter led to a reduction of the plant fitness due to a shift toward parasitism along the mutualism-parasitism continuum of the interaction between *S. latifolia* and *H. bicruris*. Indoor experiment data confirmed this pattern. We conclude that flower-visitor interactions can be altered due to artificial light at night beyond the illuminated area.

What Went Wrong? The Failure of New York City's Crime-Reducing Lighting Scheme

Theme: Society

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Introduction

In 2016, over 300 lights at a cost of $80 million USD were installed at New York City Housing Authority (NYCHA) complexes in. Dubbed "safety lights", the lights were part of the Mayor's Action Plan for Neighborhood Safety, aimed at reducing violent crime in public housing.

Prior to this, Chalfin et al. (2017) conducted a study that sought to determine whether outdoor lighting at these housing sites would reduce crime. Temporary generator-powered portable light towers were distributed in a random selection of 39 NYCHA developments, with an additional 38 developments left as control sites. After a public consultation process, the 39 test sites were given a random allotment of light towers averaging 10, but ranging from as few as one. The study indicated as much as a 39% reduction in nighttime index crimes (includes murder, robbery and aggravated assault, as well as certain property crimes).

However these impressive results were not matched by the permanent lighting installed later (Bittle and Craven 2018), a result that mirrors inconclusive results from prior research on lighting and nighttime crime in the U.S and U.K. For example, Farrington and Welsh (2002) noted "It is not clear why the studies produced different results..." Earlier, Painter (1988) had written "The nub of the case against lighting as a means of crime prevention is that there is no unanimous evidence that it reduces crime."

Three issues with the Chalfin et al. (2017) study serve to undermine the value and reliability of its conclusions.

Methodological Issues

Lighting and nighttime crime studies can be methodologically divided into two basic classes. 'Passive crime monitoring' studies compile data from reported crimes to police departments, and 'active crime monitoring' data are collected by field researchers in the study area. The conclusion of the study (crime up or down with lighting) is 100% correlated with the type of study. Passive crime monitoring shows that light at night is at best ineffective, and may actually worsen crime. Active crime monitoring leads to the conclusion that light at night aids in reducing crime. The issue with active crime monitoring is summed up by Painter (1988), "[a]wareness of the crime study was widespread amongst potential perpetrators. The presence of the highly-focussed study directly impacted the results."

Based on this, the best designed street light/crime studies are 'passive' in their crime data collection and they find that as illumination levels are increased, there is an increase in nighttime crime rates. There is some evidence that this is due to daytime crime shifting to the nighttime.

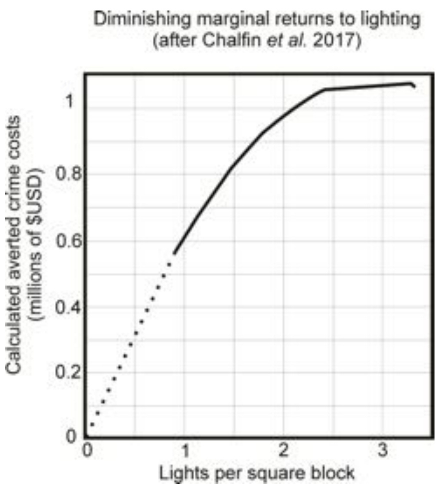
Chalfin et al. (2017) lighting study engaged in extensive public consultations in each of the housing projects that were to have the temporary lighting installed. Their study was likely common knowledge amongst potential criminals.

Data Classification and Presentation Issues

Chalfin et al.'s (2017) analysis focused "on four main outcomes: 1) index crime complaints, 2) felony complaints, 3) "assault, homicide, and weapons" complaints…, and 4) misdemeanor complaints." They present the first three categories as separate entities; however the first three definitions are more or less dominated by the same crimes. This is the equivalent of reporting on a farm's status using the 'separate' categories of cows, livestock and cattle.

Data Analysis Issues

Despite the 'headline' value of a 39% nighttime crime reduction with the additional lighting, Chalfin et al. (2017) note that "the simple comparison left us with insufficient statistical power to detect differences in crime between the treated and control developments." One would think that such a strong result should be present in the raw data without recourse to statistical acrobatics.



The analysis presented by Chalfin et al. (2017) indicates that the strongest effect between nighttime lighting and crime occurs with the fewest light sources. The first light tower 'saves' $600K USD, the second, approximately $400K USD, and a third one accounted for less than $100K USD in calculated 'savings'.

If a single light tower can account for about 55% and two such units total about 90% of the crime reduction effect, how is it that it is impossible to determine if the presence or absence of the lighting has an effect on nighttime crime? One way that both parts of this can be true is if the addition of more lighting per block brings down the magnitude of the effect so that at higher light counts, the entire calculated effect approximates zero. In other words, the averted crime cost for additional lighting is negative. Indeed, despite Chalfin et al. (2017) have cut off their graph, there is a hint that the curve slopes downward for higher number of lights. Note that the average light tower count per housing complex was 10 and some sites received more lighting units than that.

Conclusions

What about the reported robust effect of a few light towers? One or two light towers on a city block do not constitute a well-designed lighting scheme with respect to illumination levels or uniformity. Only higher light tower counts could provide effective, uniform illumination. The study appears to show that more light towers led to a reversal of the positive impact provided by one to three units. It is likely that the few noisy, obtrusive generator-powered light towers likely reminded potential criminals that the area was part of a crime study, thus changing their behaviours.

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Stream Insect Acclimation to ALAN

Theme: Biology & Ecology

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Introduction

Over the past ten to twenty years, great strides have been made in identifying the behaviors and physiological processes in organisms that are affected by artificial light at night (ALAN), and current research is making progress in understanding how relationships between organisms might be changing under exposure to ALAN. However, many of these studies hinge on comparing the responses of "light naïve" organisms under lit and "naturally dark" conditions. Given the prevalence and spread of ALAN, it is increasingly difficult to find appropriate control populations, and it is unclear how easily organisms *acclimate* (i.e., adjustment within an individual) or how quickly populations *adapt* (i.e., evolution in a population) in response to exposure to ALAN, or indeed, whether any acclimation or adaptation is possible at all, and how that acclimation or adaptation may influence the results of ALAN research.

The goal of this research was to find evidence for acclimation or adaptation to ALAN in the drifting behavior of riverine aquatic invertebrates. Normally, aquatic invertebrates will drift—or detach from river substrates at night and float in the water column for several meters before re-settling—when the chance for detection by visual predators is low. Numerous studies have found that these stream invertebrates are less likely to engage in drifting behavior when ALAN is present (Chaston 1969, Henn et al. 2014, Perkin et al. 2014a); however, other studies were unable to find evidence of decreased drift rates under ALAN (Perkin et al. 2014b, Newman 2015). We hypothesize that one of the causes for the lack of response in drift to ALAN found by Perkin et al. (2014b) and Newman (2015) is acclimation and/or adaptation by the invertebrate populations used in their studies. That is to say, the low light levels present in the areas the invertebrates were sampled from were still high enough to invoke an adjustment to light at night, and those populations were not, in fact, light naïve.

To test this hypothesis, we sampled the drift rates of stream invertebrates in fifteen different streams in Oregon, USA, across a light gradient ranging from 0.01 lux to 20.00 lux. Drift samples were taken during the day as well as the night, so comparisons across the light gradient could be made as a ratio of night:day drift rates. Results from pilot studies on a sub-sample of these streams have shown that more brightly lit streams have a night:day drift rate ratio ≤ 1, while darker streams have night:day drift rate ratios >> 1, indicating acclimation or adaptation.

In this talk, we will present the results from a full study on fifteen streams, as well as discuss the implications for acclimation/adaptation to ALAN study design and for future research on the potential evolutionary effects of ALAN.

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Night shift work, cancer risk, and beyond: new insights from epidemiological studies

Theme: Health

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Introduction

Melatonin is a hormone that is produced primarily by the pineal gland and secreted almost exclusively at night, when it is dark. Experimental studies provide compelling evidence for melatonin's oncostatic properties. Growing evidence also demonstrates that visible light, including electric light, can acutely suppress melatonin production– a phenomenon often referred to as "circadian disruption" particularly if it occurs at night, as commonly observed in shift workers. These observations led to the formulation of the 'melatonin hypothesis' by Richard Stevens und Scott Davis in 1986, suggesting that diminished secretion of melatonin might promote the development of cancer.

Triggered by the melatonin hypothesis, researchers accelerated their efforts to clarify whether increases in exposure to light at night could indeed increase cancer rates. With convincing experimental evidence and supportive, but still limited, epidemiologic data of higher cancer (particularly breast cancer) rates among night shift workers, the International Agency for Research on Cancer (WHO) in 2007 classified shift work as a probable (class 2A) carcinogen, Since then, epidemiologic data has continued to accumulate, with the majority of currently existing studies continuing to indicate that shift work is related to a modest increase in the risk of breast cancer. Initial studies have identified links between shift work and other cancers as well, although this evidence is very limited.

In addition to cancer, several other chronic disease endpoints have recently been linked by large prospective cohort studies to chronic night work exposure (e.g., diabetes, cardiovascular disease, hypertension). Some initial studies are also beginning to unravel the importance of chronotype and meal timing in the observed association between circadian disruption and chronic disease risk.

In this presentation, I will review epidemiologic studies of circadian disruption/sleep and chronic disease risk, including some initial studies on the mediating effects of chronotype, sleep, and meal timing, as well as circadian phase biomarkers (melatonin/cortisol).

Artificial light at night (ALAN), blue light spectrum exposure and colorectal cancer risk in Spain (MCC-Spain study)

Theme: Health

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Abstract

Background. Night shift work, corresponding exposure to artificial light-at-night (ALAN) and the consequent circadian disruption, may increase the risk of hormone-dependent cancers. Recent studies have also identified increased risk of colorectal cancer, the third most common cancer globally, among night shift workers (Papantoniou et al, 2017). We evaluated the association of exposure to ALAN during sleeping time with colorectal cancer in a general population case-control study in Spain (MCC-Spain), among subjects who had never worked at night. We examined individual residential information on ALAN focusing on blue light spectrum exposure. We have previously shown that exposure to ALAN, blue light spectrum was associated with an increased risk for breast and prostate cancer (Garcia-Saenz, et al 2018).

Methods. We enrolled 557 incident histologically verified colorectal cancer cases and 1120 age, sex and region-matched population controls, from Barcelona and Madrid between 2008 and 2013 (Castano-Vinyals et al, 2015). All subjects were interviewed and residences geocoded. Outdoor-ALAN was analyzed using images from the International Space Station (ISS) available for Barcelona and Madrid, including data of remotely sensed upward light intensity and blue light spectrum information for each geocoded longest residence of each MCC-Spain subject. Residential mobility was low in this study population and the longest residence was on average above 30 years and coincided with the last residence for about 80% of the subjects. Images were downloaded from the Earth Science and Remote Sensing Unit, NASA Johnson Space Centre (url: https://eol.jsc.nasa.gov). images were calibrated applying the procedure described in Sánchez de Miguel (2015), by using existing databases of standard typical emission spectra of known types of outdoor lighting (white LED, low pressure sodium, metal halide, etc) and inferring the observed lighting type from the RGB signature (Sánchez de Miguel et al. 2014). There are no major changes in the two cities on their street lighting from 2001 to 2014. We also calculated an index of outdoor blue light spectrum using an approach described in Aubé et al. (2013) to calculate the melatonin suppression index (MSI) at each pixel of the image. All effect estimates are adjusted for potential confounders. To analyze the effect of

ALAN during sleeping time, we excluded subjects who had ever worked in night-shift.

Results. Exposure to the higher vs. lowest tertile of blue light spectrum was positively associated with an approximate 70% increased risk for colorectal cancer (adjusted Odds Ratio (OR) = 1.69, 95%confidence interval (CI) 1.28, 2.23). 1.47; 95%CI: 1.00, 2.17). ORs were adjusted for age, sex, center, education and a score indicating adherence to cancer preventive policies (World Cancer Research Fund score including smoking, physical activity, red meat consumption and other). Adjusting further OR for area based socioeconomic status (urban vulnerability index), family history of colorectal cancer and sleep duration modified little this positive association (OR=1.79, 95% CI 1.31, 2.44). In a sensitivity analysis we included subjects who reported having worked in night shift and this resulted in very similar estimates (OR=1.74, 95%CI 1.35, 2.24). Outdoor visual light was not associated with colorectal cancer risk (OR for highest vs low tertile 0.93, 95%CI 0.70,1.23).

Conclusion. Outdoor ALAN and particularly blue enriched light spectrum, was associated with an increased risk of colorectal cancer in the general population. .

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Residential outdoor light at night and breast cancer risk in Vancouver, British Columbia

Theme: Health

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Introduction

Chronobiological and epidemiologic studies suggest that exposure to light at night may disrupt circadian rhythms, which may increase cancer risk, particularly breast cancer. In a case-control study in the greater Vancouver area, we investigated the hypothesis that residential outdoor light at night (LAN) is associated with breast cancer, controlling for confounders and considering interactions such as menopausal status and shift work.

Methods

A population-based case-control study was conducted in Vancouver, British Columbia (BC), Canada. Incident breast cancer cases (n=1055) were recruited through the BC Cancer Registry. Controls (n=1016) were recruited through the Screening Mammography Program of BC, and frequency matched by age to cases living in the same geographic region. All participants completed a study questionnaire assessing a range of personal, health, and lifestyle characteristics. A total of 622 cases and 647 controls had complete residential histories and this analysis was restricted to these women. Outdoor LAN exposure was estimated using time-weighted average measurements for residential histories of each participant, derived from 3 sources: 1) satellite imagery data from the International Space Station (resolution of ~10m), 2) Visible Infrared Imaging Radiometer Suite Day-Night Band data (DNB) (resolution of ~750m), and 3) the U.S. Defense Meteorological Satellite Program (DMSP) imagery data (resolution of ~5-7 km). Cumulative average LAN exposure was calculated across participants' residential histories for the exposure time window from 10 to 30 years before study entry. Six measures of cumulative average outdoor LAN were calculated using the ISS data: luminance, wavelength-based lamp melatonin suppression estimates using blue-green or green-red colour band ratios, wavelength-and-intensity based melatonin suppression estimates using blue-green or green-red colour band ratios, and melatonin suppression estimates based on the technological source of the light that best matches the color bands. One measure of cumulative average outdoor LAN was calculated using the DNB data, and one measure of cumulative average outdoor LAN was calculated using the DMSP data. Outdoor LAN measures were categorized into quintiles for all analyses, with the reference (lowest quintile) representing the lowest level of outdoor LAN exposure. Logistic regression was used to estimate the relationship between outdoor LAN and breast cancer, adjusting for confounders.

Results

Cases and controls were similar in both age (56.7 years vs. 58.2, respectively), and menopausal status (70.1% vs. 66.6% postmenopausal respectively). Cases were significantly less likely to be Caucasian, more likely to have a family history of breast cancer and be current smokers, but did not differ in terms of body mass index, never vs. ever shift work status, and age at menarche. For all women combined, there were few clear patterns of risk associated with outdoor LAN exposure, and many odds ratio (OR) estimates suggest a protective effect of outdoor LAN. Among 402 pre-menopausal women, OR estimates trended towards a higher risk of breast cancer at higher quintiles of outdoor LAN exposure, with the highest OR at 2.07 (0.98-4.40) for the DMSP measured LAN exposure. For the measure of melatonin suppression estimated based on the blue-green band, OR estimates suggested a higher risk for breast cancer, with quintiles 2, 3 and 4 ranging from 1.33 to 1.64 (although the 95% confidence level interval also overlapped with 1.0). In contrast, for 867 post-menopausal women, a reduced risk for breast cancer was apparent for some measurements of outdoor LAN exposure. Interactions with exposure to shift work (ever/never) and exposure to permanent night work (permanent night work/never permanent night work) were not apparent.

Conclusion

Results for pre-menopausal women are consistent with The Nurses' Health Study and the MCC-Spain Study. Strengths here compared to previous studies include use of high quality images with higher resolution around participants' residence, and analysis of outdoor LAN using several biologically relevant parameters. In addition, the study examines women living at a considerably higher latitude than in previous studies. More work is needed to understand the specific mechanisms linking overall outdoor LAN to breast cancer risk, particularly in terms of blue light exposure.

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The Balance of Roadway and Outdoor Lighting

Theme: Measurement & Modeling

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Lighting has long been shown to have an impact on roadway safety. Analyses have determined that the addition of lighting to a roadway can have a positive impact on the reduction of vehicle crashes. Historically, these crash reductions have been as high as 50%. Similarly, lighting is being shown to have an impact on the driver behavior and speed choices. However, as these positive impacts of lighting are being more well understood, more evidence is available on the negative impacts of these lighting systems on the environment, the users and adjacent flora and fauna.

A balance must be struck between the positive and negative aspects of roadway lighting. Considering the use of light as similar to the use of a drug, the correct dose must be selected to provide light when and where it is needed and reduce or remove light when it is not needed. This discussion will consider this balance.

NASA’s Black Marble nighttime lights product suite

Theme: Measurement & Modeling

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NASA’s Black Marble nighttime lights product suite (VNP46) is derived from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB) onboard the Suomi National Polar-orbiting Platform (SNPP). The product is being routinely made available from the NASA Level 1 and Atmosphere Archive and Distribution System (LAADS) Distributed Active Archive Center (DAAC). The standard product (Level 3 daily and multi-date formats) is available at 500 m spatial resolution since January 2012, and is being processed on a daily basis within 3-5 hours after acquisition, enabling both near-real time uses and long-term monitoring applications. The algorithm produces high-quality cloud-free daily nighttime light (NTL) imagery that have been corrected for atmospheric-, terrain-, snow-, lunar BRDF-, thermal-, and straylight-effects. The corrected nighttime radiances, resulting in a superior retrieval of nighttime lights at short time scales and a reduction in background noise, enable quantitative analyses of daily, seasonal and annual variations. Recent product validation activities, conducted in partnership with Puerto Rico's Working Group on Light Pollution (PRWGLP), include the use of in-situ NTL measurements at the Pitahaya Farmland site in Cabo Rojo, Puerto Rico. A stable point source was reflected by a 30 m^2 Lambertian target to generate an in-band DNB radiance at sensor to measure the sensitivity of the VIIRS/DNB’s High Gain Stage (HGS). Some recent applications of the product include: (i) measuring the impacts of Hurricane Maria on Puerto Rico’s energy sector, (ii) monitoring the effects of conflict and population displacement across Syria, (iii) assessing the effectiveness of rural electrification programs across India, (iv) monitoring the impacts of Hurricane Florence on across neighborhoods in North Carolina.

IDA's first International Dark-Sky Reserve is 10 years old: Monitoring the evolution of night sky brightness over Mont-Megantic's protected dark sky

Theme: Measurement & Modeling

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Introduction

More than 10 years after it's creation, the Mont-Megantic area is still IDA's largest Dark-Sky Reserve and continue to be very active in resolving the challenges of balancing the activities of scientific astronomy, astro-tourism and the needs of its residents. While the regulations and means to control light pollution evolved in the last decade, actual measurements of the light pollution situation in the Reserve were scarce and needed to be better addressed.

Here we present a comparison of all-sky photometric data taken in 2007 and 2017 from Mont-Megantic's summit and the results of more than two years of continuous monitoring of zenithal sky brightness from the core of the Reserve.

The Sky Quality Meter (SQM) is one of the most used devices for light pollution measurement around the world. This makes it very practical for comparing to other sites and to monitor sky brightness over longer periods of time (Hänel 2018). To avoid the uncertainties and variability associated with taking measurements manually, we chose to do continuous measurements with an SQM-LE pointed at zenith.

The SQM data revealed that there is virtually no artificial light present at zenith over Mont-Megantic. While this represents good news for the observatory and the Dark-Sky Reserve, it also complicates the analysis of the data because it means the SQM measurements are greatly affected by natural sources like the Milky Way and airglow. This influence of natural light sources also makes it more difficult to quantify the actual brightness of the sky and compare it to older measurements or other sites. By taking into account each of those natural sources and their respective variability, it is possible to filter the large amount of data provided by a continuously logging SQM and deduce the true dark sky conditions of a site. For the Mont-Megantic Observatory, the zenithal sky brightness reaches 22,0 $mag_{SQM}/arcsec^2$ under clear conditions and away from the galactic plane, but can get as high as 21,6 $mag_{SQM}/arcsec^2$ when the Milky Way is overhead. In order to obtain measurements other parts of the Dark-Sky Reserve, a car-mounted SQM with GPS was also used.

To verify the measurements obtained with the SQM and to assess the quality and see the evolution of the night sky in every direction and zenithal angles, we also took new all-sky observation with the help of the Colorado State University and NPS (Duriscoe 2007 and Duriscoe 2013). The new dataset was then compared to the one made a decade earlier, when the Dark-Sky Reserve was just created. Benefiting from very similar atmospheric conditions and made at almost the same time of the year, the all-sky measurements show that the artificial sky brightness didn't increase while the population of the Reserve grew by 9% in 10 years. This gives us a good indication that the lighting ordinances put in place in the region and the continuous efforts to control light pollution do actually work.

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A proposed method for estimating regional and global changes in energy consumption for outdoor lighting

Theme: Measurement & Modeling

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Introduction

Satellite imagery of the Earth at night is extraordinarily useful, but there are limitations on how directly it may be interpreted. For example, the total luminous flux of a city cannot be directly measured by satellite because:

1) The observed radiance consists of a mix of both direct and indirect (reflected) light.
2) Much of the emitted and reflected light may be screened from the satellite's view, due to buildings or vegetation.
3) The instrument's sensitivity does not match human visual sensitivity (V_λ).
4) The spectra of light that reaches space does not match the spectra of light emission, due both to reflection from colored surfaces and spectrally dependent absorption and scattering in the atmosphere.

Fig 1: Europe and northern Africa at night imaged by the DMSP-OLS. Public domain image by Craig Mayhew and Robert Simmon.

Despite these issues, it is nonetheless clear from visual inspection of nighttime imagery (e.g. Fig. 1) that the light observed from space must strongly correlate with installed luminous flux. Unfortunately, the correlation between the two parameters is almost currently changing, due to the global introduction of LED lighting. The reasons for this are the spectral shift from mainly orange to broadband (white) light (see e.g. Sanchez de Miguel et al. 2017), and the introduction of entirely new forms of public and private lighting (e.g. decorative bridge lighting), thanks to the novel capabilities of LEDs. This presentation will outline a method to account for these effects, in order to estimate global and regional changes in energy consumption for outdoor lighting. In addition to observing satellite data, the method requires the active participation of dozens of cities and thousands of citizen scientists worldwide.

Methods

Data from the Visible Infrared Imaging Radiometer Suite Day/Night Band (DNB) serves as a base source of information about geographic patterns and changes in temporal light emissions worldwide. However, a number of corrections must then be applied to account for changes in lighting practice due to the introduction of LEDs, and to convert radiance observed in space (nW/cm^2sr) to power consumption on the ground (W).

The shift in spectra can be accounted for by examining changes in the color ratios of photographs taken by astronauts on the International Space Station (Fig. 2, Sanchez de Miguel et al. 2014). An estimate of average annual color ratios can be developed for a set of regions on the Earth. This would make it possible to convert the DNB data into a global map of approximate luminance, rather than radiance.

Public and private lighting likely have different emission properties. For example, newly installed street lights are increasingly likely to be fully shielded, with no upward emissions, while even downlit billboards radiate fully half of their reflected light towards the sky. It is therefore necessary to understand what fraction of light comes from public vs private sources and what the angular emission properties of each type is, as well as to estimate separate conversion factors for the relation between satellite detected luminance and installed luminous flux and energy consumption.

Fig 2: Lighting change in a 22km^2 portion of Calgary, Alberta, Canada, from 2012-2015. At left, a neighborhood changed to white LED, at right, a ring road is newly lit with HPS lamps. Images ISS026-E-12438 and ISS045-E-155029 courtesy of the Earth Science and Remote Sensing Unit, NASA Johnson Space Center.

The relative fraction of public vs. private lighting could be estimated based on experiments conducted in partnership with cities that dim their lights after midnight. By alternating the level of dimming (e.g. 45% on some nights, 55% on others), the relative fraction of emissions due to public and private lighting can be calculated. In combination with data from the cities about luminous efficacy, this would allow calculation of a factor to convert luminance derived from satellite radiance to Watts for public lighting.

The average upward emission function of cities can be estimated by fitting data from radiative transfer simulations (e.g. using Illumina, Aubé 2015) to sky brightness data. In addition to all-sky photographs, the newly available eVScope (enhanced vision telescope, UNISTELLAR) could be used as a sky brightness data source. If a skyglow measurement campaign was developed, the EVScope would allow thousands of citizen scientists to make observations of both the sky brightness in various directions and the atmospheric extinction coefficient. The upward emission pattern can then be used to estimate the luminance to energy conversion factor for private lighting.

The proposed methodology is ambitious, but achievable. Light emissions are continuing to increase worldwide (Kyba et al. 2017), so understanding trends in the energy consumption to produce this light is a critical input for the discussion of transition towards a sustainable society.

Acknowledgements

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Modelling the night sky brightness and light pollution sources of Montsec protected area

Theme: Measurements and Modelling

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We proceeded to the modelling of the night sky brightness of Montsec astronomical protected area (northeast of Spain). This region is labeled as Reference Point according to the legal framework of Catalonia and also certified as Starlight Reserve due to its pristine conditions. The main goal of this study is to evaluate the light pollution that the astronomic observatory located in Montsec (PAM) is receiving from the most relevant light pollution sources nearby.

The present study is based on the light pollution numerical model known as ILLUMINA (Aubé 2005). It has been used because it is the model that best matches the characteristics of our case: heterogeneity of ground-based light sources (spectra and light output angle distribution), low number of lighted grid points and large distance between the observer and the sources. Ground based measurements in Montsec and other areas of Catalonia (Ribas 2016), including both photometric and spectroscopic data, has been used to fit and evaluate the input parameters of the model. The output of ILLUMINA helps us better understand what kind of sources produces light pollution and in which manner. We also used it, after converting it to astronomical magnitudes, to know how they affect astronomical observations: the resulting data is used to build all-sky maps comparable with the ones obtained with ground based measurements (see Figure 1). We focus on the effect of light pollution in the Johnson-Cousins photometric system visual filters *B*, *V* and *R* (Johnson and Morgan 1953, 1955; Cousins 1976) in any line of sight from the observer.

In the first modelling attempt (Linares 2018) the city of Lleida, 140000 inhabitants located 50km south-west from the observatory, was considered as the unique source of light pollution. Here we present an extended version of the model that includes the cities of Balaguer, 17000 inhabitants located 15km south-east from the observatory, and Tremp, 6000 inhabitants located 20km north-east from the observatory.

This case of study is interesting not only for the relevance of the PAM but to compare the effects of two different city lighting systems. In 2014 Lleida updated its light source inventory mostly by replacing mercury vapor and some metal halide lights by LEDs, we use the available information to make a detailed comparison of the sky brightness before and after the change (see figure 2). This information could be used to plan for future updates and improvements of the lighting systems in the area.

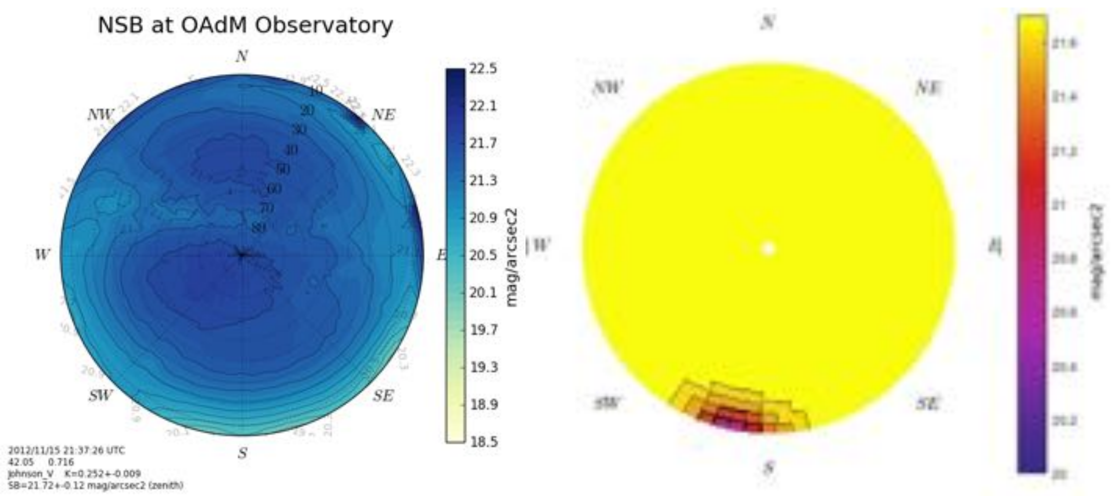

Figure 1. All sky maps over PAM at night. Left: made from ground measurements. Right: made with the model considering only Lleida as a light source.

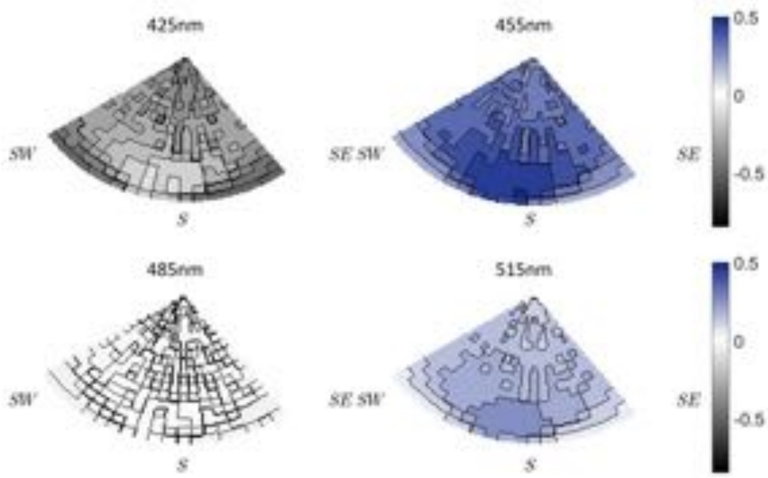

Figure 2. Comparison of emitted flux (F) by Lleida in different spectral ranges before and after the update of the lighting system of the city. The comparison follows the expression: $(F_{2015} - F_{2013})/F_{2013}$. Blue regions mean the new light lights are more polluting and grey ones that old lights were more polluting.

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Effects of artificial light at night on wildlife habitats: integrating science with decision-support tools

Theme: Biology & Ecology

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Introduction

A growing body of literature indicates that changes to the natural light regime due to the spatial distribution, timing, and composition of artificial light at night (ALAN) has significant consequences on wildlife populations and communities, and potentially affects ecosystem function in unanticipated ways. However, quantitative information on how ALAN alters wildlife habitat quality and connectivity over large spatial extents relevant to conservation planners is lacking. In this presentation, I will describe a collaborative research effort to demonstrate the effects of human activities on wildlife using a functional sensory ecology approach and, combined with NASA and the US National Park Service, develop spatially-explicit estimates of ALAN exposure on mammals and birds across the contiguous US. Initial results are indicative of wide-spread effects across multiple taxa. For example, using FeederWatch data (3.5 million observations), we found that ALAN has a strong negative effect on the abundances of numerous bird species across the contiguous US, and this negative relationship appears to be growing in magnitude over time. At finer spatial scales, we are finding that large predator species, such as cougars and coyotes change their habitat selection, movement, and behaviors in response to ALAN along the wildland-urban interface, with implications on their management and human-wildlife conflict. We are also merging expert information with a web-based visualization tool to help land managers more effectively allocate resources toward the management of ALAN on wildlife habitats. We discuss how this project can inform future efforts to understand and mitigate the negative effects of ALAN on wildlife species.

Nocturnally-migrating birds traverse Earth's most light-polluted regions, and bright lights confound their habitat use *en route*

Theme: Biology & Ecology

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Nearly half of the world's bird species undertake migrations twice yearly, traversing large expanses of land at up to continental scales and often under great selective pressure to reach their destinations in a timely manner. Most birds migrate at night, and therefore need to repeatedly locate suitable stopover habitats to rest and rebuild energy reserves. Given the extensive and increasing encroachment of artificial light at night (ALAN) globally, we evaluated 1) the annual mean intensity of ALAN over land within the geographic ranges of nocturnally-migrating terrestrial bird species from around the world (Cabrera-Cruz et al., 2018) and 2) how light pollution affects stopover distributions of nocturnal migrants in the northeastern United States. (McLaren et al., 2018).

We assessed how ALAN varied among 298 species worldwide with respect to five factors: 1) season of the year (i.e., migration, breeding, non-breeding), migration distance, range size, global hemisphere, and IUCN category of conservation concern. ALAN was relatively greater within migration routes over stationary ranges, for shorter-distance migrants, for species with smaller ranges, and for species in the western hemisphere, but did not differ by conservation concern. Hence, during migration, many long-distance migrants that spend the stationary periods of the year at extreme latitudes with low levels of light pollution must traverse mid-latitudes between 30°N and 45°N where human urban development is most prevalent and widespread ALAN is the brightest. The novel exposure to bright light pollution for birds during migration may enhance its influence on their behavior, particularly for juvenile birds during their first autumn migration.

The influence of ALAN on migratory birds likely reaches beyond the extent of urban areas. The skyglow of large cities can be perceived by migrating birds aloft from hundreds of kilometers away. Brightly-lit structures at a local scale can attract airborne migrants and lead to collisions, but skyglow might also influence broad-scale selection of stopover sites and ultimately acquisition of food resources for migrants. We demonstrate that autumnal bird stopover density increased at regional scales with proximity to bright areas using multi-year weather radar measurements of nocturnal migrants across the northeastern United States. Our findings imply broad-scale attraction to city skyglow by birds while airborne confounds their selection for high-quality extensively forested stopover habitat away from cities. Given that high-quality stopover habitat is critical to successful migration, and hindrances during migration can decrease fitness, light pollution presents a potentially heightened conservation concern for migratory bird populations. Others have found urban sources of ALAN are associated with higher levels of migrant stopover abundance both within green spaces at the interior of urban areas and along urban boundaries (Bonter et al., 2009; Buler & Dawson, 2014; La Sorte et al., 2017), supporting the conclusion that observed associations with urban areas during migration are driven, at least in part, by broad-scale attraction to urban light pollution. In contrast, areas containing high levels of ALAN are generally avoided by migratory birds during the breeding and non-breeding seasons (Zuckerberg et al., 2016; La Sorte et al., 2017). Thus, urban sources of ALAN broadly effect migratory behavior and may have a role in shaping migratory routes of individual species, emphasizing the need to better understand the implications of ALAN for migratory bird populations.

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Zooplankton response to "skyglow" revealed by high-resolution *in-situ* video in large experimental lake enclosures

Theme: Biology and Ecology

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Introduction and Approach

Skyglow from cities at night represents a dramatic recent anthropogenic modification of Earth's biosphere that extends into nocturnal landscapes also far from urban areas (Kyba 2013). Many organisms have evolved behaviours that directly depend on daily variation in light levels. Among aquatic organisms, zooplankton specifically depend on light for vertical migration while balancing between feeding in the productive surface waters at night and hiding from predators in darkness at depth during the day. This dial vertical migration (DVM) is one of the world's most spectacular synchronized behaviour, and has major importance for regulation of the energy flows and food webs in oceans and lakes (Hays, 2003). In aquatic food webs zooplankton link the bacteria and phytoplankton production with higher trophic levels and is therefore of vital importance in providing food, oxygen as well as water quality and many other ecosystems services critical for humans (Davies 2014). Thus, if skyglow alters DVM of zooplankton this could have cascading effects on aquatic food webs globally. Nevertheless, little is known about these potential effects in aquatic ecosystems in general, and for lake ecosystems in particular. However, investigating urban light pollution, Moore et al. (2001) reported reduced amplitudes in DVM of the zooplankton *Daphnia retrocurva* under relatively strong direct light effects. Although acute and often fatal effects of direct light on nocturnal organisms have been reported, very little is known about what effect, if any, the diffuse light surrounding urban areas (skyglow) may have on biodiversity (Gaston 2013; Hölker 2010). Although it has been shown that skyglow may alter nightscapes located far from urban areas and several publications have argued that skyglow must affect food webs and biodiversity, no studies have so far demonstrated this (Kyba & Hölker, 2013).

To fill this gap we report the first high-resolution measurements of zooplankton DVM under experimentally induced skyglow within the Leibniz funded project Iluminating Lake Ecosystems (ILES, http://www.igb-berlin.de/en/project/iles). This study was enabled by a combination of new video and sampling techniques deployed at a unique ecosystem-scale

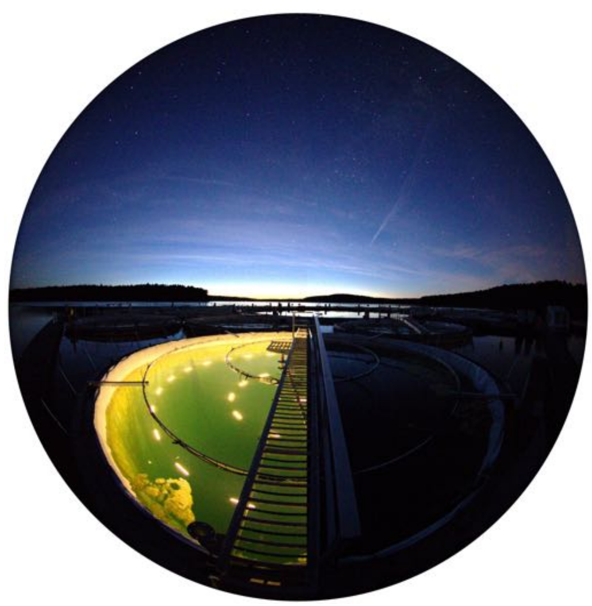

Fig 1: Enclosure at LakeLab Photo: A. Jechow.

experimental facility, the IGB LakeLab, installed in a deep clearwater lake, Lake Stechlin, 70 km north of Berlin, Germany. The site is located in one of the darkest regions in Germany providing excellent dark control conditions (Jechow 2016). The LakeLab, has 24 very large enclosures (1270 m^3 each) equipped with automatic water sensors (Giling 2017), and has a specifically developed lighting system creating realistic skyglow scenarios (Fig. 1, http://www.lake-lab.de/index.php/iles.html). This allows to conduct realistic, highly replicated skyglow-studies on lake ecosystems encompassing all trophic levels up to fish, a feature presently unique in the world.

As the low skyglow levels used here (ca. 0.06 and 6 lux, at surface) could theoretically induce only very small migration effects on the plankton, this sets a new level of demand on measuring zooplankton migration, on the order of cm-dm, that may not be handeled by classical approaches such as stratified net samples. We therefore:

1. developed a device to sample zooplankton near the surface (10 cm) and automatically digitalized the samples in the lab using a SLR-camera and self built x-y table (dElfi),
2. used a Mini Deep-Focus Plankton Imager (MDPI) equipped with a far red light source to assess *in situ* mesozooplankton abundance and depth distribution throughout the water column 0-20 m.
3. developed deep-learning neural network approaches to semi-automatically classify and size the high amount of video data from the dElfi and the MDPI systems. The neural networks allowed MDPI data to be classified at group level (cladocerans, copepods and large rotifers) ≥500 µm body length, and the dElfi distinction of organisms to genus level ≥200 µm body length.

Conclusion

The novel combination of replicated skyglow experiments in large lake-mescosms and high-resolution video technique revealed species- and size-specific responses in dial vertical migration induced by different levels of Skyglow, that would not be possible to obtain with classical approaches. This is the first study of its kind. With this presentation we aim to give insights into size-dependent migration of mesozooplankton under realistic close to natural skyglow scenarios in lakes, as well as presenting methods that can be adopted to wide range of systems and research questions.

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Notes