Dark and Quiet Skies for Science and Society

UNITED NATIONS
Office for Outer Space Affairs

International
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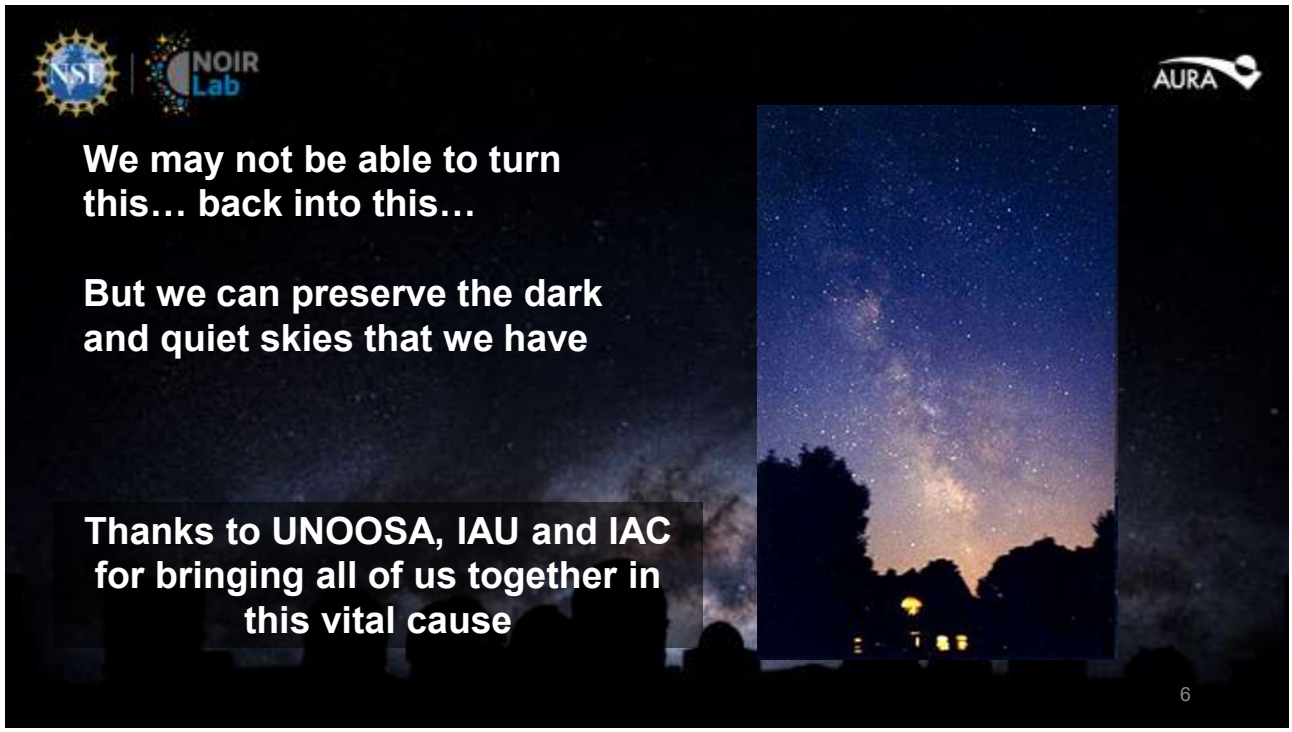
NOIR Lab
The night sky belongs to us all – and not just Homo sapiens
As scientists and leaders of international laboratories, we have a responsibility for its protection.
5

5


NOIR Lab
AURA
We may not be able to turn this… back into this…
But we can preserve the dark and quiet skies that we have
Thanks to UNOOSA, IAU and IAC for bringing all of us together in this vital cause
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Dark and Quiet Skies for Science and Society: Draft Reports

Five Draft Reports are available and open for comments until 16 October

- Download them from http://bit.ly/DQS_reports
- Please comment recommendations at http://bit.ly/DQS_comment

If you registered for today's Workshop then you have received the links on Thursday in an email from UNOOSA-Events@un.org and on Friday in an email from DQSkies@iac.es

Not received even though you had registered? Please email UNOOSA-Events@un.org

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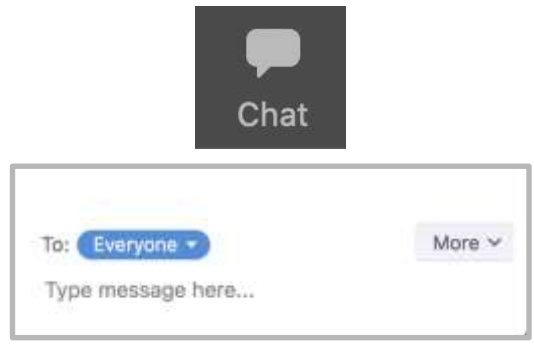
Zoom Meeting Housekeeping

Have a question?

- Use the chat at any time
- Keep it short!



Participants will **not** be unmuted
Q&A monitors will read a subset of questions

Bio-Environment WG Team

James Lowenthal - US
WG Chair, presenter

Costis Bouroussis - GR
WG co-Chair, presenter

Salvador Bara - ES

Annika Jägerbrand – SE
presenter

Andreas Jechow - DE

Travis Longcore - US

Mario Motta - US
presenter

Pedro Sanhueza - CL

Luc Schlangen – NL
presenter

Sibylle Schroer - DE
presenter

James Lowenthal

Bio-Environment Working Group charge

- Review existing literature on effects of artificial light at night (ALAN) on human health
  - Melatonin suppression
  - Sleep disruption
  - Cancer
  - Diabetes
  - Obesity
  - Visibility and safety impaired by glare
- Review existing literature on effects of ALAN on flora and fauna
  - Birds, Mammals, Amphibians, Insects including pollinators and fireflies, Fish, Coral, Plants
  - Migration and habitat
  - Ecological Function
  - Reproduction
  - Immune Responses
  - Biodiversity
- Propose recommended guidelines for regulation of ALAN (for BioEnv only, not astronomy etc.):
  - Illumination levels and total luminous flux
  - Shielding, uplighting, and glare
  - Directionality of light
  - Spectral distribution of light sources
- …. including applicable zones, e.g. Urban, Suburban, Rural, Pristine wilderness areas.
- Propose targets for reduction of light pollution (for BioEnv only, not astronomy etc.)
- Coordinate with other Working Groups e.g. Optical Astronomy for proposed guidelines
- Coordinate with International Union for Conservation of Nature

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Presenters

1. Dr. Luc Schlangen (Eindhoven University of Technology, NL)
   The effect of light on circadian rhythms and melatonin
2. Dr. Mario Motta (North Shore Medical Center/Tufts Medical School, US)
   Human health effects of light at night
3. Dr. Sibylle Shroer (Leibniz-Institute of Freshwater Ecology and Inland Fisheries, DE)
   Effects of anthropogenic light at night on flora and fauna
4. Dr. Annika Jägerbrand (Halmstad University, SE)
   Protecting humans and ecosystems from anthropogenic light at night

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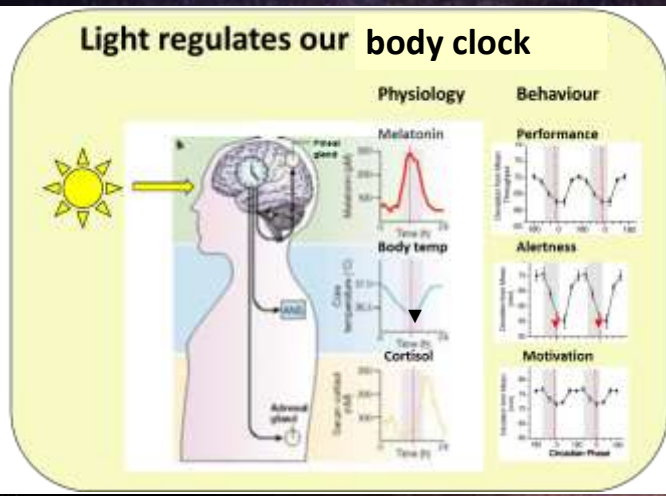
Circadian rhythms, melatonin and light



" light affects our circadian rhythms more powerfully than any drug "

Chuck Czeisler (2013) Nature

DARK & QUIET SKIES

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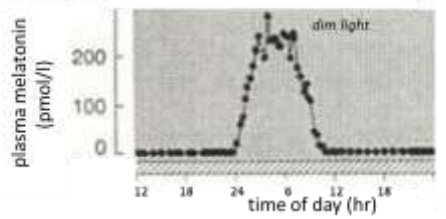
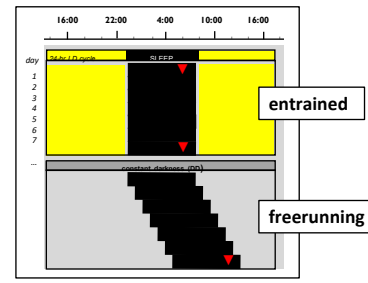
Light regulates the circadian rhythm:
melatonin and the sleep-wake cycle

Melatonin

- ✔ peaks during (habitual) night
- ✔ supports night time behaviour:
  facilitates sleep initiation & sleep consolidation
- ✔ not detectable/low during day (even in darkness!)
- ✔ marker of body clock:
  usual bedtime is about 2 hrs after melatonin onset (in dim light)

-> **constant darkness: freerunning** (endogenous period is ~24.2 h in humans)





Dijk et al. (1997) J Physiol (Lond)
Duffy & Wright (2005) J Biol Rhythms
Carskadon et al. (1999) Neurosci.Lett.
Kelly et al. (1999) J.Biol.Rhythms
Czeisler et al. (1999) Science
Brown et al. (2005) PLoS.Biol.

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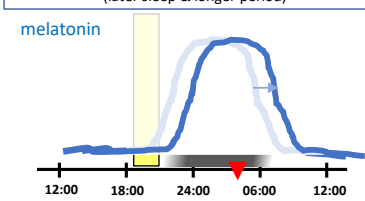
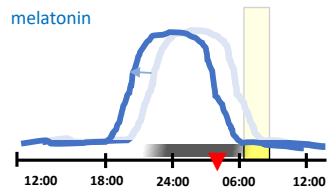
Light regulates the circadian rhythm:
light regulates timing and amount of melatonin secretion

Evening light delays melatonin peak
(later sleep & longer period)

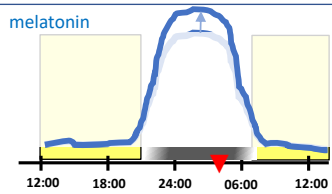


Morning light advances melatonin
(earlier sleep & shorter period)



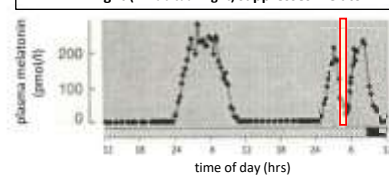
Khalsa et al. (2003)
J Physiol

Daytime light strengthens melatonin secretion



Mishima et al. (2001)
J Clin Edocrinol Metab

Light (in habitual night) suppresses melatonin



Lewy et al. (1980)
Science

Czeisler et al. (1995)
New Eng. J. Medicine

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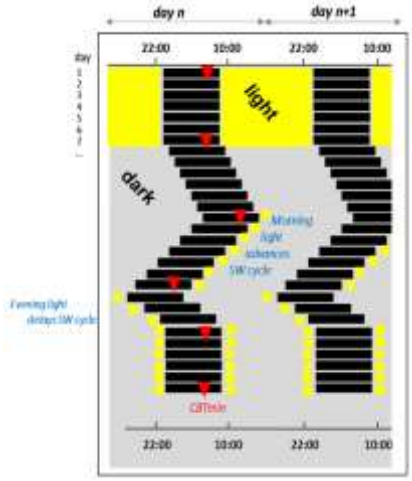
Light regulates the sleep-wake cycle



Light adjusts timing of sleep-wake cycle:

- without light our sleep timing shifts slowly:
  - natural drift to become later (τ =24.2h)
- light (re) aligns the body clock
  - morning light advances sleep timing
  - evening light delays sleep timing
- light resets the circadian rhythm to 24 hrs

Luc Schlangen, NL

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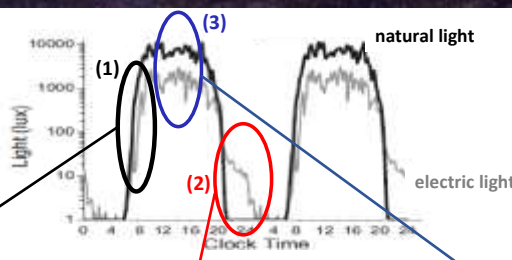
Human Light Environment

with electric light vs. natural light only



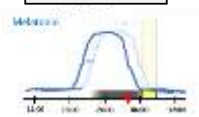
Wright et al. (2013) Curr Biol
Stothard et al. (2017) Curr Biol

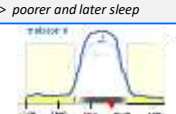
Electric light creates more "eveningness"

(1) Less morning light:
- less early sleep-wake cycle
  -> later sleep

(2) **More evening light:**
- more melatonin suppression
- later sleep-wake cycle
  -> poorer and later sleep

(3) **Less daytime light:**
- less melatonin @ night
- more sensitive for evening light
  -> poorer and later sleep





Hebert et al. (2002) J Pineal Res
Smith et al. (2004) J Clin Endocrin Metab
Zeitzer et al. (2011) Sleep Med
Chang et al. (2013) Sleep
te Kulve et al. (2019) Sci Rep

Luc Schlangen, NL

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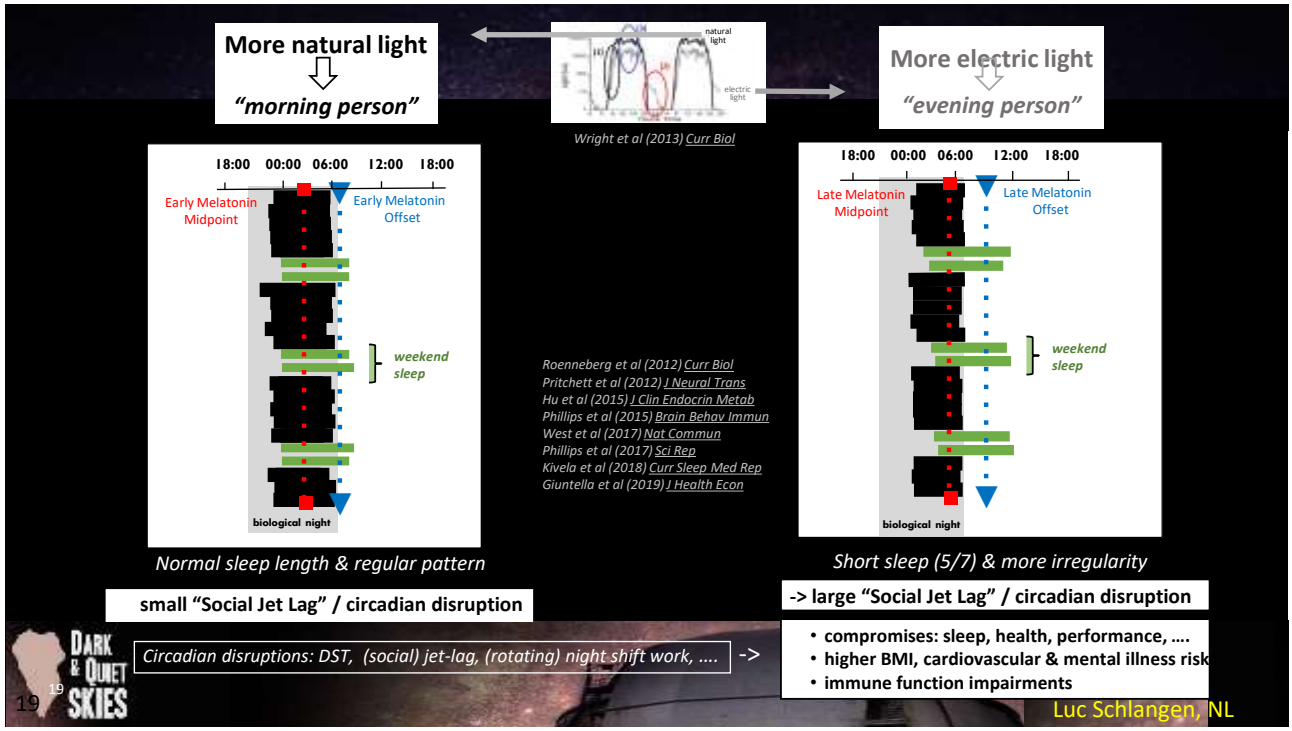

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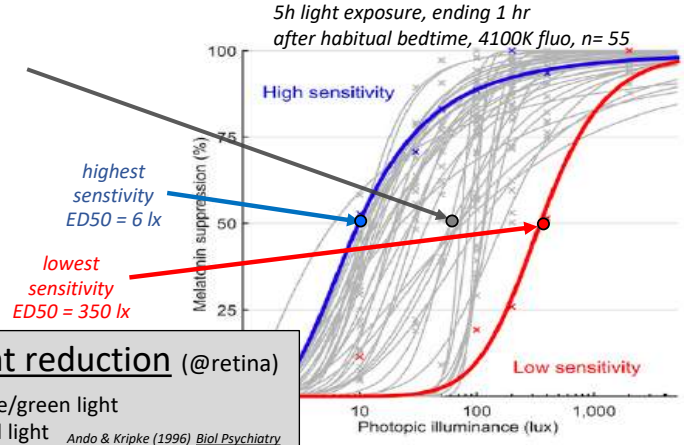
melatonin suppression by light:
high sensitivity and large interindividual variability

- Group mean: 50% melatonin suppression (ED50) at 25 lx
- ED50 has high interindividual variability (factor ~60)



Phillips et al (2017) PNAS

Closing eyelids: strong light reduction (@retina)

attenuation: > 99.5% for blue/green light
> 90% for red light

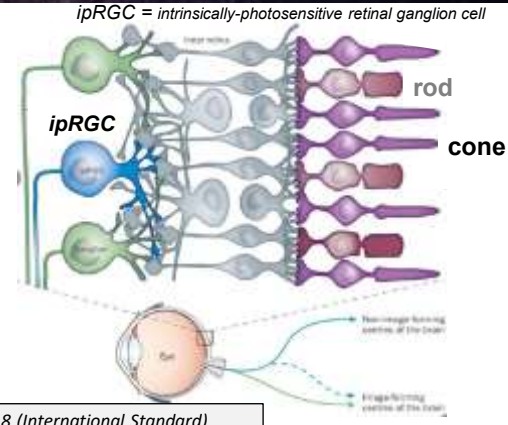
Ando & Kripke (1996) Biol Psychiatry
Bierman et al (2011) J Biomed Opt

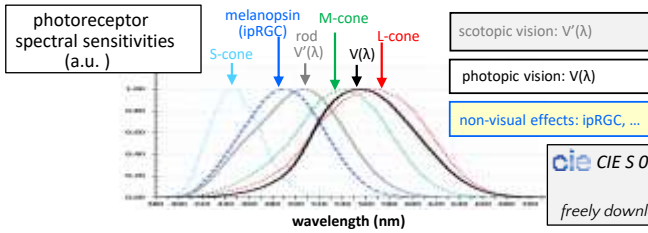
20

The human eye has five retinal photoreceptors

- Rods enable night vision
- Red-, Green- and Blue-cones drive colour vision (L-M-S-cones)
- Melanopsin-based (*ipRGC*) photoreceptor: strongly drives light's non-visual

ipRGC = intrinsically-photosensitive retinal ganglion cell





CIE S 026:2018 (International Standard)
DOI: 10.25039/S026.2018
freely downloadable (CIE website): CIE S 026 Toolbox

Lucas et al. (2014) Trends Neurosci.
Brown (2020) J Pineal Res

Luc Schlangen, NL

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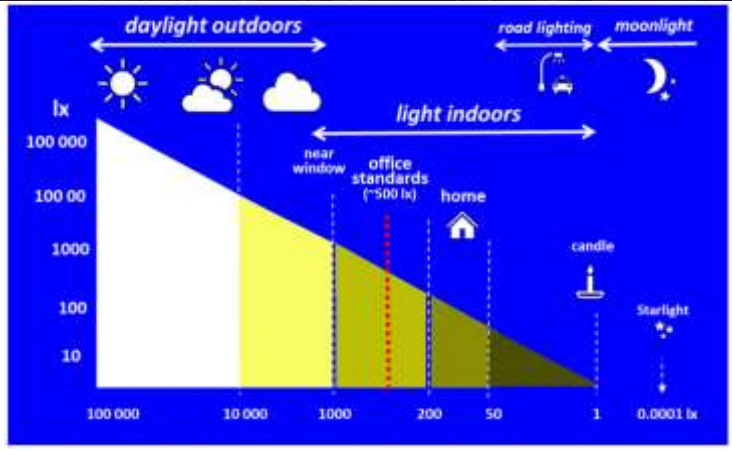
How much light do we get?



How much light do we need?

Luc Schlangen, NL

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Recommending proper light at the proper time

CIE position statement, Oct 2nd 2019; downloadable via
http://www.cie.co.at/publications/

Initial guidance on how to manipulate the human lighting environment for non-visual responses:

✔ **Brighter days**: high melanopsin activation

Supports alertness, the circadian rhythm and a good night's sleep

✔ **Dimmer nights:** low melanopsin activation (in evening & night)

Facilitates sleep initiation and sleep consolidation

LECTURE SUMMARY & CONCLUSION

Reduce circadian disruption: *use light wisely*

		humans	***bio-environment***
circadian disruption:	is electric light a symptom?	Yes ✔ light=sympto	✘
	is electric light the root cause ?	Yes & No lifestyle+light=cause	Yes ✔ light = cause

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AMA statement on street lighting
June, 2016 (Mario Motta, Stevens, Brainard, Longcore)

- The very aggressive marketing of “white” LED street lights throughout the country has taken no account of ecological impact or human health.
- Nationwide, little or no direct citizen input to utility’s plans for municipal LED retrofits.
- In the absence of any guidance from the industry, DOE, or IES, the AMA stepped up to say “slow down”.
- AMA said LED technology is a good thing, properly done.
  - energy efficiency
  - conserve fossil fuels

Industry involvement is sought to provide simple guidelines for local communities to become actively engaged with the streetlight selection process and to inform citizenry as to the least intrusive LED bulb they can obtain for their own use

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Glare Sensation: Discomfort and Disability

- LEDs: “intense point sources that cause visual discomfort when viewed by the human eye, especially by older drivers. This effect is magnified by higher color temperature LEDs, because blue light scatters more within the human eye, leading to increased disability glare”.
  - **Average LED: approx. 125 millions nits**
  - **Human tolerance: 50,000 nits**
- Sweater-Hickcox K, Narendran N, Bullough JD, Freyssinier JP. (2013) - **Effect of different coloured luminous surrounds on LED discomfort glare perception.** Lighting Research Technology. 3;45(4):464-75. http://lrt.sagepub.com/content/45/4/464. April 5, 2016. Vos JJ.
- **Vos JJ (2003) On the cause of disability glare and its dependence on glare angle, age and ocular pigmentation**. Clin Exp Optom. 86(6):363-70.
- E.J., PIRENNE M.H. (1954) **THE ABSOLUTE SENSITIVITY AND FUNCTIONAL STABILITY OF THE HUMAN EYE** Physiol. ([1]954) [12]3, 417-442

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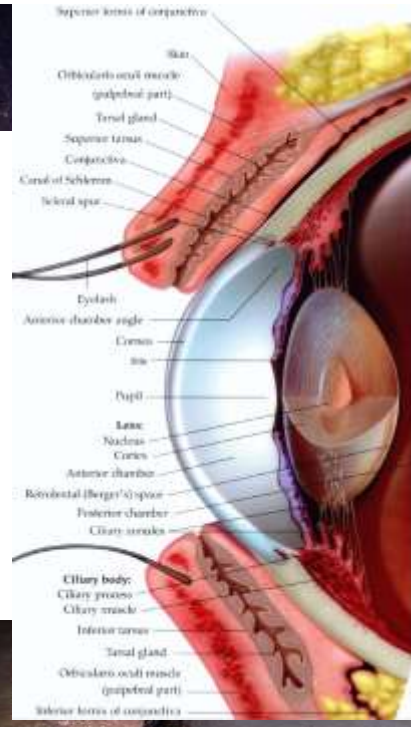

Mario Motta, US

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Glare: Disability and discomfort

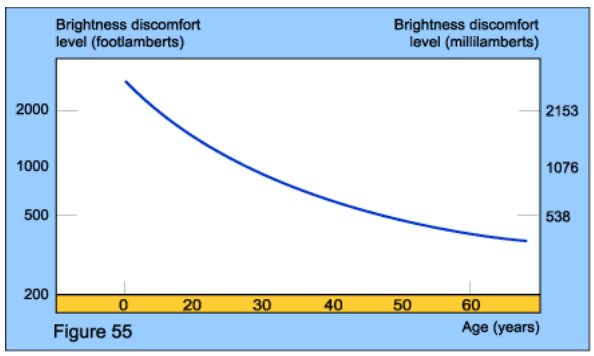
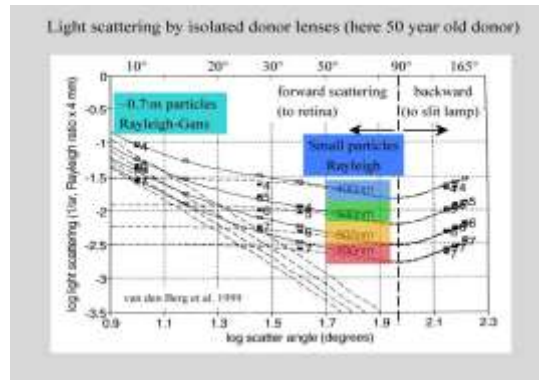


Figure 55



Mario Motta, US

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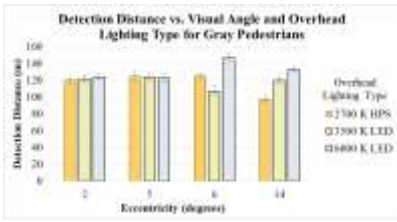
High Speed Roadway Eccentricity and Light Type

- Light source impact was minimal on-axis roadway detection
- Mesopic Effects evident at 14 degrees, detection distance increases with color temperature
  - Not significant at high speed with loss of peripheral function.



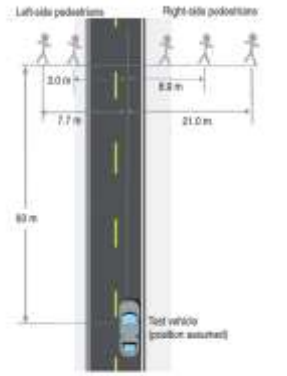
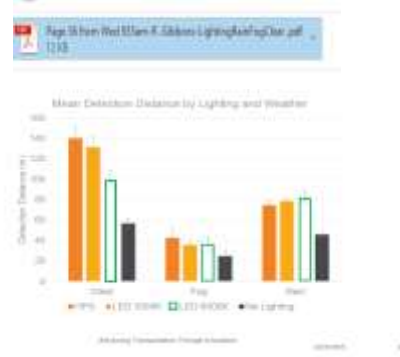


Figure 2. Pedestrian positions and offsets from the roadway



Alan Lewis, IES

Mario Motta, US

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Breast Cancer and 'Light-at-Night'

- Theory: light-at-night alters hormones, increasing risk, and thereby explains some of the high risk in industrialized societies
- Predictions (i.e., 'hypothèses'):
  - shift workers at higher risk
  - blind women at lower risk (including twins)
  - lighted bedrooms at night increase risk
  - long sleep lowers risk

Mario Motta, US

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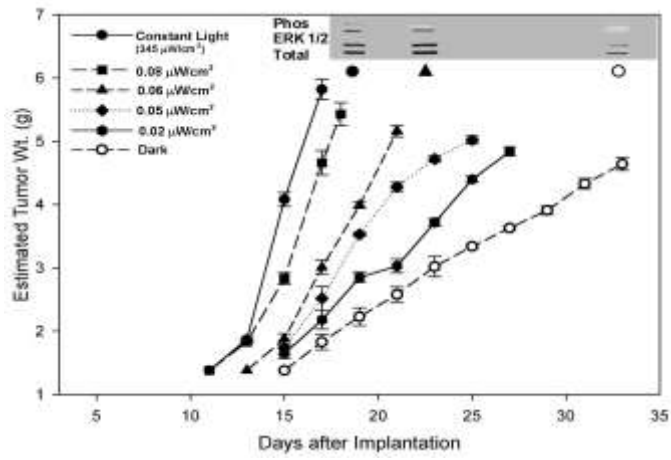
The Circadian Clock: clock-controlled genes

- Cell cycle regulation crucial to normal and malignant cell growth (e.g., cyclin D1)
- 5-10% of all mammalian genes are clock controlled.
- Among these are genes for the key regulators of cell-cycle progression and apoptosis (e.g., cyclins and caspases).
- Light-dark cycle strongest circadian cue
- *Per3 variant and breast cancer in young women - Yong Zhu et al. Cancer Epidemiol Biomark Prev, 14:268, 2005*

GROWTH RATES vs. LIGHT INTENSITY FOR HUMAN BREAST CANCER XENOGRAFTS



Blask et al, 2003

- Comprehensive Longitudinal study 1989 – 2013
- 110K women NURSES STUDY

- Women exposed to the highest levels of outdoor light at night—those in the top fifth—had an estimated **14% increased risk of breast cancer** during the study period, as compared with women in the bottom fifth of exposure…As levels of outdoor light at night increased, so did breast cancer rates.- https://www.hsph.harvard.edu/news/press-releases/outdoor-light-night-breast-cancer/

- The study found a direct relationship between a woman's neighborhood nighttime light level before diagnosis and her later risk of developing breast cancer: The higher the light level, the higher the risk. These findings held even when taking into account many other factors that may also affect risk such as age, number of children, weight, use of hormone medications and a long list of additional potential confounders.

  Peter James, Kimberly A. Bertrand, Jaime E. Hart, Eva Schernhammer, Rulla M. Tamimi, Francine Laden,Outdoor **(2017) Light at Night and Breast Cancer Incidence in the Nurses' Health Study II,"** *Environmental Health Perspectives*, August doi: 10.1289/EHP935

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Evaluating the Association between Artificial Light-at-Night Exposure and Breast and Prostate Cancer Risk in Spain (MCC-Spain Study), Environmental Health Perspectives, April 2018

Qian Xiao, Peter James, Patrick Breheny, Peng Jia, Yikyung Park, Dong Zhang, Jared A. Fisher, Mary H. Ward, Rena R. Jones. Outdoor light at night and postmenopausal breast cancer risk in the NIH-AARP diet and health study. International Journal of Cancer, 2020; USA

Kloog, I., A. Haim, R. G. Stevens, M. Barchana, and B. A. Portnov. 2008. Light at night co-distributes with incident breast but not lung cancer in the female population of Israel. Chronobiology International 25:65–81.

Kloog, I., A. Haim, and B. A. Portnov. 2009. Using kernel density function as an urban analysis tool: investigating the association between nightlight exposure and the incidence of breast cancer in Haifa, Israel. Computers, Environment and Urban Systems 33:55–63.

Kloog, I., R. G. Stevens, A. Haim, and B. A. Portnov. 2010. Nighttime light level co-distributes with breast cancer incidence worldwide. Cancer Causes & Control 21:2059–2068.

Li Q, Zheng T, Holford TR, Boyle P, Zhang Y, Dai M. Light at night and breast cancer: results from a population-based case-control study in Connecticut, USA. Cancer Causes Control. 2010;21:2281-2285.

Rybnikova N, Haim A, Portnov BA. 2015. Artificial light at night (ALAN) and breast cancer incidence worldwide: A revisit of earlier findings with analysis of current trends. Chronobiol Int 32(6):757–773,

Keshet-Sitton A, Or-Chen K, Huber E, Haim A. 2016a. Illuminating a risk for breast cancer: A preliminary ecological study on the association between streetlight and breast cancer. Integr Cancer Ther,

Anbalagan M, Dauchy RT, Xiang S, et al. Disruption of the circadian melatonin signal by dim light at night promotes bone-lytic breast cancer metastases. Presented at: ENDO 2019; March 23-26, 2019

Kim YJ, Lee E, Lee HS, Kim M, Park MS. 2015. High prevalence of breast cancer in light polluted areas in urban and rural regions of South Korea: An ecologic study on the treatment prevalence of female cancers based on National Health Insurance data. Chronobiol Int 32(5):657–667,

One negative study from Canada has been published (Ritonja, 2020), possibly explained by higher use of blackout shades for northern summer sleeping.*"Outdoor light at night at residences and breast cancer risk in Canada." European Journal of Epidemiology (2020):1-11*

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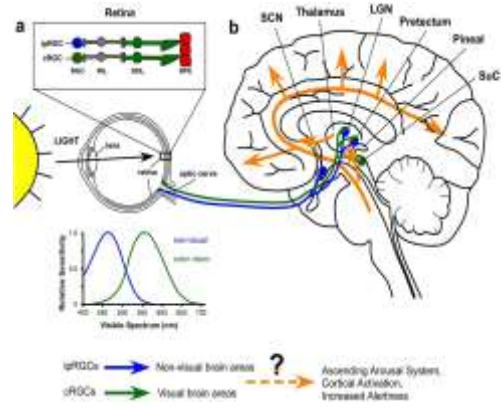
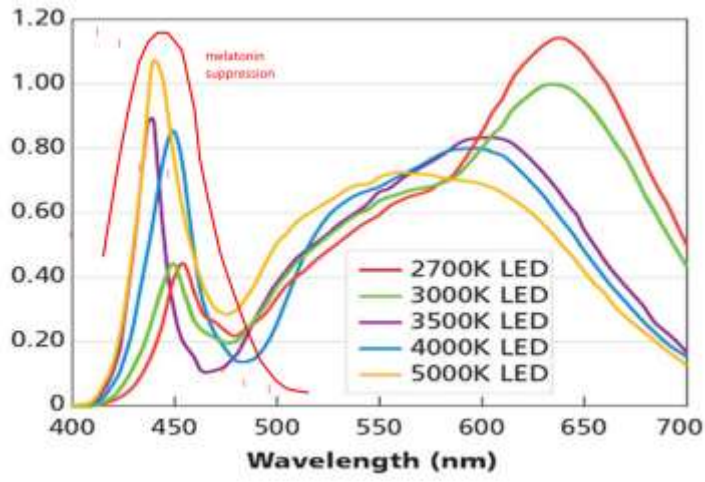
Blue-Rich Light: A Health Risk?

- Blue light suppresses melatonin, a hormone that influences circadian rhythms.*
  - Even dim light can interfere with a person's circadian rhythm and melatonin secretion.
- Eyes exposed to blue light experience decrease in visual acuity since blue light scatters in eye.*
- May disrupt circadian rhythm of wildlife.



*http://www.health.harvard.edu/staying-healthy/blue-light-has-a-dark-side

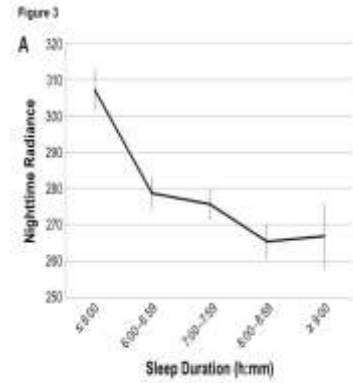


Sleep Research

- Shorter sleep duration
- delayed bedtime and wake up time
- increased daytime sleepiness increased
- likelihood of having a diagnostic profile congruent with a circadian rhythm disorder

CONCLUSIONS:

"nighttime lights in our streets and cities are clearly linked with modifications in human sleep behaviors and also impinge on the daytime functioning of individuals living in areas with greater ONL".



Ohayon MM et.al(2016) **Artificial Outdoor Nighttime Lights Associated with Altered Sleep Behavior in the American General Population** SLEEP Jun;39(6):1311-20 doi: 10.5665/sleep/5860

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Circadian Disruption

- Short-term effects on sleep and cognition are no longer in dispute.
- Evidence mounting for:
  - cancer – breast and prostate, maybe others
  - obesity – altered leptin and ghrelin
  - diabetes – glucose metabolism
  - mood disorders – depression, bipolar

Stevens, Blask, Brainard, Hansen, et al. EHP, Sept., 2007

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New York City complains, 4000K

Some NYers Are Struggling To Adapt To Harsh, 'Authoritarian' LED Streetlights

BY NATHAN TEMPEY IN NEWS ON FEB 2, 2017 12:42 PM

some cities now taking down 4000K lighting
eg Seattle

DARK & QUIET SKIES

Mario Motta, US

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Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting, 2012 and 2016,

CSAPH Rep. 4-A-12. "Light Pollution: Adverse Health Effects of Nighttime Lighting". Action of the AMA House of Delegates 2012 Annual Meeting: Council on Science and Public Health Report 4 Recommendations Adopted as Amended (June 20, 2012), and Remainder of Report filed.

2016 CONCLUSIONS:

- That our American Medical Association (AMA) support the proper conversion to community-based Light Emitting Diode (LED) lighting, which reduces energy consumption and decreases the use of fossil fuels. (New HOD Policy)
- That our AMA encourage minimizing and controlling blue-rich environmental lighting by using the lowest emission of blue light possible to reduce glare. (New HOD Policy)
- **That our AMA encourage the use of 3000K or lower lighting for outdoor installations such as roadways. All LED lighting should be properly shielded to minimize glare and detrimental human and environmental effects, and consideration should be given to utilize the ability of LED lighting to be dimmed for off-peak time periods. (New HOD Policy)**

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Mario Motta, US

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Night as living space

- Vertebrates 28%
- Invertebrates 64%
- Bats 100%
- Non flying mammals 63%
- Amphibia 93%
- Insects 49%

Hölker et al. 2010 Trends Ecol. Evol.

Who is afraid of the night?

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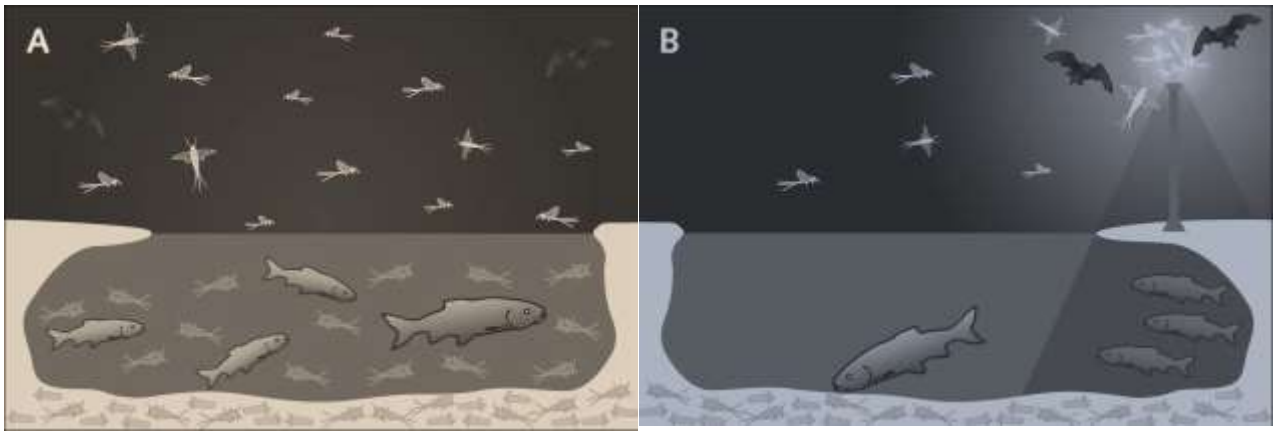
Habitat use and migration



Perkin et al. 2011; 2014

Barrier effects

Fishes

Lowe 1952; Cullen & McCarthy 2000; Nightingale et al. 2006

Bats

Voigt et al. 2017; Spoelstra et al. 2017

Birds

van Doren et al. 2019; La Sorte et al. 2017

Insects

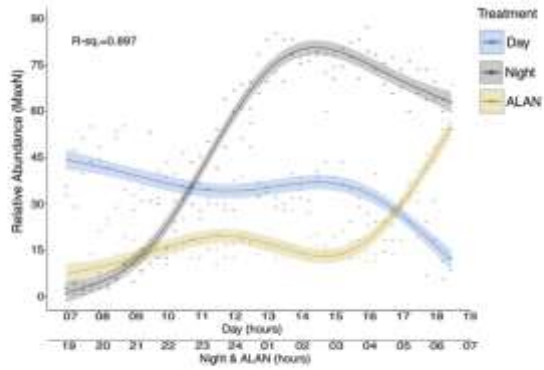
Szaz et al. 2015; Henn et al. 2014; Perkin et al. 2014

Amphibia

van Grunsven et al. 2018

Photo: K. & J. Grewe

Occurrence of small and medium size fish



Bolton et al. 2017 Sci. Total Environ. 576,1–9.

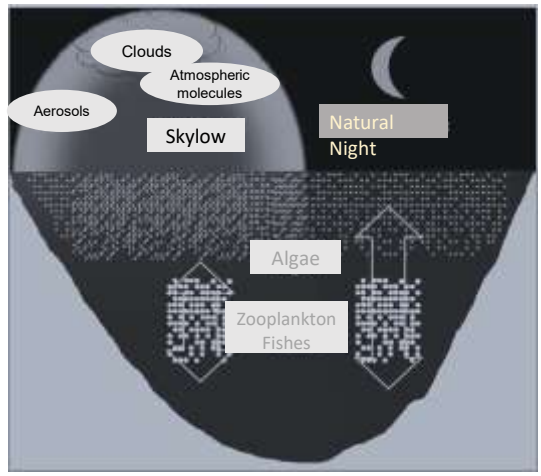
45

Migration routes of birds

Cabrera-Cruz et al. 2018 Scientific Reports 8: 3261.

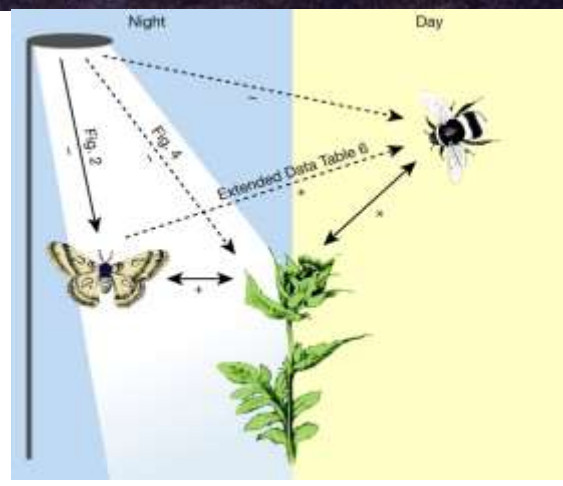
46

Ecological functions - water clarification



Moore et al. (2000) Int. Ver.Theor. Angew. Limnol. Verhandl.
Image: Hölker

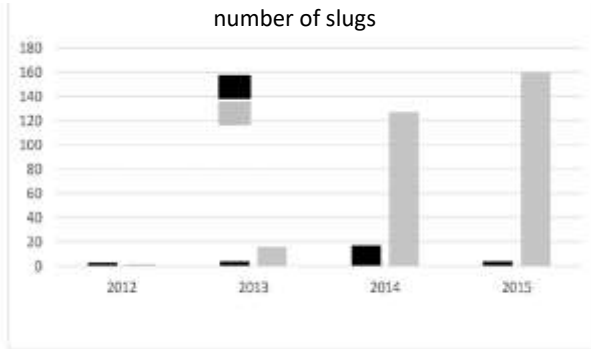
Ecological functions - pollination



Knop et al. 2017 Nature

Ecological functions - scavengers

Altered occurrence and food consumption



Davies et al. 2012; Manfrin et al.2018

van Grunsven et al. 2018

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Ecological function - food sources

Vegetation: reduced seed dispersal in illuminated landscapes

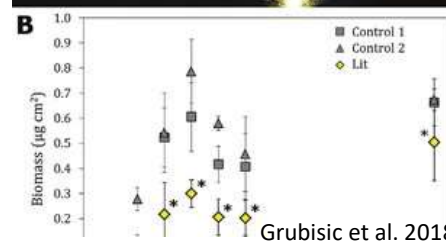
Lewanzik & Voigt et al. 2014

Insects and predator relations → pollination

Cravens et al. 2017, Manfrin et al 2018

Altered periphyton communities in freshwater systems

Grubisic et al. 2017, 2018, Poulin et al. 2014

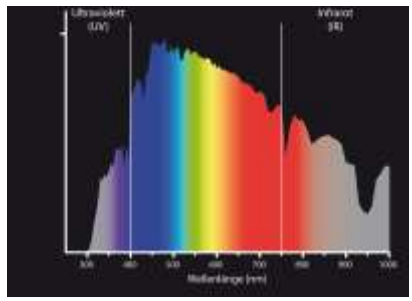


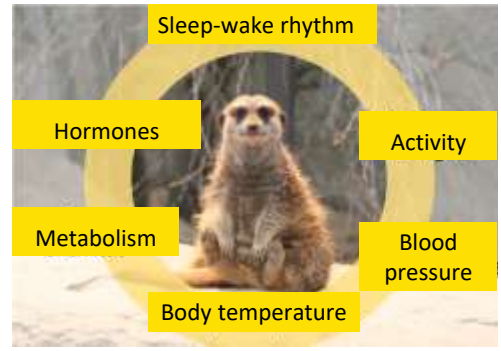
Grubisic et al. 2018

50

Zeitgeber light

460 nm





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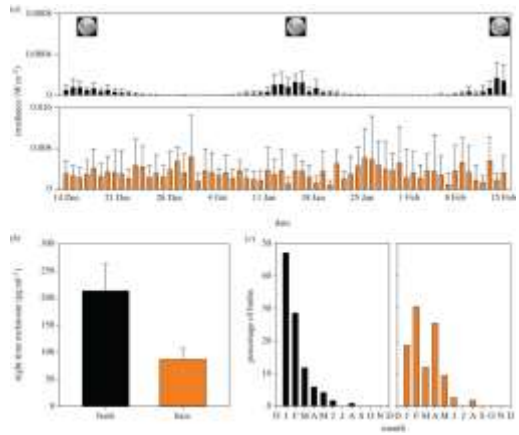
Reproduction



Robert et al. 2015 Proc. R. Soc. B. 282. 20151745

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Timing and quantity of reproduction

Mammals: expanded timing of birth
Le Tallec et al. 2013; Robert et al. 2015

Fishes: reduced follicle-stimulating and luteinizing hormone mRNA expression
Brüning et al. 2018

Birds: 0.3 lx can move reproductive seasonality of songbirds by a month and cause irregular molt progression
Dominoni et al. 2013

Insects: reduced pheromone quality and quantity in moths
van Geffen et al. 2014

Plants: early bud burst, unrelated to temperature
ffrench-Constant et al. 2016

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Immune responses

Mammals: impact on circadian rhythms, physiological functions and immune response
Bedrosian et al. 2011, Fonken et al. 2013

Birds: higher probability of malaria infection and increased bactericidal activity
Quyang et al. 2017; Saini et al. 2019

Plants: accumulation of superoxide radicals, triggered stress responses
Nitschke et al. 2016; Kwak et al. 2017; Meravi et al. 2020


Photo: Bernhard Friess

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Effects of ALAN on Flora and Fauna

Manifold (most) organisms
of various levels in ecosystems and different functions

- Habitat use and migration
- Ecological functions
- Reproduction
- Immune response

- **Conclusion: ALAN is a risk factor for biodiversity**

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Awareness and environmental protection gaps

Environmental protection efforts	vs	adverse effects of ALAN
The protection of habitats is spatially limited and would require an individual impact assessment.		Assessments for lighting systems are so far not subject to approval procedures.
Most provisions require either a significant increase in killing risks or a decline of a local population.		ALAN reduces fitness of organisms and ecosystems, it mostly does not trigger stress or direct mortality.
Species and landscapes without special protection status are in most cases not protected by environmental regulations.		ALAN affects manifold species and landscapes without special protection status.

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Conclusions

Numerous studies indicate ALAN as a major biodiversity risk

Environmental protection regulation do not consider ALAN sufficiently

Existing regulations can not cover the various effects of ALAN

More awareness about the adverse effects of ALAN is needed

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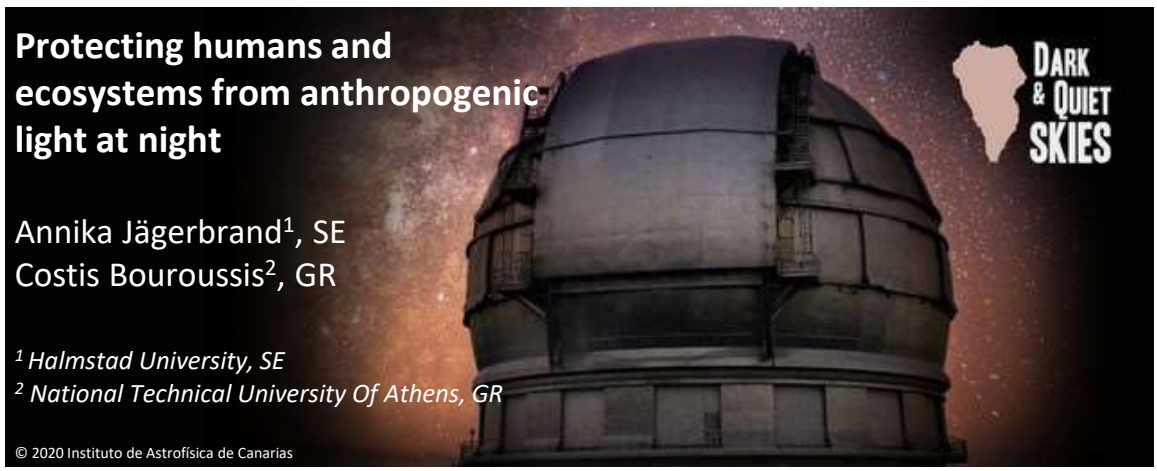
Dark and Quiet Skies for Science and Society



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Protecting humans and ecosystems from anthropogenic light at night
Recommendations from the Bio-Environnement WG

General recommendations should enable

- Regulations for environmentally friendly lighting for countries, regions, municipalities, and communities.
- Implementation of the lighting scheme: The right light, at the right place, at the right amount, for the right duration."
- Coverage of most of the environmental aspects of obtrusive light.

Source: Costis Bouroussis

Annika Jägerbrand, SE
Costis Bouroussis, GR

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Identified and prioritized aspects targeting towards environmental friendly lighting

1	Areas to be illuminated	7	Glare control in roads and outdoor working places
2	Definition of ALAN-free areas and ecosystems	8	Spectral content of the emitted light
3	Illumination levels for outdoor areas	9	Modulated light in color façades and illuminated signs
4	Lighting control and adaptive lighting	10	Light measurements, obtrusive light and skyglow monitoring
5	Light distribution and orientation	11	Urgent research topics
6	Intrusive light	12	Strategic targets

Annika Jägerbrand, SE
Costis Bouroussis, GR

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1. Areas to be illuminated

- Governing bodies should define the decision criteria whether an area must or is allowed to be illuminated, the selected illumination classes, etc.
- Master planning should include strategies for maintaining dark areas dark and reducing lighting in currently over-illuminated areas
- Zoning system for urban and environmental areas with specific regulations (e.g. CIE 150)
- Monitoring of ALAN using commonly agreed and scientifically correct criteria and metrics

Source: Wikipedia

2. Definition of ALAN-free areas and ecosystems

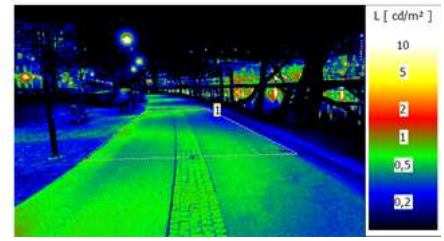
- Environmental sensitive areas, wilderness areas, ecosystems and other relevant areas can be characterized as ALAN-free zones (even inside cities).
- The zoning system defined by the CIE 150:2017 (Zones* E0 and E1) can initially be adopted for these areas.
- Further development of outdoor lighting in ALAN-free zones should be prohibited or restricted by national legislation.

Source: Annika Jägerbrand

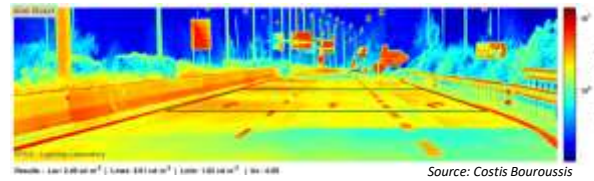
**E0: Intrinsically dark area (e.g. UNESCO Starlight Reserves, IDA Dark Sky Parks, Major optical observatories)*

3. Illumination levels for outdoor areas

- For all areas the appropriate lighting class should be selected according to the relevant guideline/standard (e.g. CIE 115 for road lighting).
- Over-illumination should be avoided.
- The maintained average illumination levels shall not exceed the targeted value.



Source: Annika Jägerbrand



Source: Costis Bouroussis

4. Lighting control and adaptive lighting

Lighting control

- Deliver the right amount of light for the right amount of time.
- New and renovated installations should incorporate control of luminous flux.
- Lighting control systems should be added to existing installations when feasible.
- Control during curfew hours (predefined or adaptively).
- Control on spectral distribution of emitted light.
- Lighting reduced to absolute minimum level when no users are present and adapted to traffic flow.
- Switching off is recommended mainly for rural areas and certain urban areas (e.g. shopping centres, sport centres, industrial areas not active at night).

Source: Costis Bouroussis

5. Light distribution and orientation

- Efficient and environmentally conscious lighting design is strongly recommended (e.g. avoid spill light, avoid waste of luminous flux, etc.).
- Luminaires should be designed efficiently (optics, lenses, accessories).
- Light should be distributed only to the targeted area.
- Appropriate lighting equipment should be used for each application.
- Temporary lighting should avoid negative environmental impact.
- Outdoor lighting should be designed in a way to disturb ecosystems as little as possible (e.g. orientation, polarization, intrusion to habitats, etc.).

Source: Annika Jägerbrand

Source: Gavriil Papadiotis

6. Intrusive light

Light entering indoor living areas should be minimized by using the following techniques

- Efficient lighting design near residential buildings (mounting height, shielding, light distribution).
- Adaptive control of lighting levels during curfew hours.
- Minimization of façade lighting and colorful and dynamic lighting and switching off after curfew hours.
- Control of obtrusive light from distant light sources of high intensity by proper lighting design and luminaire shielding.

Source: Costis Bouroussis

7. Glare control in roads and outdoor areas

- Glare levels should be controlled and reduced acc. to recommendations (i.e. CIE 115 for road lighting, CIE S 015 and ISO/CIE 8995-3 for outdoor areas, etc.).
- Relevant glare control should be applied for colourful and dynamic outdoor lighting (*ongoing work - CIE TC4-58*).

Source: Annika Jägerbrand

Source: Creative commons

Source: Costis Bouroussis

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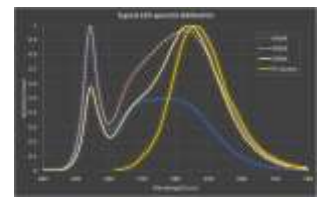
8. Spectral content of the emitted light

General recommendations

- Rural and residential areas should be illuminated with sources having the minimum amount of blue emission possible (i.e. <3000K)
- Tunable white luminaires (e.g. 2200K-3000K) with variable luminous flux, for residential and other urban areas (commercial districts, parks, squares) when warm white is need.
- White light (4000K) only for sports lighting and similar applications
- Environmentally sensitive areas should be illuminated only with sources with minimal spectral content in blue (e.g. PC amber LED).



Source: Costis Bouroussis

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9. Modulated light in color façades and illuminated signs

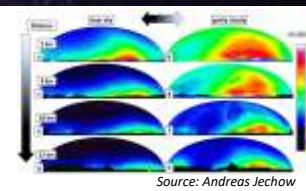
- Color façades, LED billboards, etc. are strongly discouraged.
- Reduce of luminous intensity to reduce glare and disturbance on species
- Illuminated façades and media advertisements should be switched off after curfew.
- The modulation frequency should be minimized to avoid disturbance to humans and natural species.

Source: Costis Bouroussis

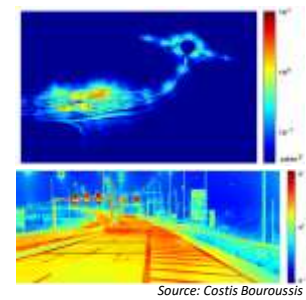
10. Light measurements, obtrusive light and skyglow monitoring

Obtrusive light and sky glow should be carefully assessed and monitored via:

- Measurements and monitoring.
- Dedicated assessment for urban, suburban, rural and ecological reserves
- Verification of lighting installations to avoid over-illumination or bad practices.
- Obtrusive light and sky glow measurements should be implemented in national or local regulations.
- Mitigation and possibly restoration measures should be applied when scientifically justified thresholds are exceeded.



Source: Andreas Jechow



Source: Costis Bouroussis

11. Urgent research topics

Interdisciplinary research among lighting, medical, and environmental research communities is urgently needed in the following fields and should be encouraged.

- Effects of ALAN on human health, on flora and fauna, on visibility levels and public safety
- Identify thresholds for impacts of ALAN on humans and natural species
- Measurement, monitoring and impact assessment of ecological effects of ALAN
- Studies on impact of new technologies including adaptive lighting, and other characteristics of light such as light modulation (flicker) and glare.

Studies should use the correct and appropriate light quantities and metrics, which in many cases are not properly used

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12. Strategic targets

- Establish specific regulations for outdoor lighting within each country.
- Establish an accreditation system for outdoor lighting installations.
- Ensure that new installations and renovations follow the relevant regulations.
- Review and revise lighting legislation to consider negative environmental effects of ALAN.
- Review and update the requirements for illuminating roads and highways.
- Minimize the negative effect of outdoor lighting on human health and natural species.
- Restore and protect affected existing ecosystems by implementing environmentally conscious lighting technology.
- Promote lighting education to research communities new to studying the influence of light on humans and biological systems.
- Develop a scale of ecological classes of dark skies.

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Dark and Quiet Skies for Science and Society: Draft Reports

Five Draft Reports are available and open for comments until 16 October

- Download them from http://bit.ly/DQS_reports
- Please comment on recommendations at http://bit.ly/DQS_comment

If you registered for today's Workshop then you have received the links on Thursday in an email from UNOOSA-Events@un.org and on Friday in an email from DQSkies@iac.es

Not received even though you had registered? Please email UNOOSA-Events@un.org

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Thank you!

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