

**IGB**

Leibniz-Institute of  
Freshwater Ecology  
and Inland Fisheries



**STARS4ALL**

## Sustainable outdoor lighting

And how light pollution is affecting our ecosystems



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*Department of Ecohydrology*

**Belektro, Berlin 6<sup>th</sup> of November 2018**

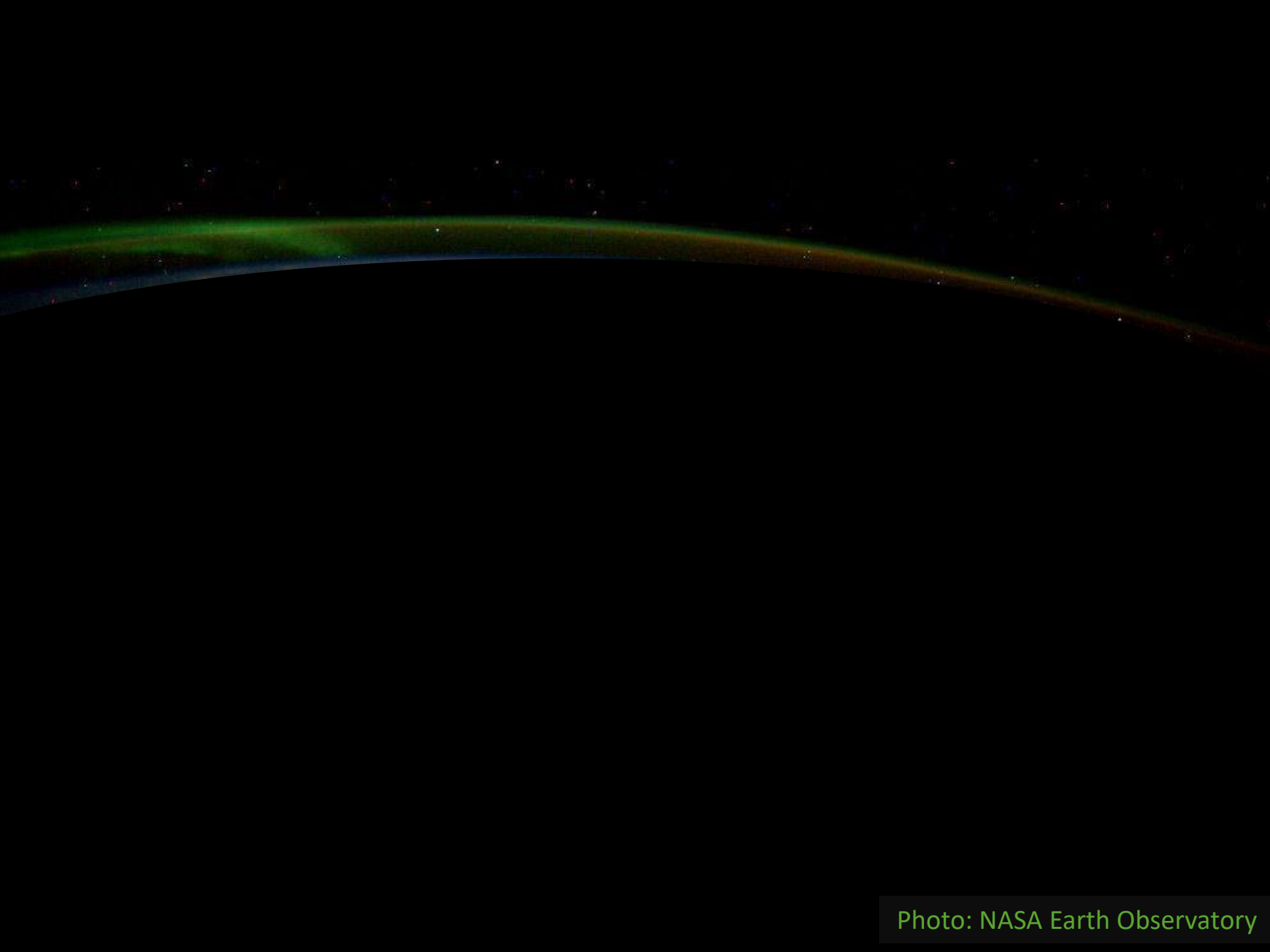
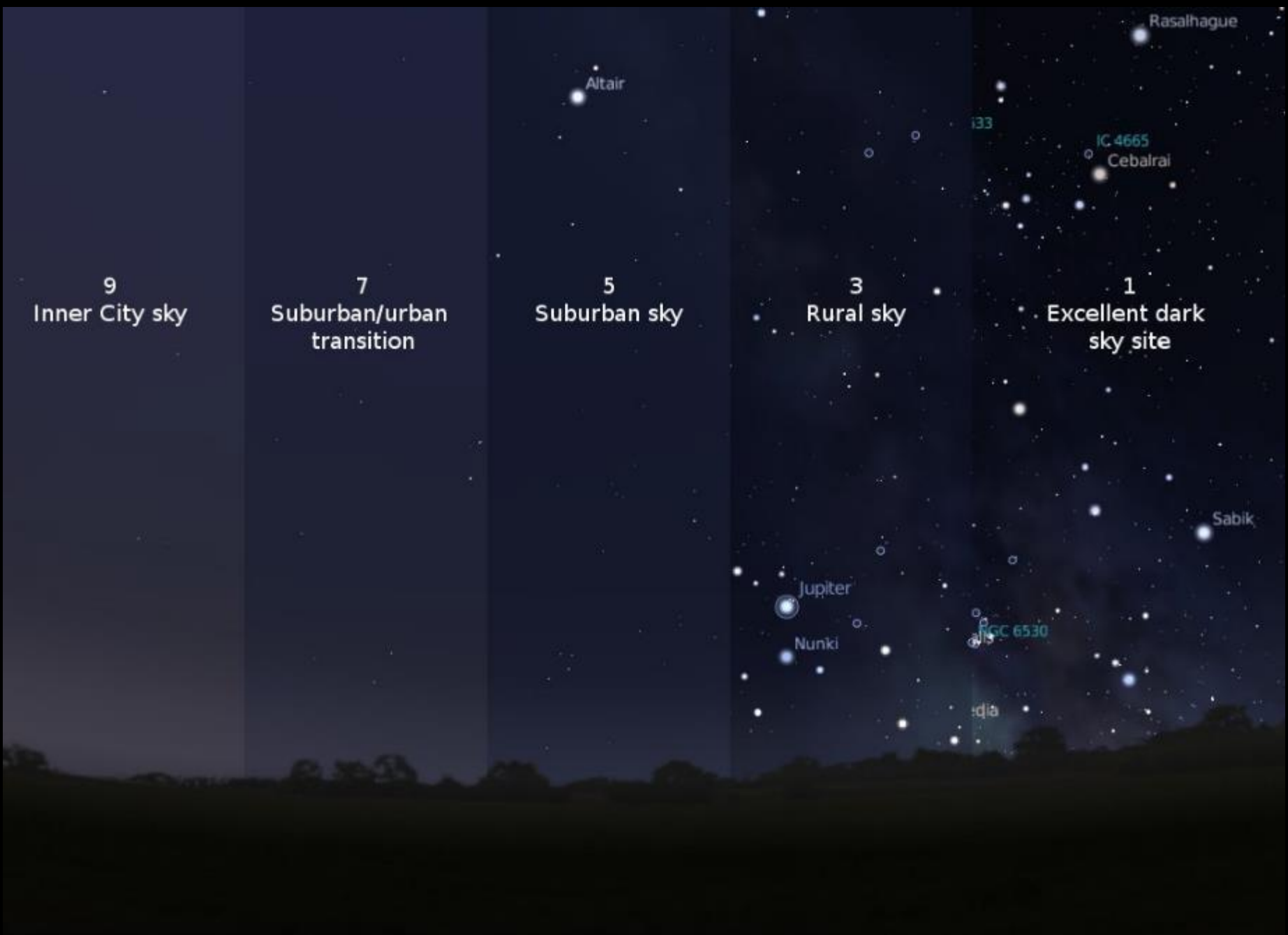


Photo: NASA Earth Observatory



Foto: NASA Earth Observatory



9  
Inner City sky

7  
Suburban/urban  
transition

5  
Suburban sky

3  
Rural sky

1  
Excellent dark  
sky site

Altair

Rasalhague

IC 33

IC 4665  
Cebalrai

Sabik

Jupiter

Nunki

PGC 6530

Idia

# Red is the new black

Kyba et al. Mon. Not. R. Astron. Soc. (2012)



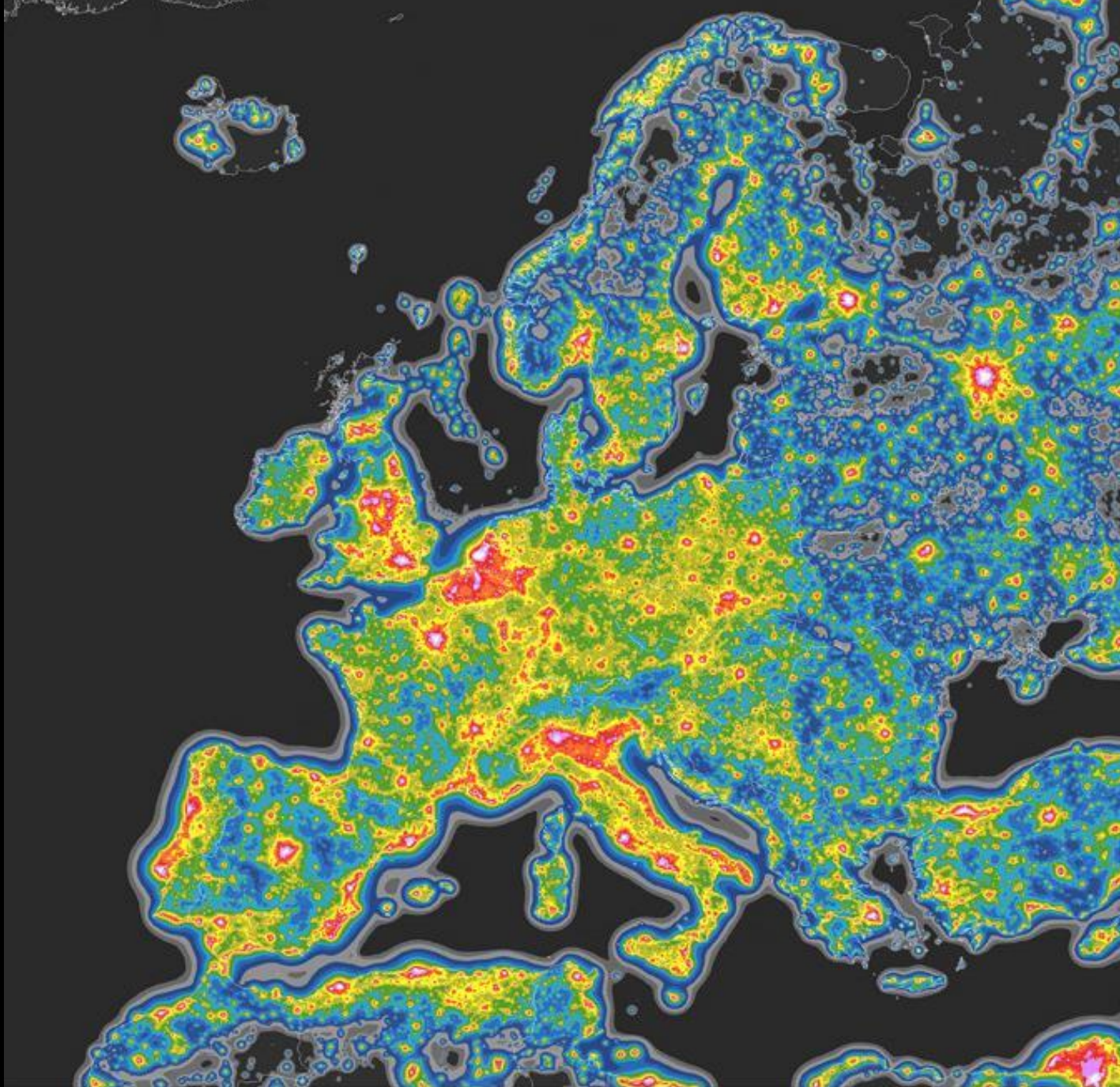
<http://airfactsjournal.com/files/2013/01/clouds-at-night.jpg>

<http://davidpj.files.wordpress.com/2009/11/night-clouds.jpg?w=800>

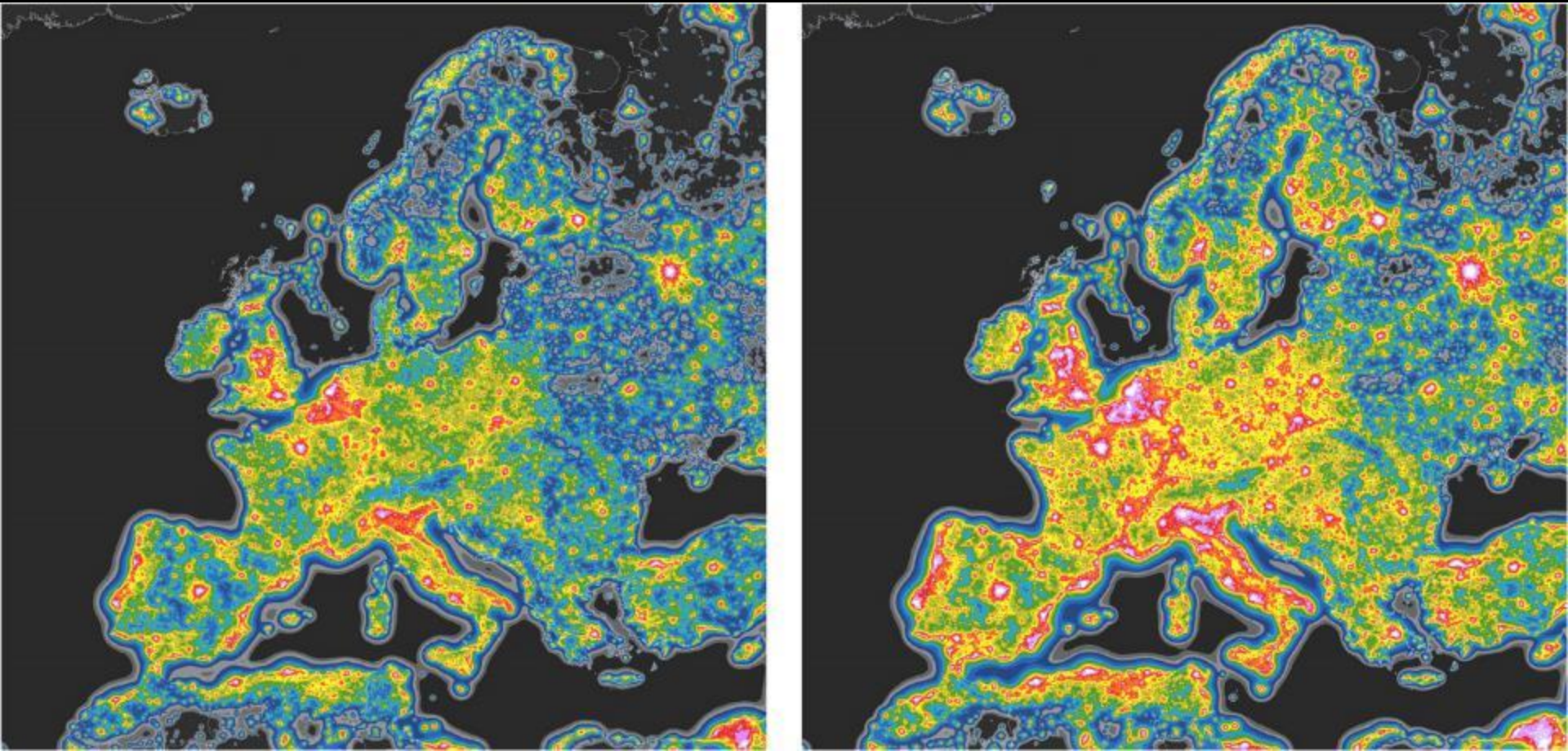
# Brightness of nightscapes



Photos: Andreas Hänel



# Increase of brightening when using 4000K LED



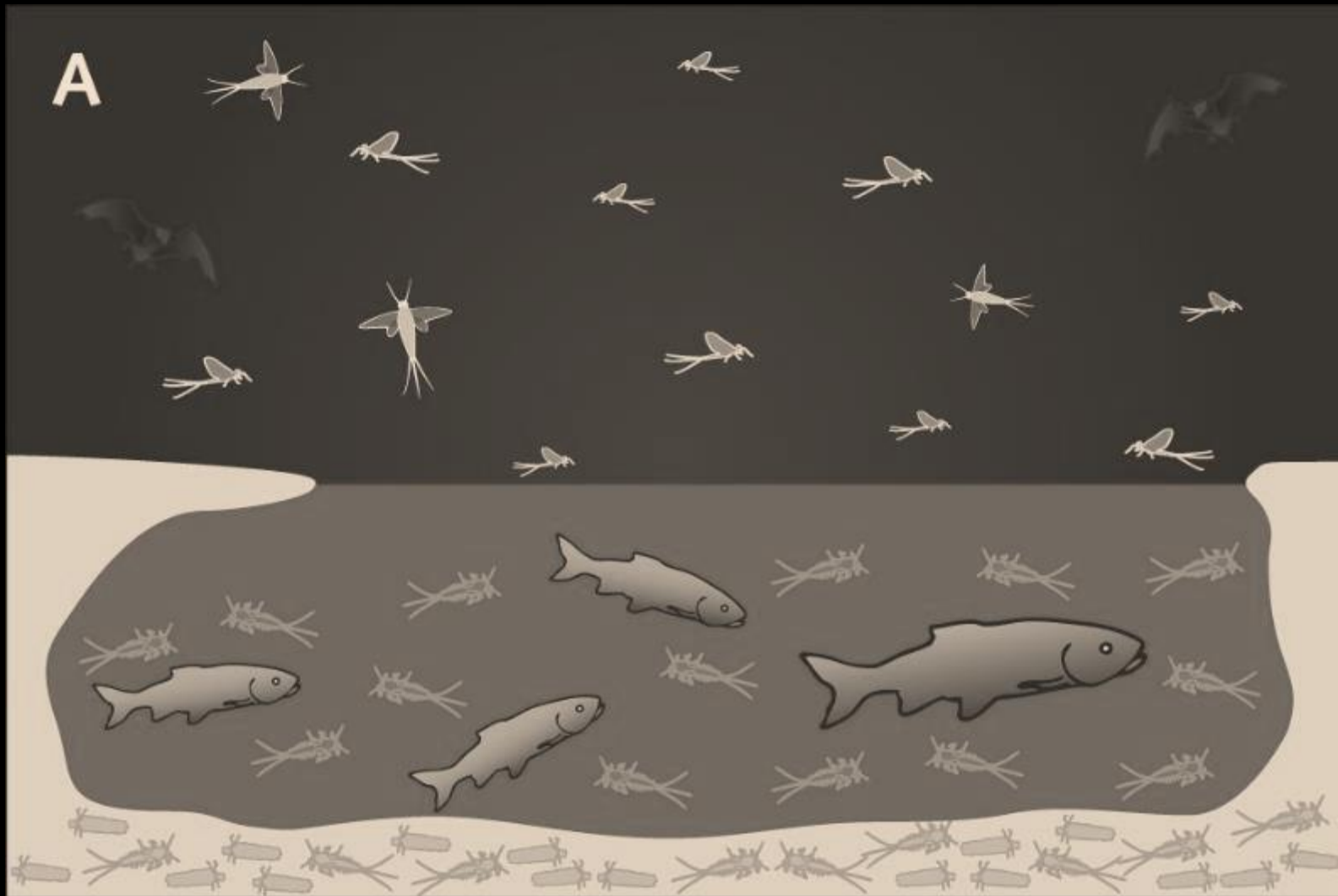


# Night as living space

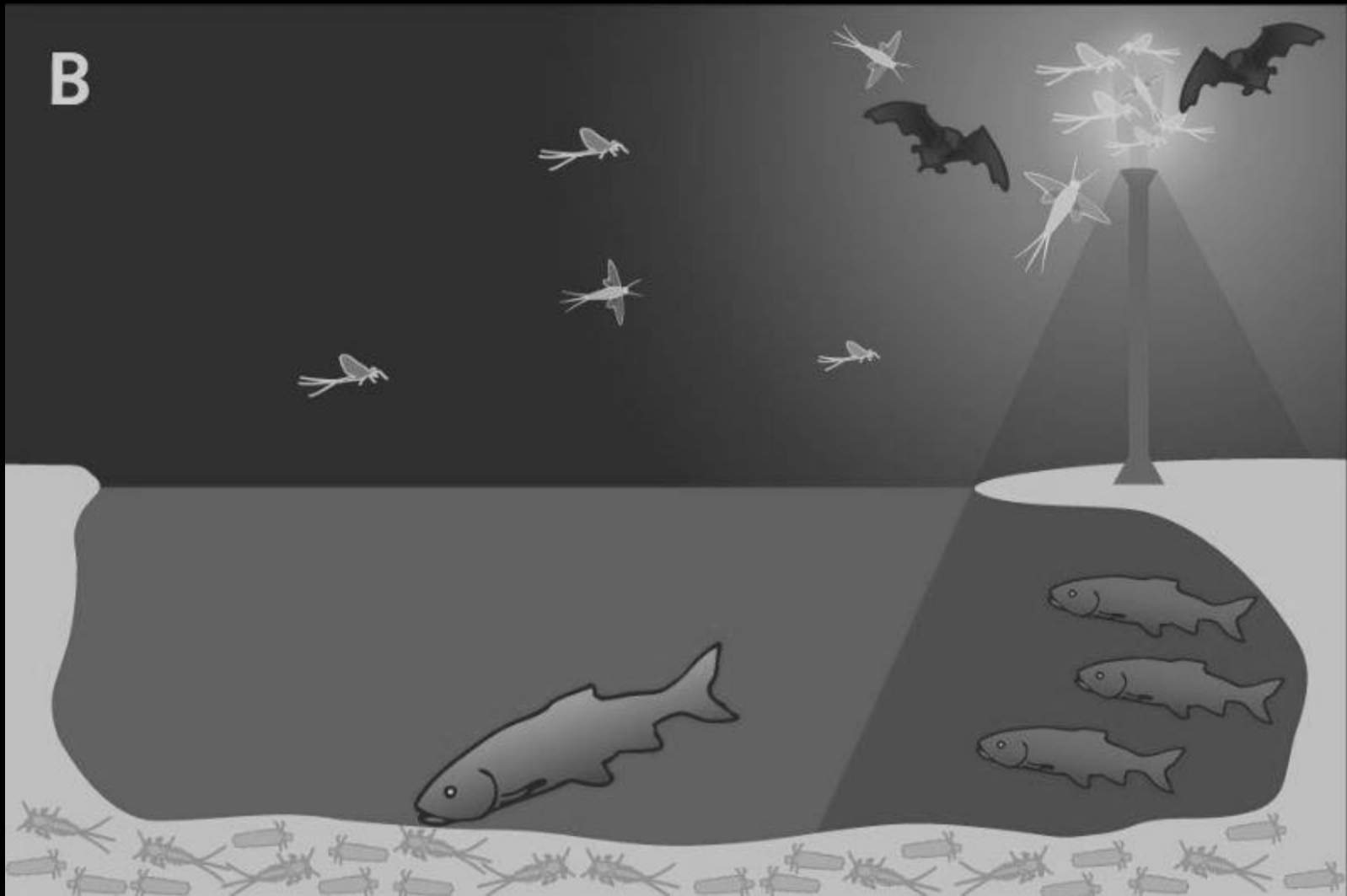
	Estimated number of described species	Thereof nocturnal [%]
<b>Vertebrates</b>		
Mammals	5 488	63,8
primates (incl. <u>H. sapiens</u> )	432	31
bats	1100	100
birds	9 990	19,6
reptiles	8 969	16,6
amphibians	6 433	93,3
Fishes	30 700	14,1
<b>Total</b>	<b>61 580</b>	<b>28,0</b>
<b>Invertebrates</b>		
Insects	950 000	49,4
Lepidoptera	180 000	77,8
Colleoptera	500 000	60
Crustacean	40 000	50
Arachnidae	98 000	5
Molluscs	81 000	?
Coral	2 175	?
others	61 209	?
<b>Total</b>	<b>1 232 384</b>	<b>64,4</b>

Hölker et al. .  
*Trends Ecol. Evol.* 12,  
 681–682 (2010)

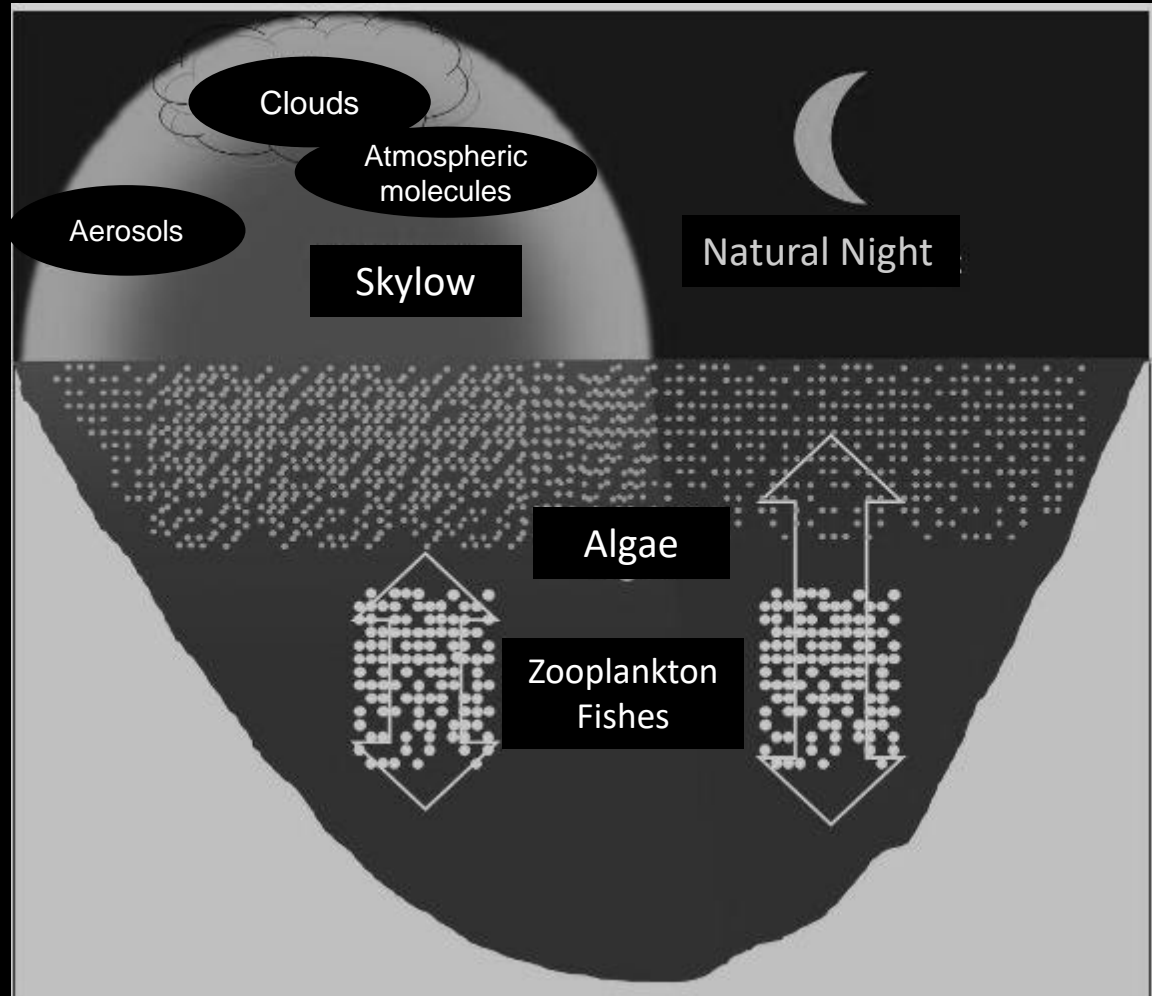
# Riparian ecosystems – a source for life



# Light has an effect



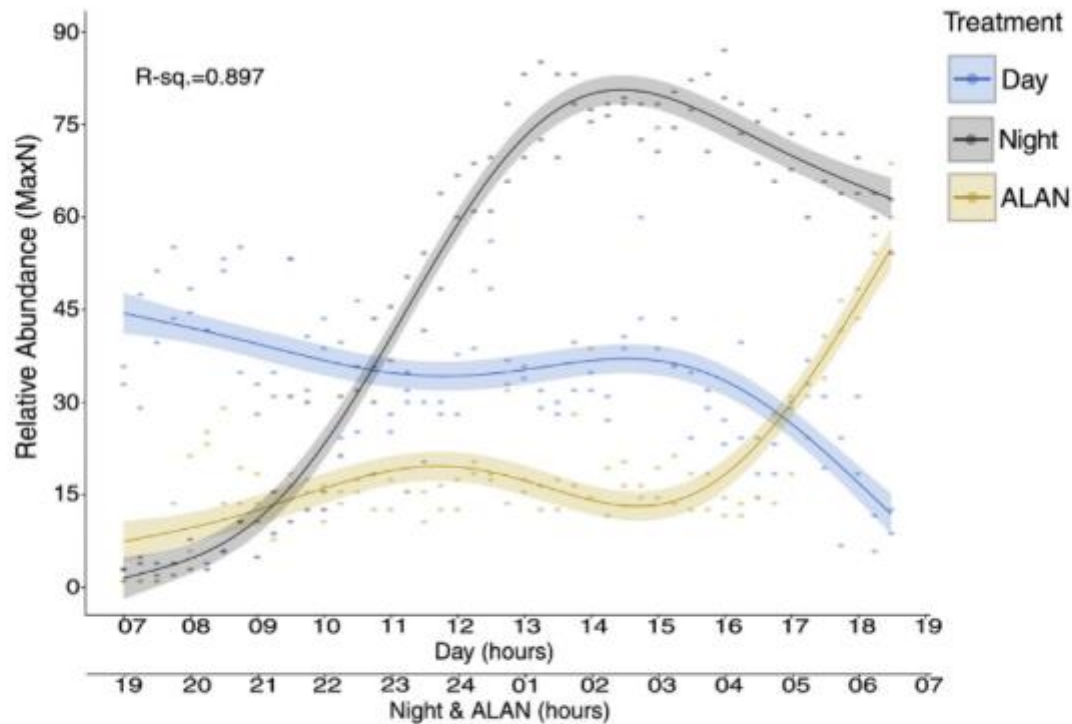
# Vertical Migration of zooplankton can be affected



Moore et al. *Int. Ver.Theor. Angew. Limnol. Verhandl.* 27, 779–782 (2000)

Image F. Hölker

# Occurrence of small and middle sized fishes



**Fig. 1.** Observed fish abundances (MaxN) per 15 min block with fitted GAMM models over an 11.5 h period between light environment treatments (from 7 am to 6:30 pm for day treatments and from 7 pm to 6:30 am for the night and ALAN treatments).

# Migration routes of birds can be affected

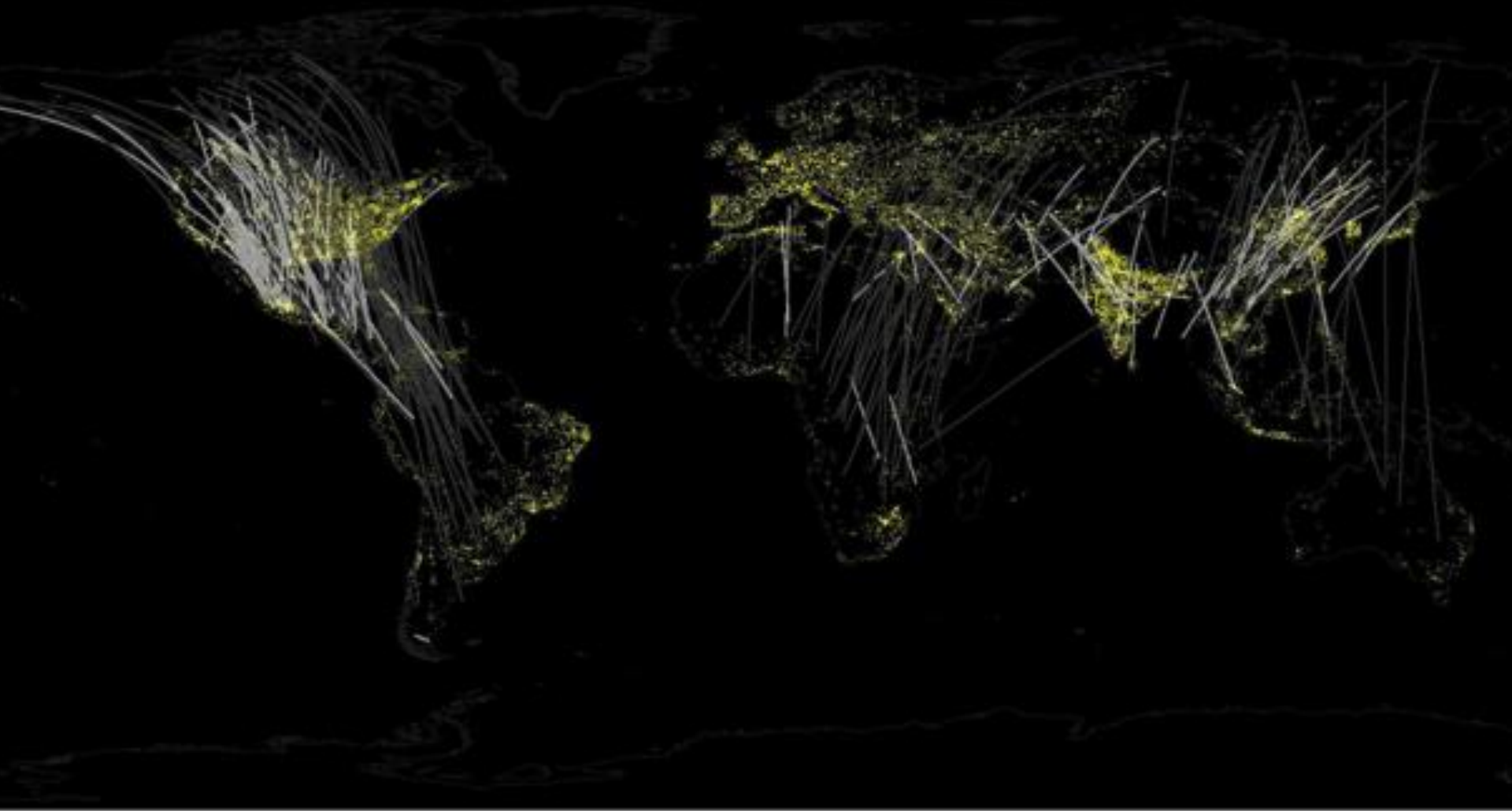




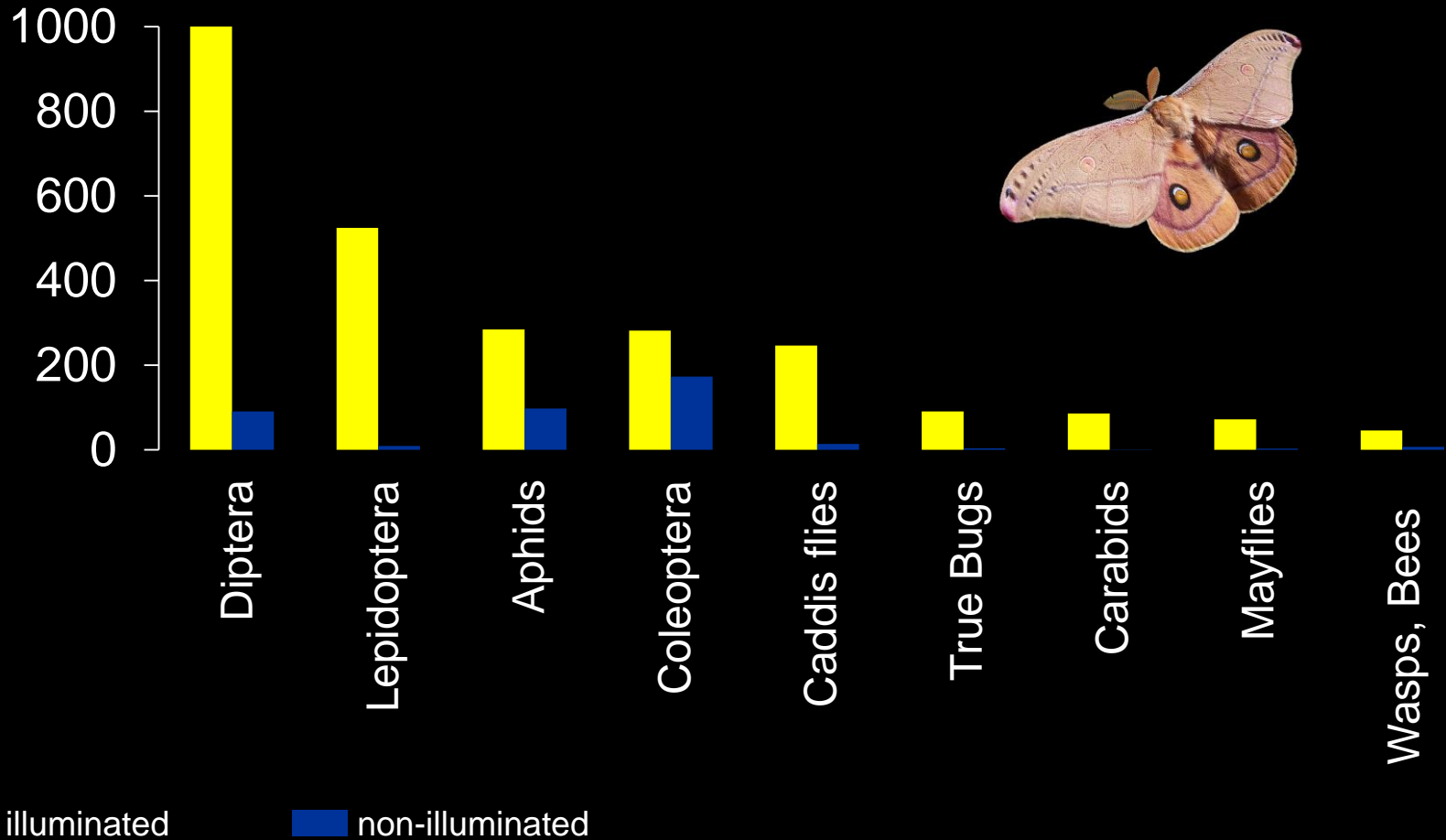
Photo: Volker Crone



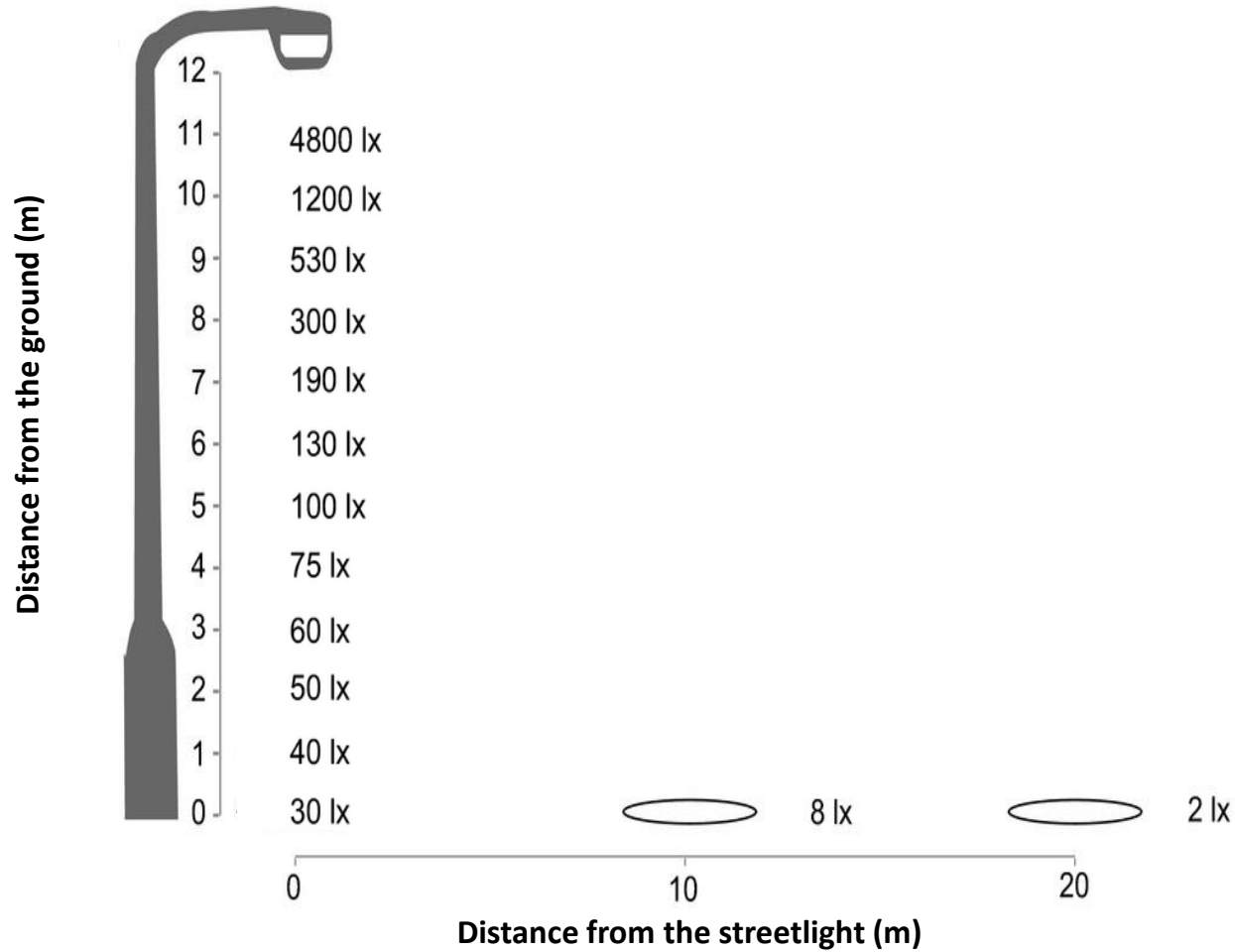
Photo: Stefan Heller



# Insect caught at streetlamps per year



# Light intensity of a street light



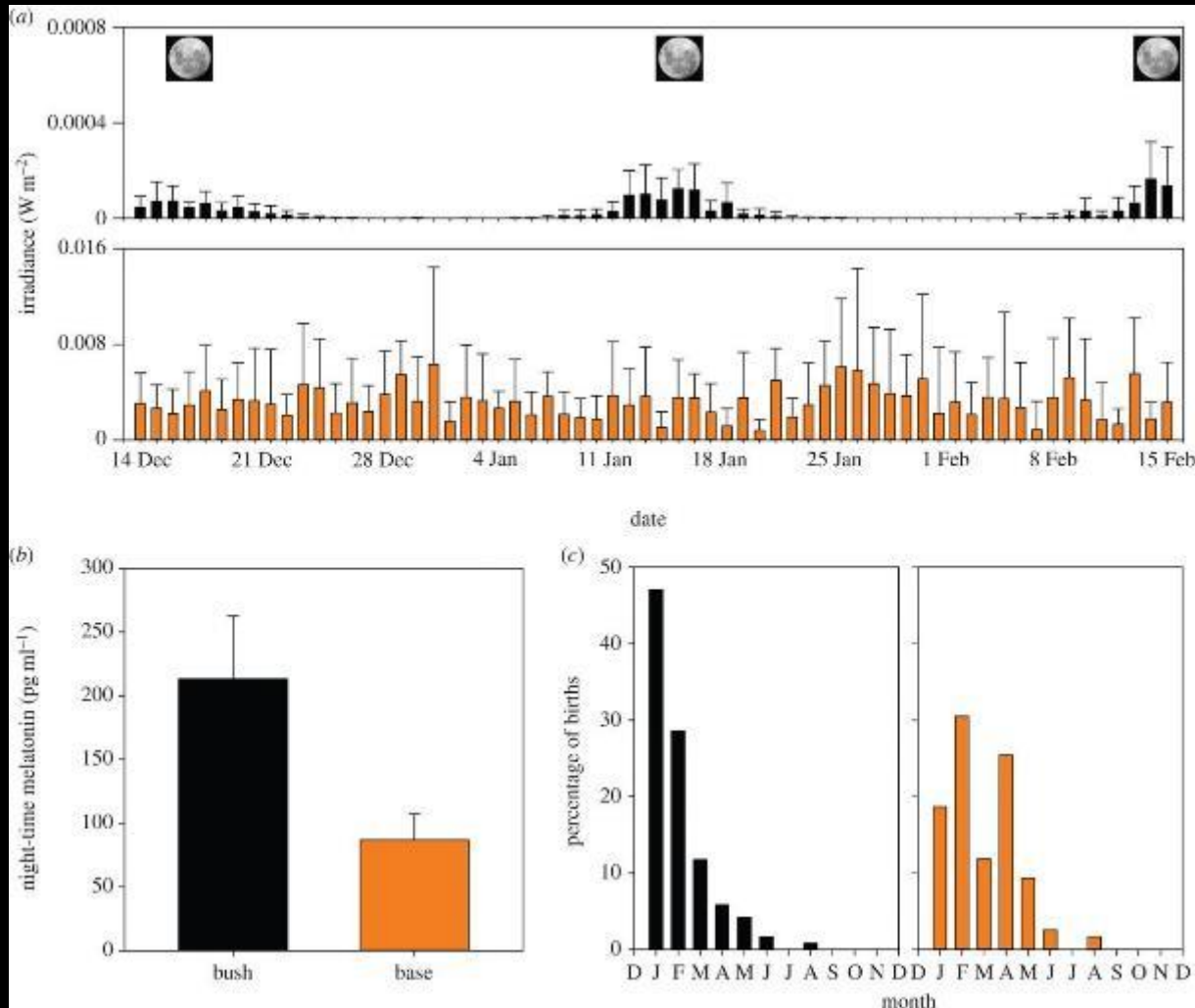
# Insect decline

- Substantial moth declines in abundance and distribution  
Fox, R. (2013) *Insect Conservation and Diversity*, **6**, 5–19.
- Out of 71 species have 30% biomass declined  
Conrad, K.F et al.(2006) *Biological Conservation*, **132**, 279–291.
- Over 75% biomass decline of flying insects within 27 years  
Hallmann et al. (2017) *Plos ONE*, **12**, e0185809.
- 80% biomass decline of insects between 1989-2013  
Vogel, G. (2017) *Science*, **356**, 576–579.
- Nocturnal Lepidoptera higher decline than day active  
van Langevelde et al.(2017). *Global Change Biology*.



Image: NASA

# Wallabies on a naval base compared to bushland



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

# Artificial light can suppress melatonin

Melatonin

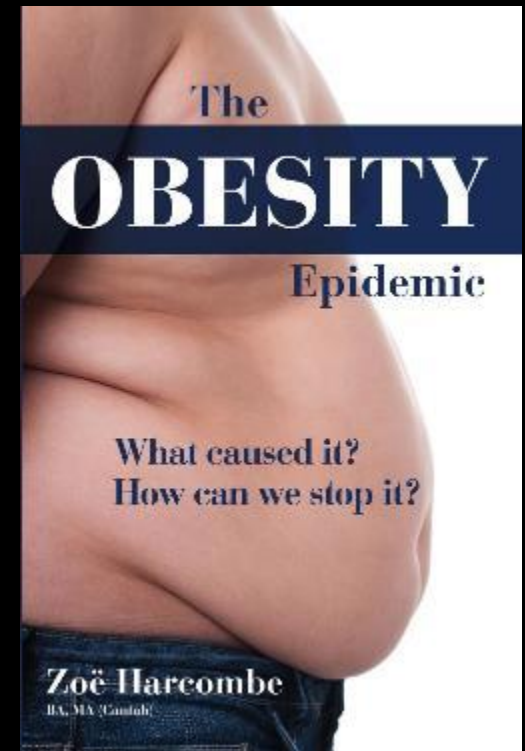


Sleep-wake-rhythm

Immune system

Metabolism

Circadian clock



**What can be done?**



Illustration: Rainer Stock, Loss of the Night Network 2016



# Optimise the radiation angle



Illustration: Rainer Stock, Loss of the Night Network 2016

# Direct the light to where it is needed

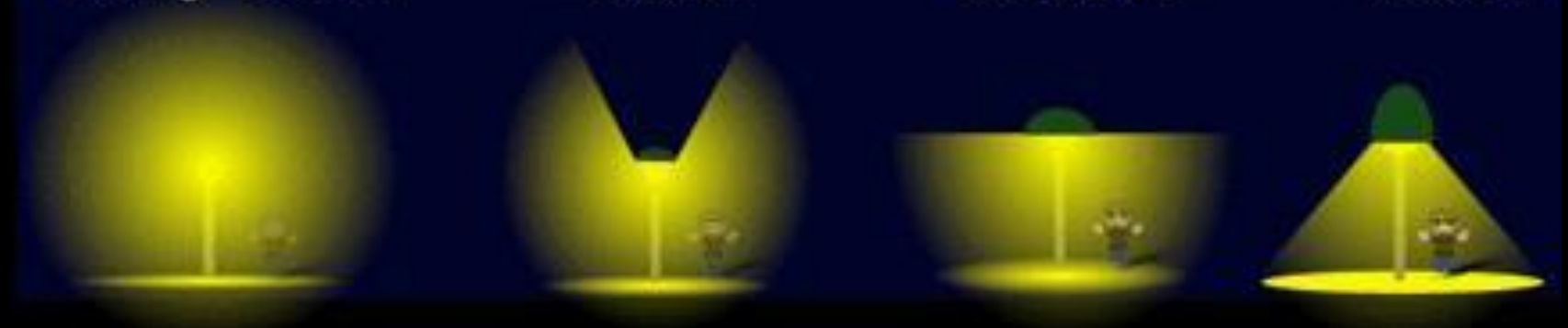


**very bad**

**bad**

**better**

**best**



# Examples of Acceptable / Unacceptable Lighting Fixtures

## Unacceptable

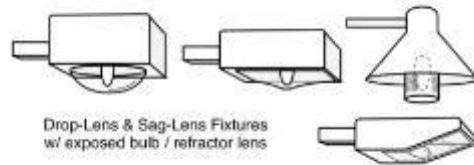
Fixtures that produce glare and light trespass



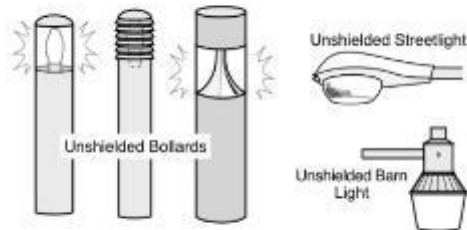
Unshielded Floodlights or Poorly-shielded Floodlights



Unshielded Wallpacks & Unshielded or Poorly-shielded Wall Mount Fixtures

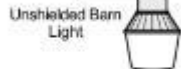


Drop-Lens & Sag-Lens Fixtures w/ exposed bulb / refractor lens

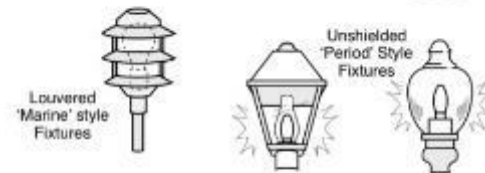


Unshielded Bollards

Unshielded Streetlight



Unshielded Barn Light



Louvered 'Marine' style Fixtures

Unshielded 'Period' Style Fixtures

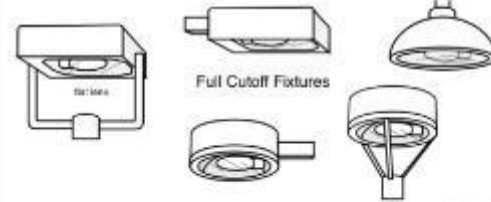
Drop-Lens Canopy Fixtures



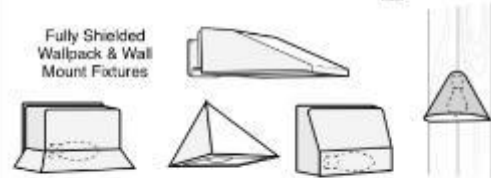
Unshielded PAR Floodlights

## Acceptable

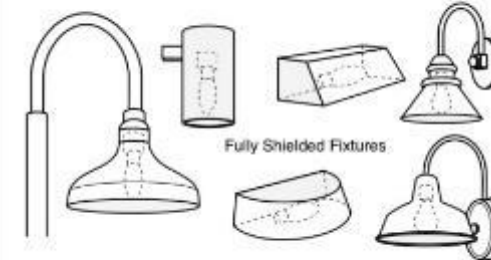
Fixtures that shield the light source to minimize glare and light trespass and to facilitate better vision at night.



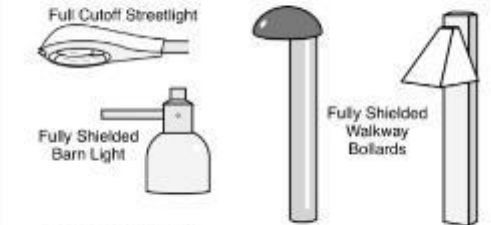
Full Cutoff Fixtures



Fully Shielded Wallpack & Wall Mount Fixtures



Fully Shielded Fixtures



Full Cutoff Streetlight

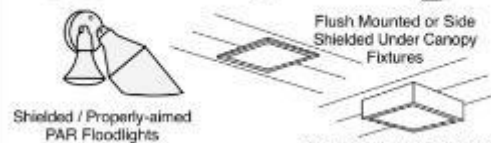
Fully Shielded Barn Light

Fully Shielded Walkway Bollards



Fully Shielded Decorative Fixtures

Fully Shielded 'Period' Style Fixtures



Shielded / Properly-aimed PAR Floodlights

Flush Mounted or Side Shielded Under Canopy Fixtures

Designed / Illustrated by Bob Crelin ©2005

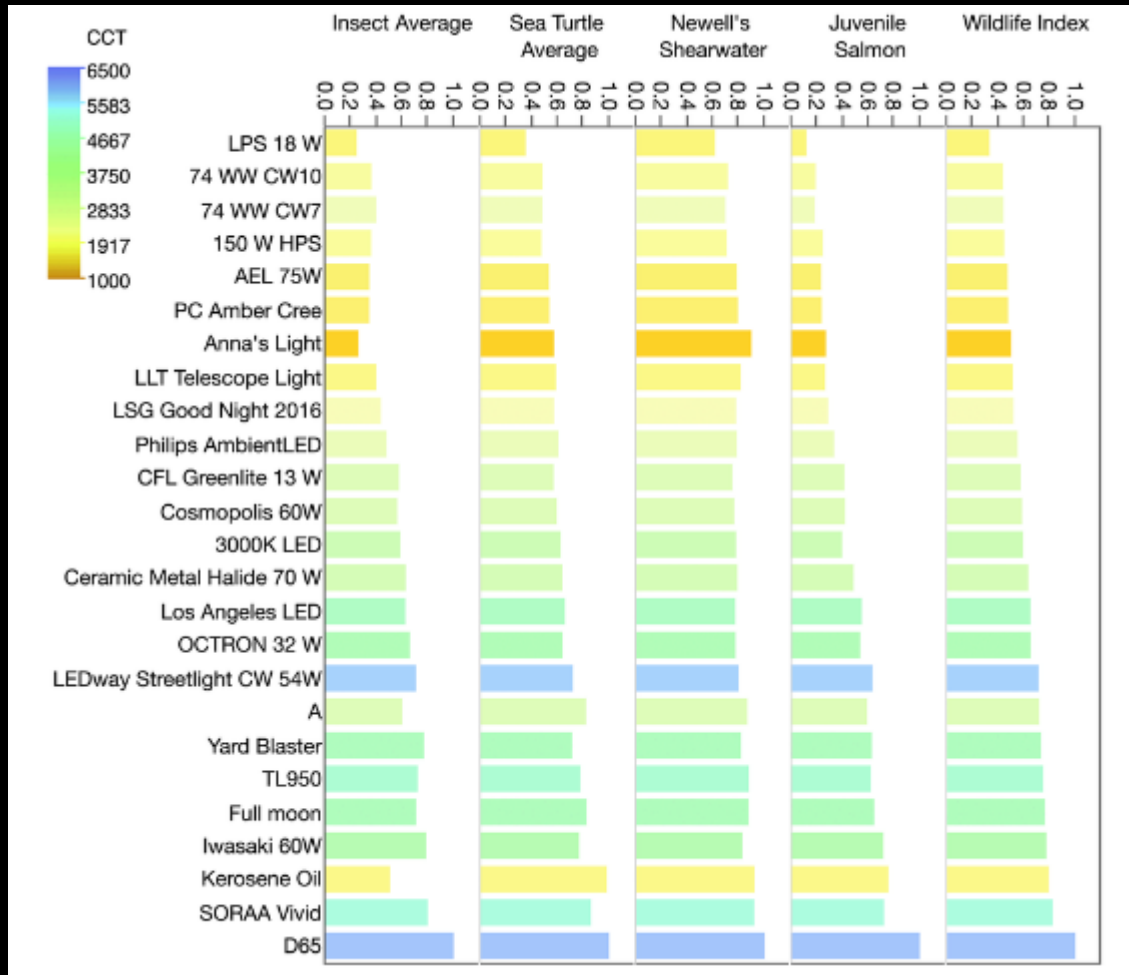
Illustration: Bob Crelin

# Use ambient light colours



Illustration: Rainer Stock, Loss of the Night Network 2016

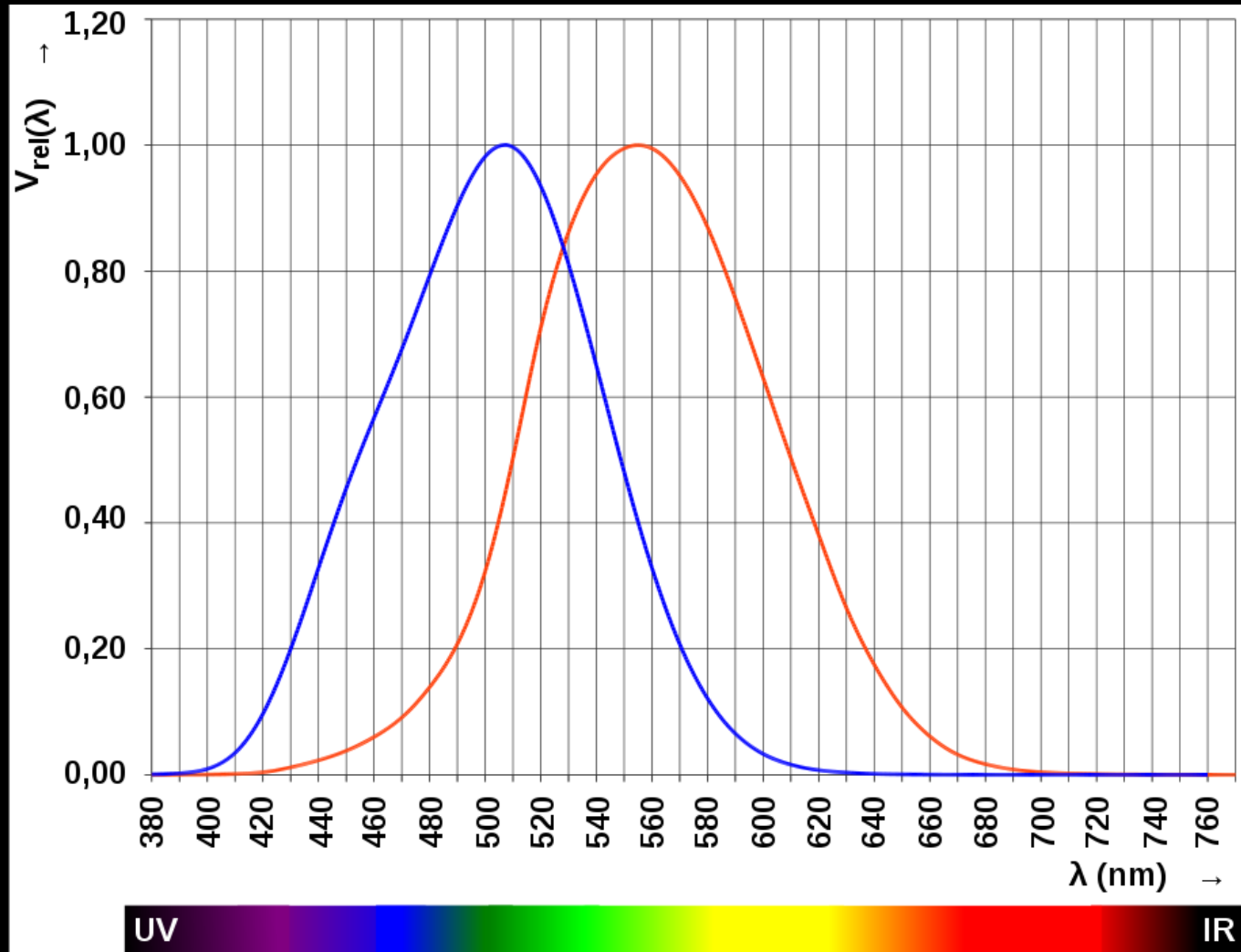
# Wildlife index for expected impact of different lamp types





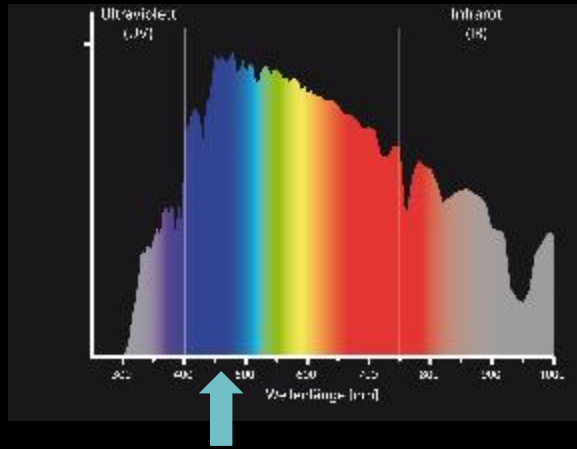
Photos: J. Hattenbach, C. Kohl, A. Lorberth, S. Frank

# Luminous flux

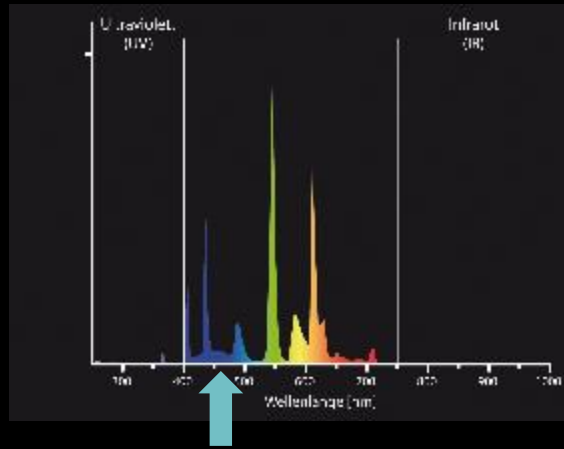


# Colour spectra of different light sources

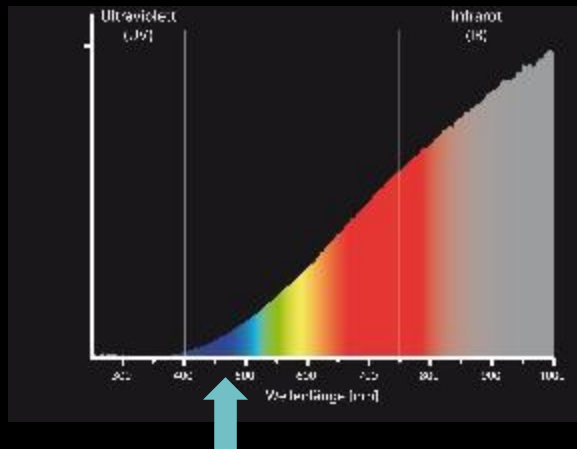
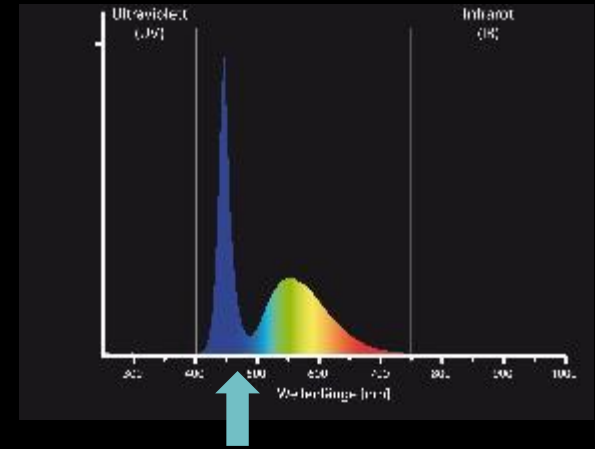
Sun light



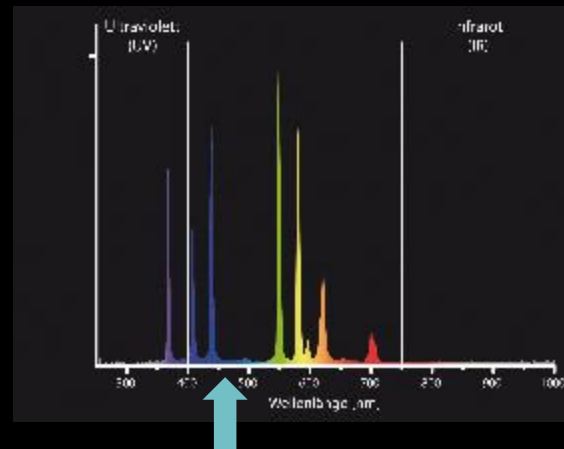
fluorescent



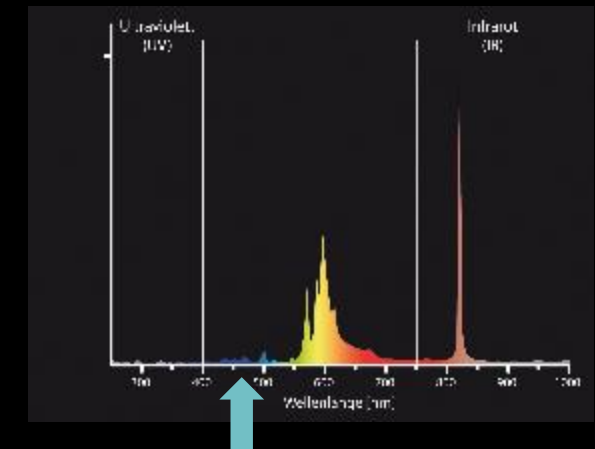
LED



Incandescent



Mercury vapour



Sodium vapour



**Use the low light intensity**



Illustration: Rainer Stock, Loss of the Night Network 2016

**Switch off the light whenever you don't need it**



Photos: C. Reinboth (l.), B. Hoffmeier (r.)

# Use dimming technology

- Saves energy
- Saves money
- Even gas-discharge lamps are dimmable



## Tucson airport, USA



- In 2014 lighting was changed around the terminal, roadways and parking lots
- Energy savings of > 1.5 million kwh
- Total project costs was \$ 813 000, payback is estimated by 4 to 27 years.

# Tucson airport: Lumen comparison

9/17/2014

TUCSON INT. AIRPORT NEW AND OLD LUMENS COMPARISON FOR LED FIXTURES ACQUISITIONS PROJECT (2014).

OLD SYSTEM					
AREA	QTY.	LGT. TYPE	DESCRIPTION	LUMENS	TOTAL
PARKING GARAGE	397	A,A2,A3	175W METAL HALIDE	12,500	4,962,500
QTA & Eco. Prk.	21	S (S3)	1000W HPS, 50' POLE	124,000	2,604,000
QTA & Eco. Prk.	60	S (S4)	1000W HPS, 50' POLE	124,000	7,440,000
QTA & Eco. Prk.	10	AAA	250W HPS @ CANOPY	26,000	260,000
QTA & Eco. Prk.	2	U2	1000W HPS, 20' POLE	124,000	248,000
QTA & Eco. Prk.	16	U4	1000W HPS, 50' POLE	124,000	1,984,000
CIRC. ROADWAY	18	R (R3)	1000W HPS, 50' POLE	124,000	2,232,000
CIRC. ROADWAY	32	R (R4)	1000W HPS, 50' POLE	124,000	3,968,000
CIRC. ROADWAY	5	P	250W HPS @ CANOPY	26,000	130,000
CIRC. ROADWAY	10	P (P2)	250W HPS @ CANOPY	26,000	260,000
CIRC. ROADWAY	24	AA	250W HPS @ CANOPY	26,000	624,000
TERM. APRON LGT.	52	T (T4)	1000W HPS, 50' POLE	124,000	6,448,000
				<b>OLD LUMENS TOTAL</b>	<b>31,160,500</b>

NEW SYSTEM				
QTY.	LGT. TYPE	DESCRIPTION	LUMENS	TOTAL
397	A	53W GARAGE LED	4,400	1,745,800
21	S (S3)	218W LED POLE LGT	21,326	447,846
60	S (S4)	218W LED POLE LGT	21,326	1,279,560
10	AAA	53W CANOPY LED LGT	4,400	44,000
2	U2	131W POLE LED LGT	10,541	21,082
16	U4	218W LED POLE LGT	21,326	341,216
18	R (R3)	218W LED POLE LGT	21,326	383,868
32	R (R4)	218W LED POLE LGT	21,326	682,432
5	P	131W POLE LED LGT	10,541	52,705
10	P (P2)	131W POLE LED LGT	10,541	105,410
24	AA	53W CANOPY LED LGT	4,400	105,600
52	T (T4)	280W POLE ARM LGT	23,435	1,218,620
			<b>NEW LUMENS TOTAL</b>	<b>6,423,139</b>

NEW SYSTEM IS 21 % LUMENS OF OLD SYSTEM

# Tucson airport: Watt age comparison

9/29/2014

TUCSON INT. AIRPORT NEW AND OLD WATTS COMPARISON FOR LED FIXTURES ACQUISITIONS PROJECT (2014).

AREA	OLD SYSTEM				
	QTY.	LGT. TYPE	DESCRIPTION	WATTS	TOTAL
PARKING GARAGE	397	A,A2,A3	175W METAL HALIDE	210	83,370
QTA & Eco. Prk.	21	S (S3)	1000W HPS, 50' POLE	1,100	23,100
QTA & Eco. Prk.	60	S (S4)	1000W HPS, 50' POLE	1,100	66,000
QTA & Eco. Prk.	10	AAA	250W HPS @ CANOPY	310	3,100
QTA & Eco. Prk.	2	U2	1000W HPS, 20' POLE	1,100	2,200
QTA & Eco. Prk.	16	U4	1000W HPS, 50' POLE	1,100	17,600
CIRC. RODWAY	18	R (R3)	1000W HPS, 50' POLE	1,100	19,800
CIRC. RODWAY	32	R (R4)	1000W HPS, 50' POLE	1,100	35,200
CIRC. RODWAY	5	P	250W HPS @ CANOPY	310	1,550
CIRC. RODWAY	10	P (P2)	250W HPS @ CANOPY	310	3,100
CIRC. RODWAY	24	AA	250W HPS @ CANOPY	310	7,440
TERM. APRON LGT.	52	T (T4)	1000W HPS, 50' POLE	1,100	57,200
<b>TOTAL</b>					<b>319,660</b>

QTY.	LGT. TYPE	NEW SYSTEM		
		DESCRIPTION	WATTS	TOTAL
397	A	53W GARAGE LED	55	21,835
21	S (S3)	218W LED POLE LGT	220	4,620
60	S (S4)	218W LED POLE LGT	220	13,200
10	AAA	53W CANOPY LED LGT	55	550
2	U2	131W POLE LED LGT	135	270
16	U4	218W LED POLE LGT	220	3,520
18	R (R3)	218W LED POLE LGT	220	3,960
32	R (R4)	218W LED POLE LGT	220	7,040
5	P	131W POLE LED LGT	135	675
10	P (P2)	131W POLE LED LGT	135	1,350
24	AA	53W CANOPY LED LGT	55	1,320
52	T (T4)	280W POLE ARM LGT	280	14,560
<b>NEW TOTAL</b>			<b>72,900</b>	

NEW SYSTEM IS 23 % LUMENS OF OLD SYSTEM

**Tucson airport: Danette Bewley**  
**Vice President of Operations and Projects**

“The lighting project not only reduced energy use but it also improved the quality of lighting and the night time aesthetics of our facility for our tenants, the staff and the traveling public”





Illustration: Rainer Stock, Loss of the Night Network 2016

# Light pollution is an environmental problem that could be solved in a life time

What is good illumination?

- Efficient
- Creates visibility and safety
- Improves aesthetics
- Has low impact on ecology, human health or well-being, and the starry nightscape



**Thank you!**