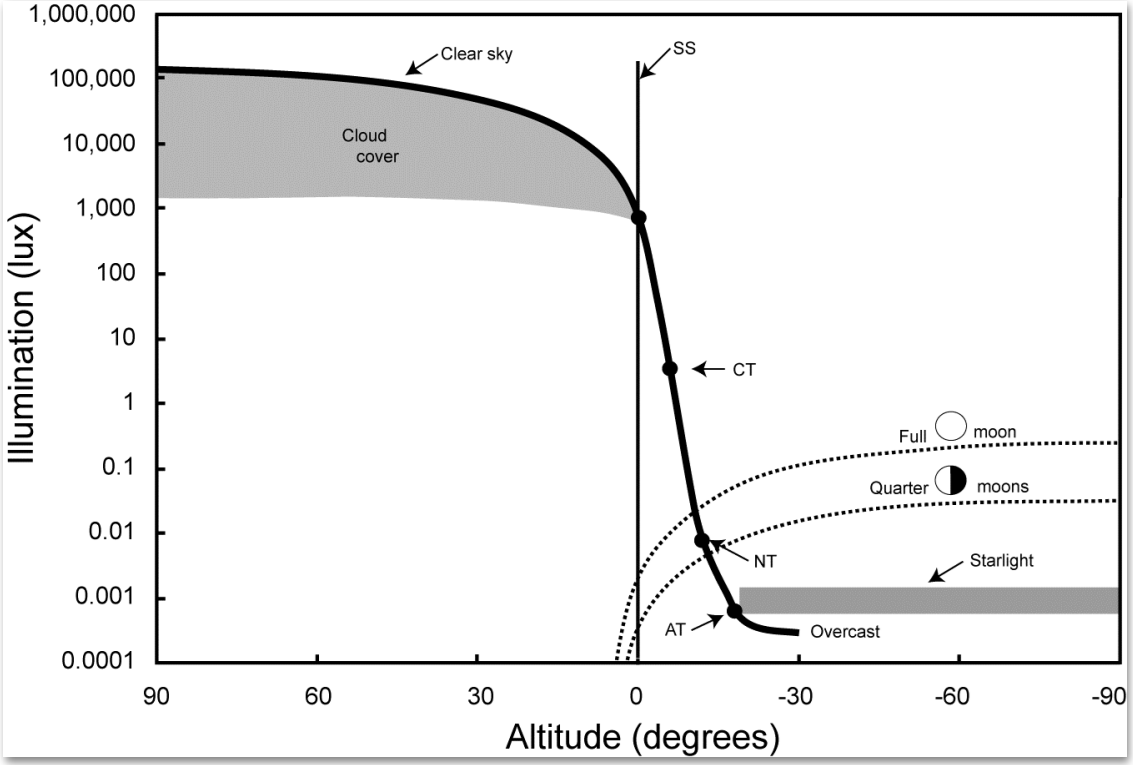
Ecological Considerations for Light at Night

DOE Lighting R&D Workshop
January 28-30 San Diego, Ca

Jeremy White
National Park Service
Natural Sounds and Night Skies Division

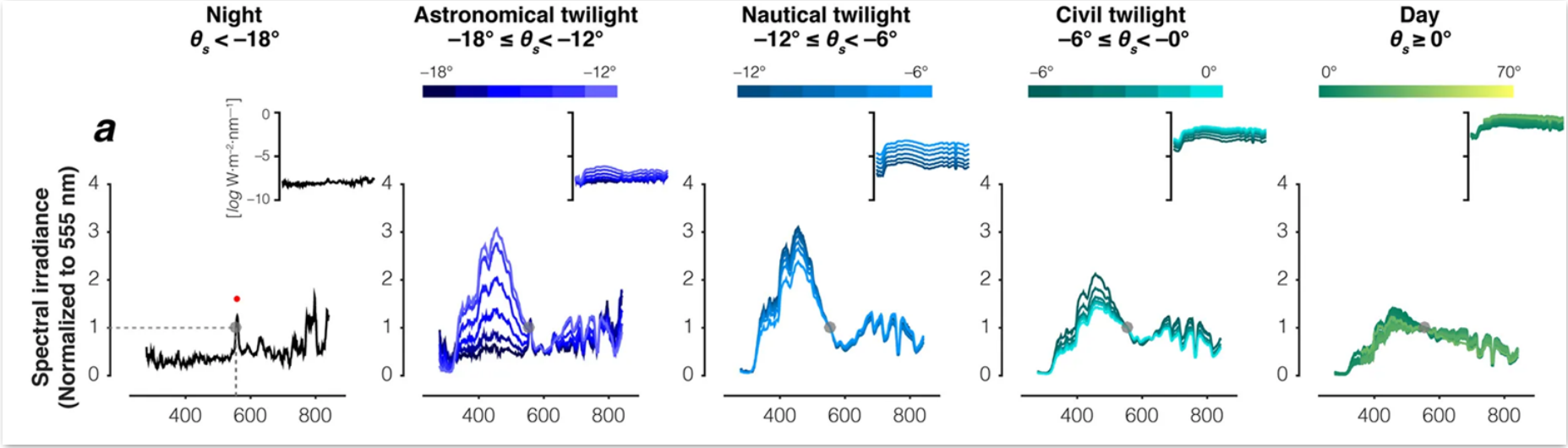
Natural Day Night Cycles



Longcore 2017 (modified with permission form Beier 2006)

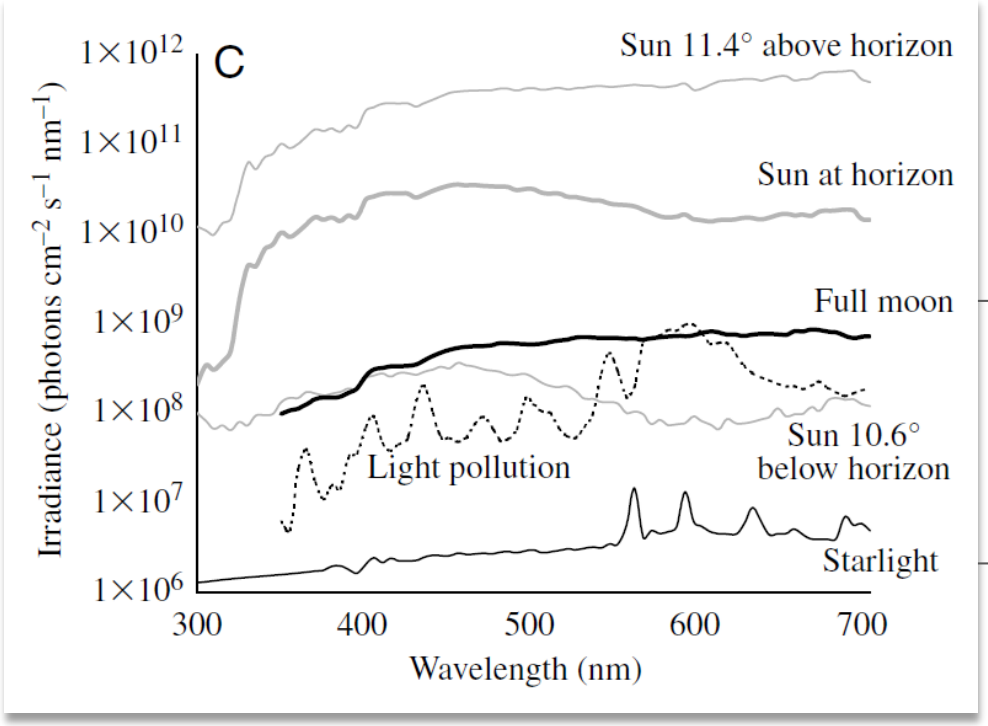
Natural irradiance over solar elevation

Normalized to 550 nm to emphasize spectral shift



Spitschan et al. 2016

Irradiance from natural and anthropogenic sources



<20% night

~50% night

Johnson et al. 2006

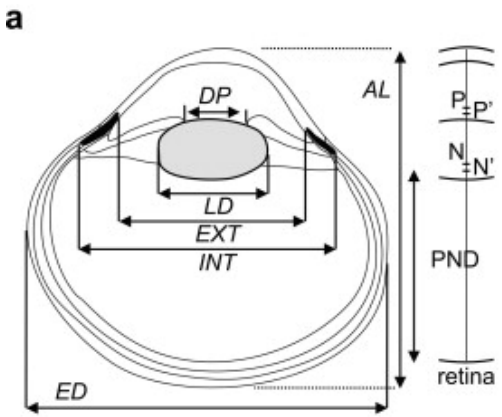
Nocturnal Species

- 28% of all vertebrate species (17,242)
  - 93% amphibians
  - 63% mammals
    - 100% bats
- 64% of all invertebrates (793,655)
  - 49% insects
    - 78% Lepidopterans
    - 60% Coleopterans
- ~63% of all species

- Almost all species are influenced by light dark cycles, not just nocturnal species

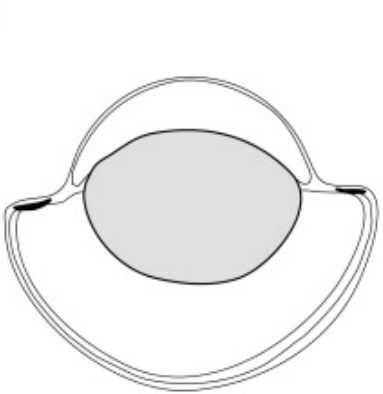
Hölker et al. 2010

Physical and neural adaptations



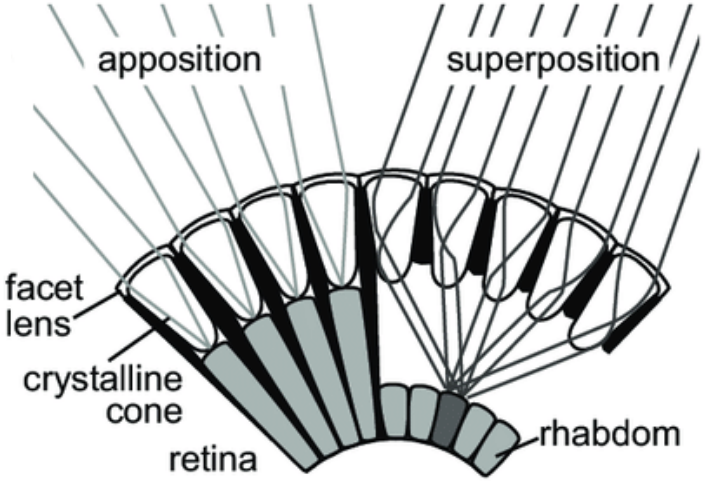
diurnal avian eye

>f/1.3



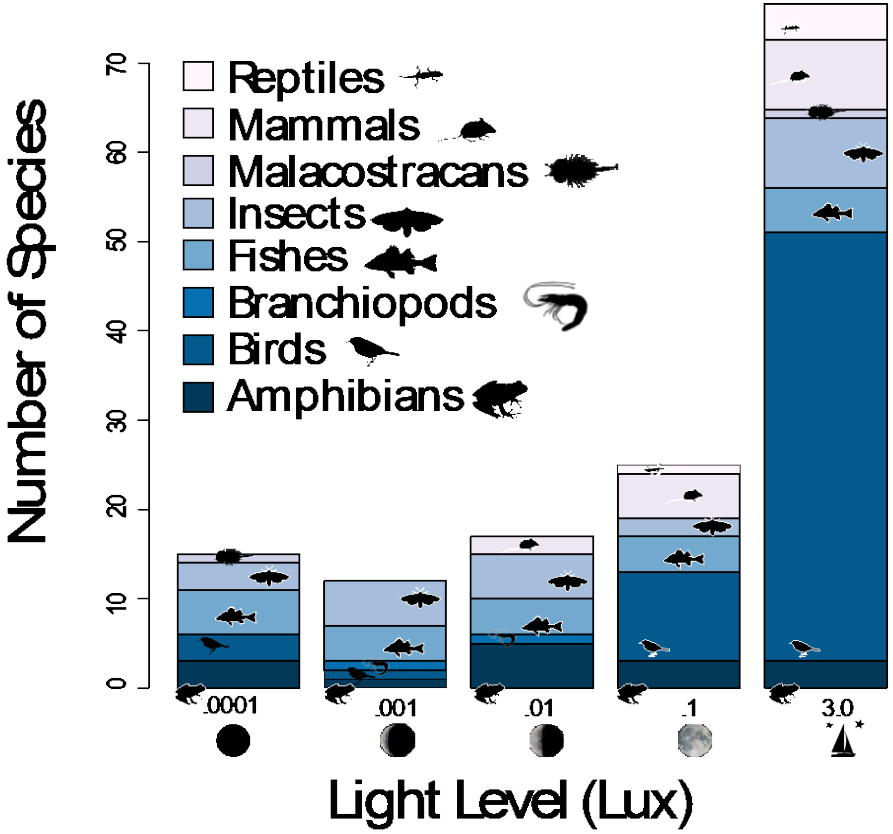
nocturnal avian eye

f/0.5-0.9



Stöckl et al. 2017

Low light performance



<0.00001 lux

<0.0001 lux

<0.01 lux

<0.05 lux

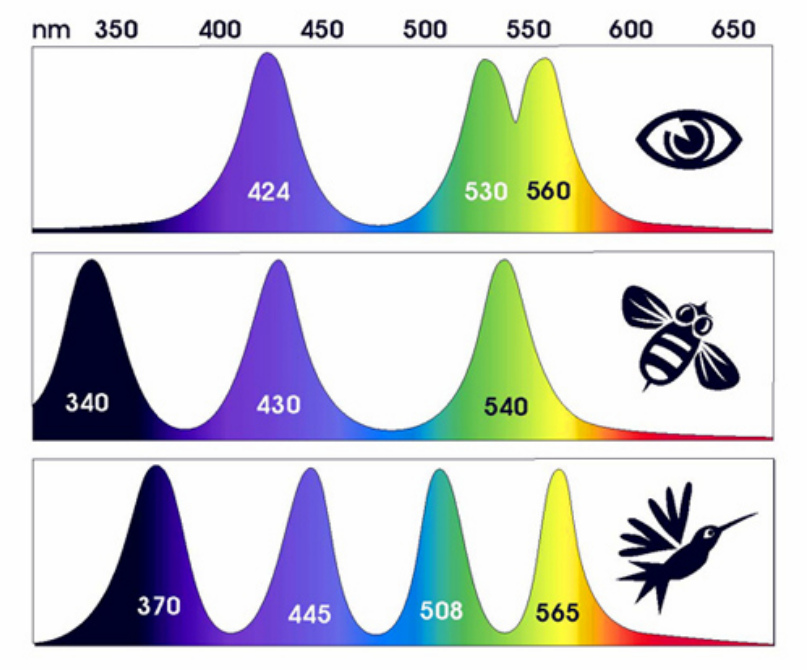
See Gaston et al. 2013 and Desouhant et al. 2018 for review

Photoreception

Photoreceptors vary in structure across taxa from simple intensity detectors to complex imagers, but all have photopigments that absorb light at specific wavelength.

Multiple pigment types allows an organism to compare intensity across a broad spectrum.

Non-visual opsins use light as a cue for biological functions such as circadian rhythms, reproductive timing and sleep and include melanopsin, neuropsin, pinopsin, and vertebrate ancient opsin



SWS-1 SWS-2 MWS LWS

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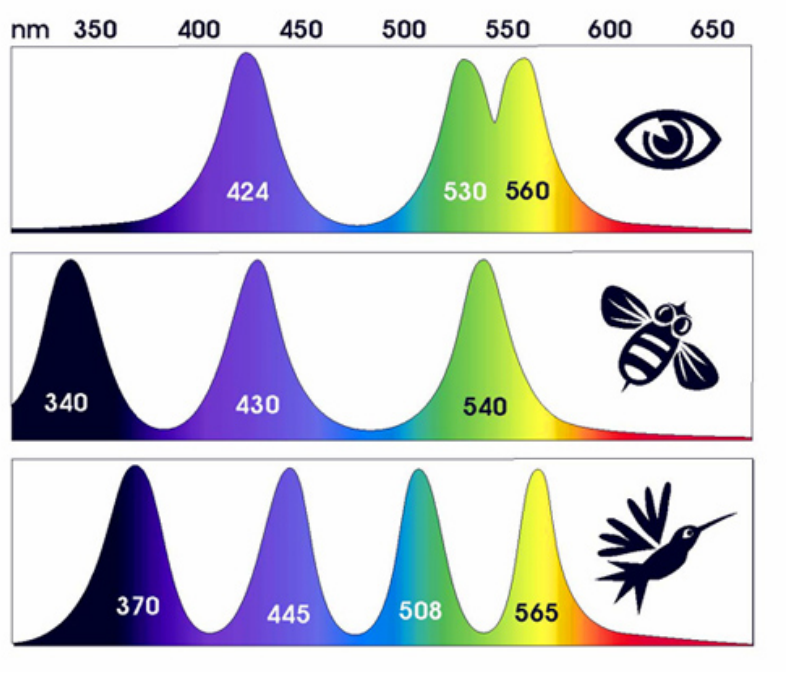
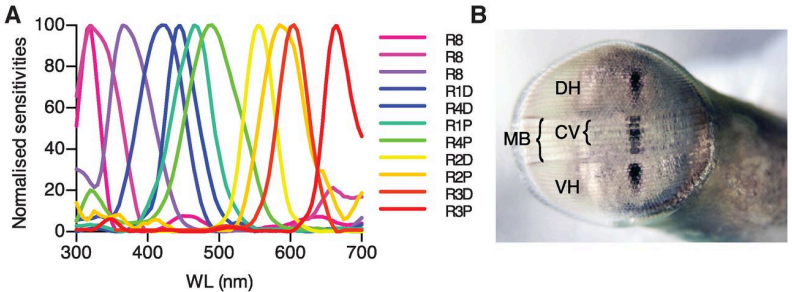
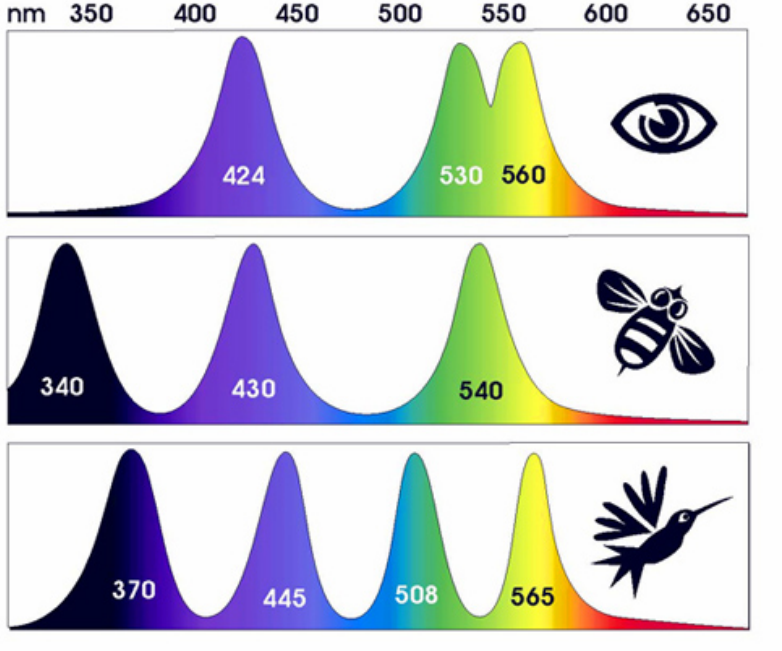


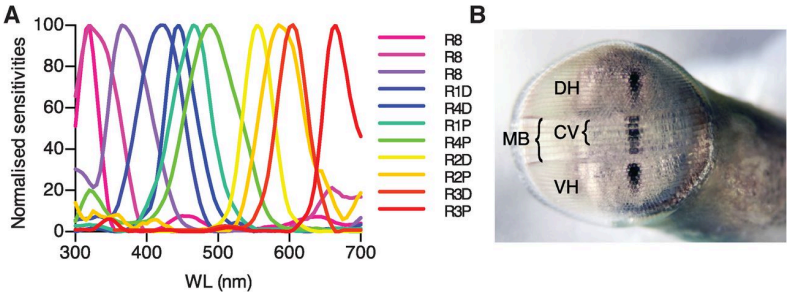


Photoreception

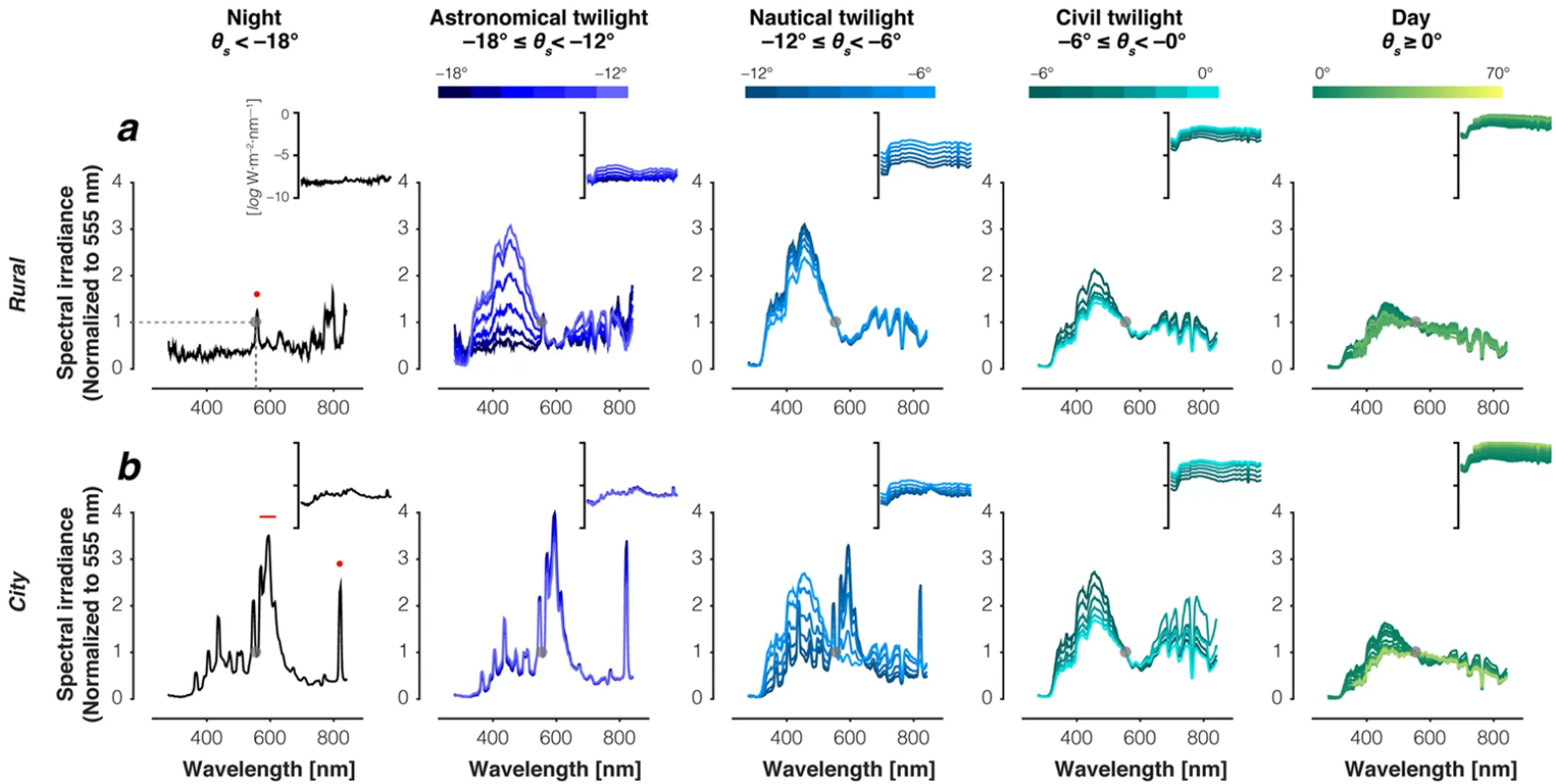
Spectral sensitivity is measured in three ways:

- behavioral responses that provide action spectra of whole animals
- electroretinograms that determine the spectral sensitivity of whole eyes
- microspectrophotometry (MSP) that measures the absorption spectra of the photopigments themselves

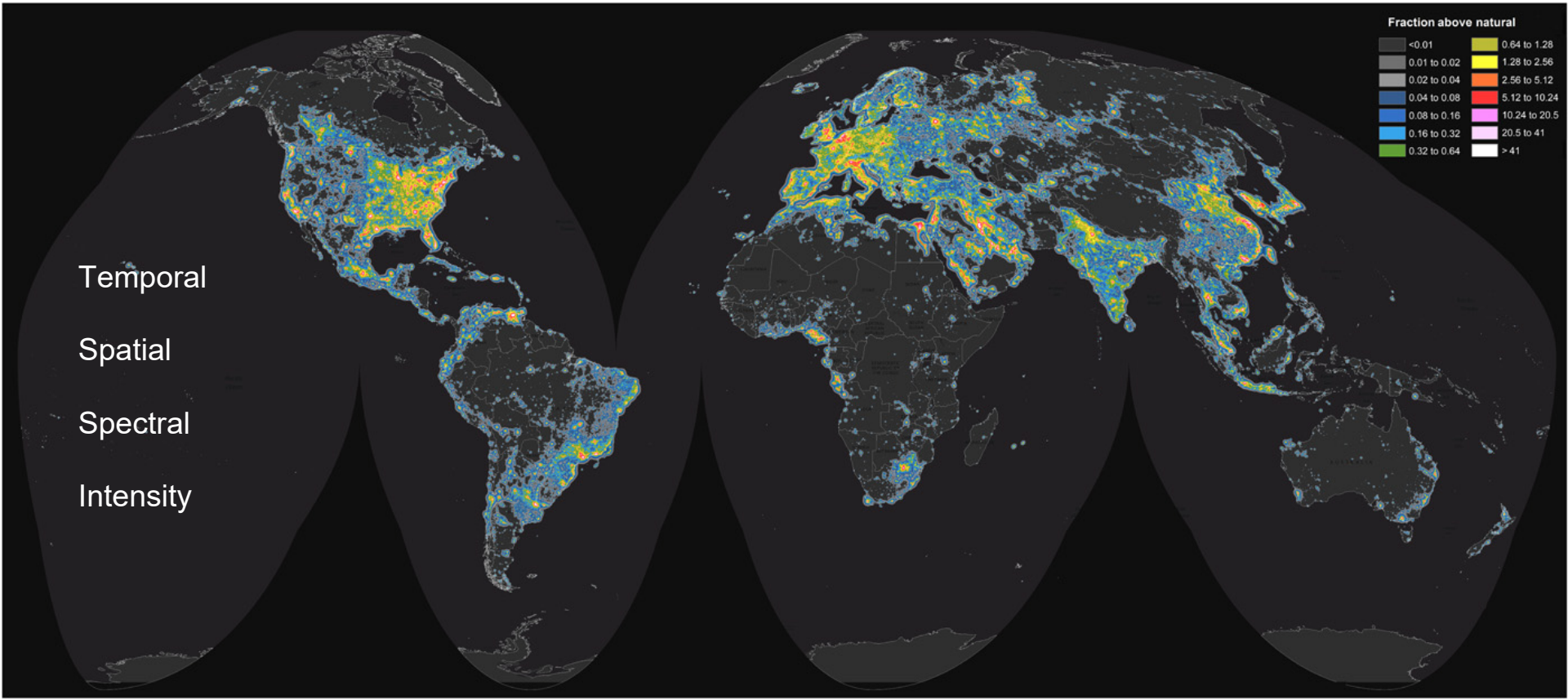




Natural vs. city irradiance over solar elevation

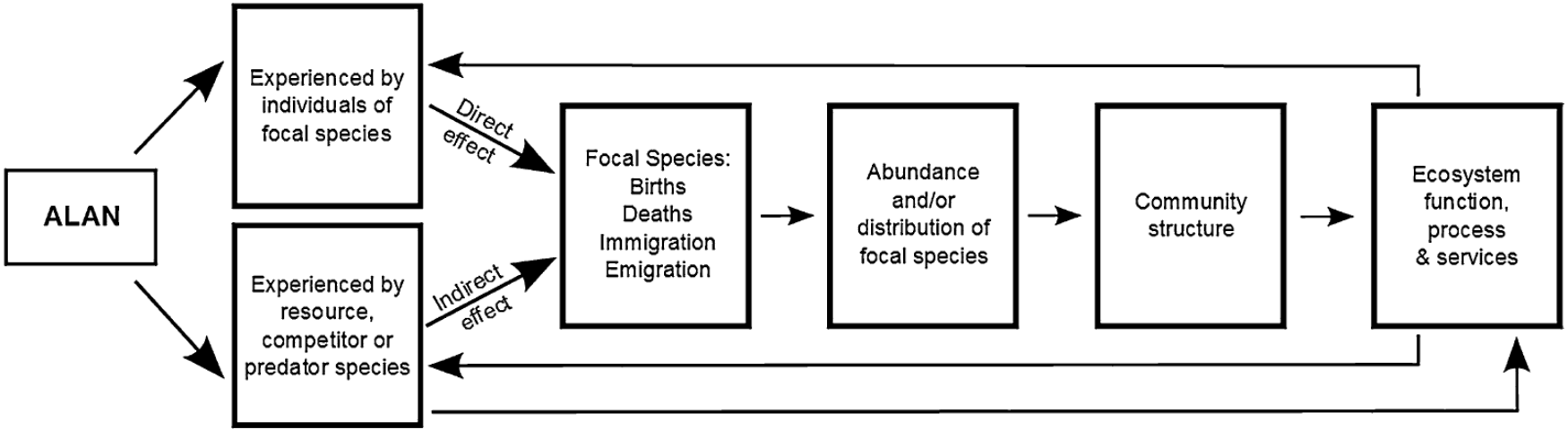


Spitchan et al. 2016



Falchi et al. 2016

Functional Effects



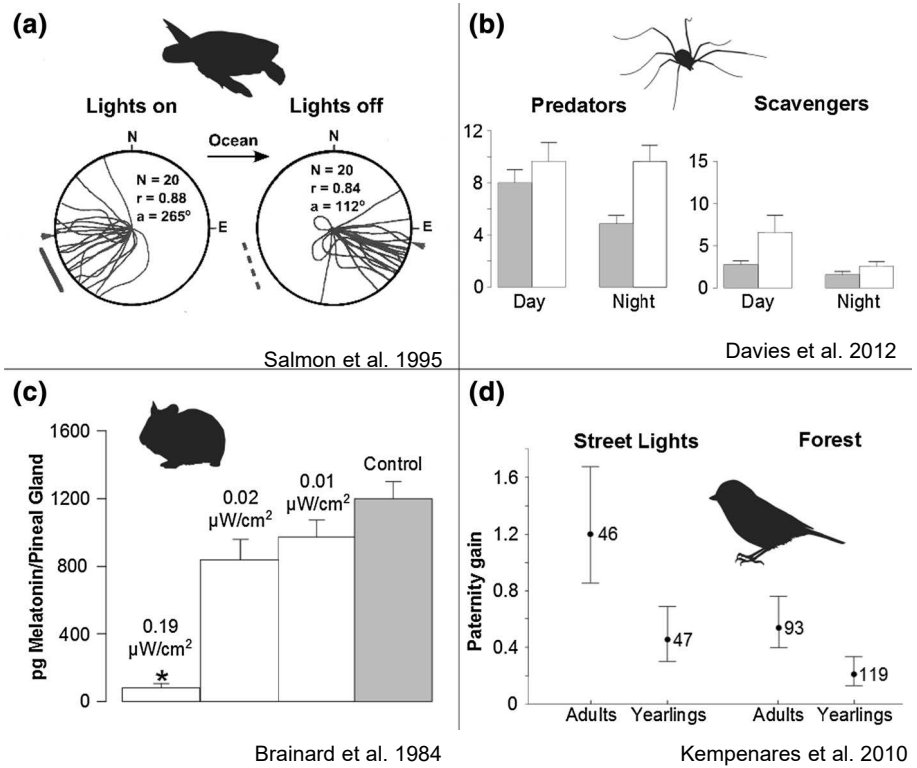
Functional effects

- Gene expression
- Physiological development
- Circadian, circannual, circalunar rhythms
- Individual survival
- Foraging
- Mate Finding
- Reproductive success
- Community composition
- Predator prey dynamics
- Pollination network
- Movement
- Population dynamics

Functional Effects

Fitness

Physiology



Salmon et al. 1995

Davies et al. 2012

Brainard et al. 1984

Kempenares et al. 2010

Community Structure

Reproduction

Gaston et al. 2014

Functional Effects

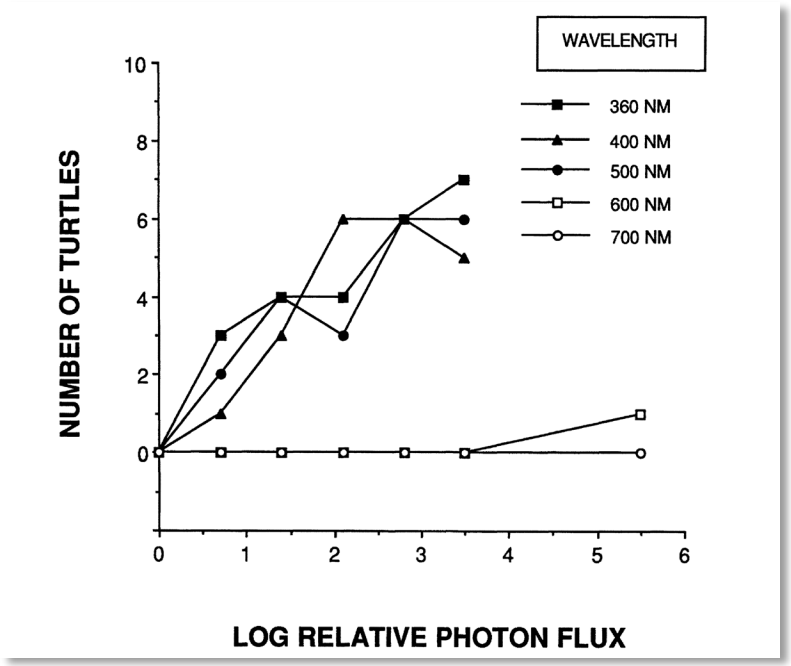
Nest PB7061 Hatch on August 28th, 2006

Gulf Islands National Seashore, FL

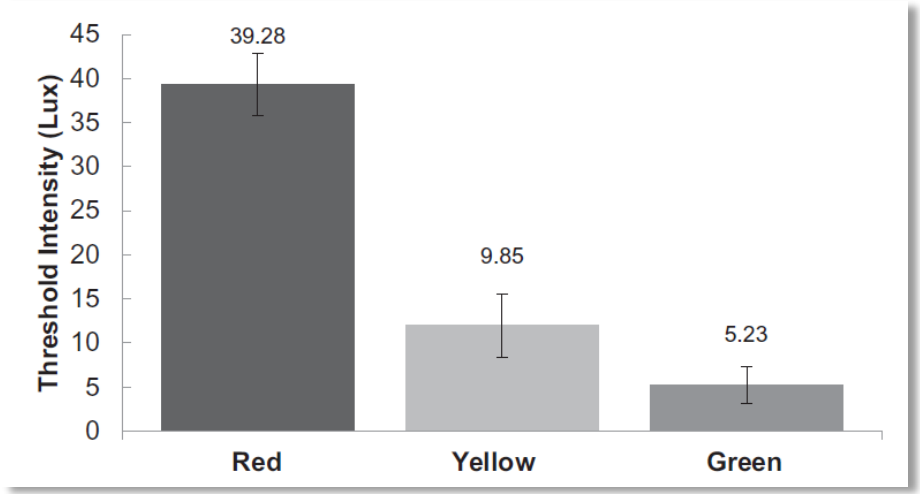
Highly developed along the gulf coast

80-90% hatchling disorientation in some years

Functional Effects

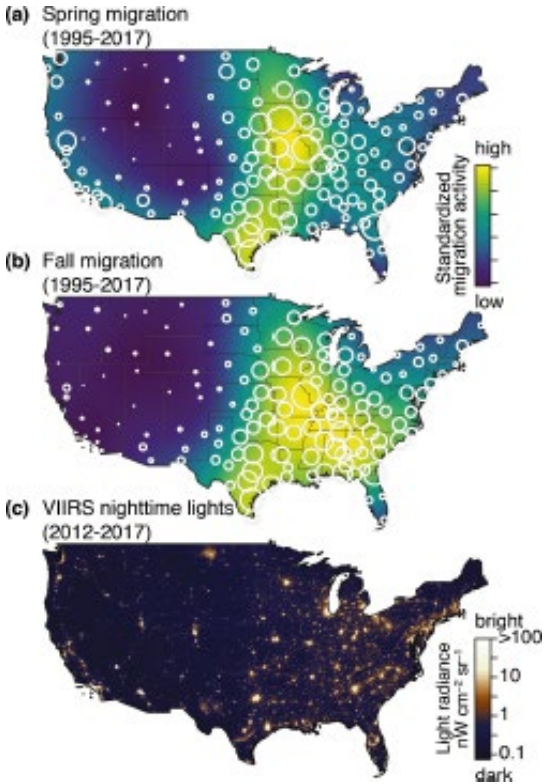


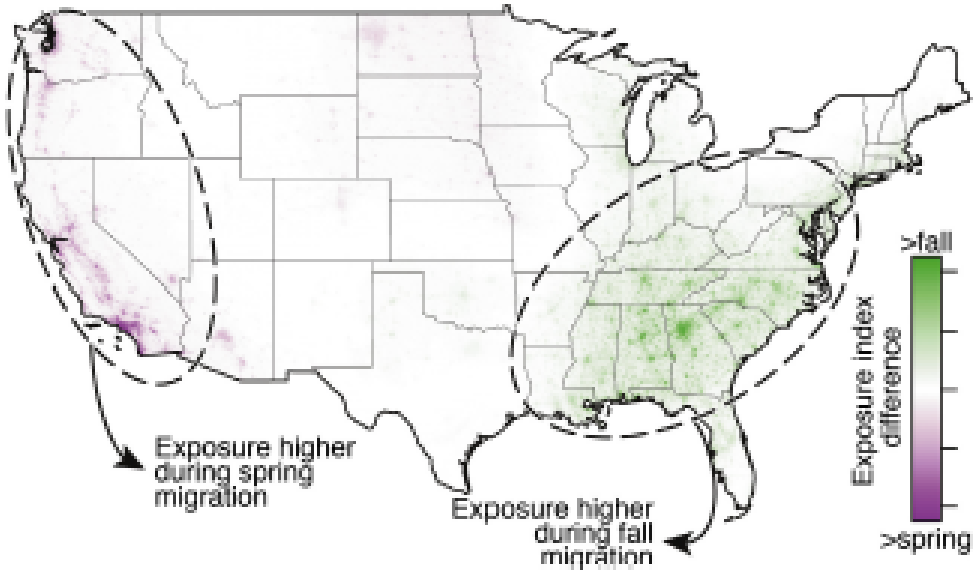
Witherington 1991



Cruz et al. 2018

Functional Effects

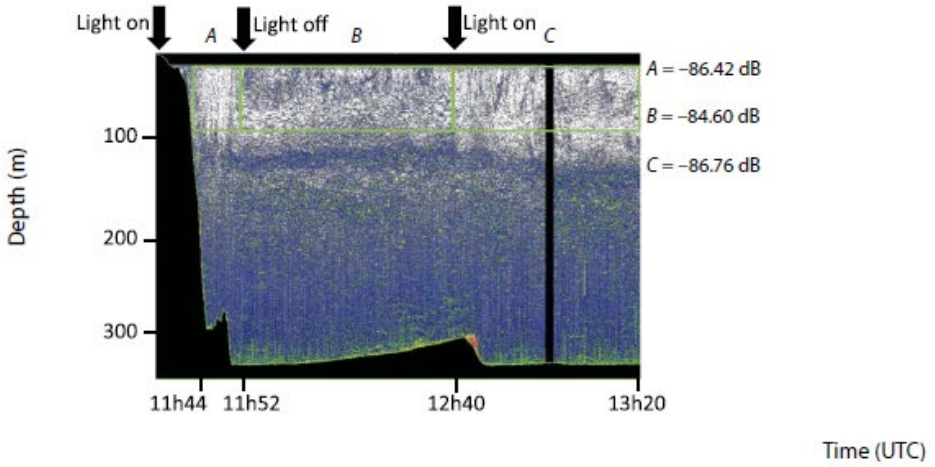


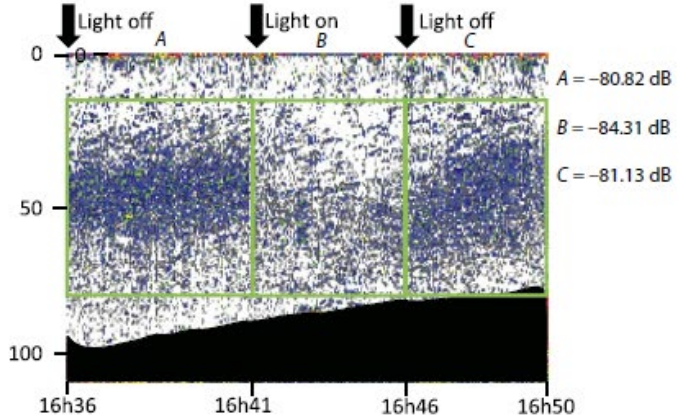


Horton et al. 2019

Functional Effects

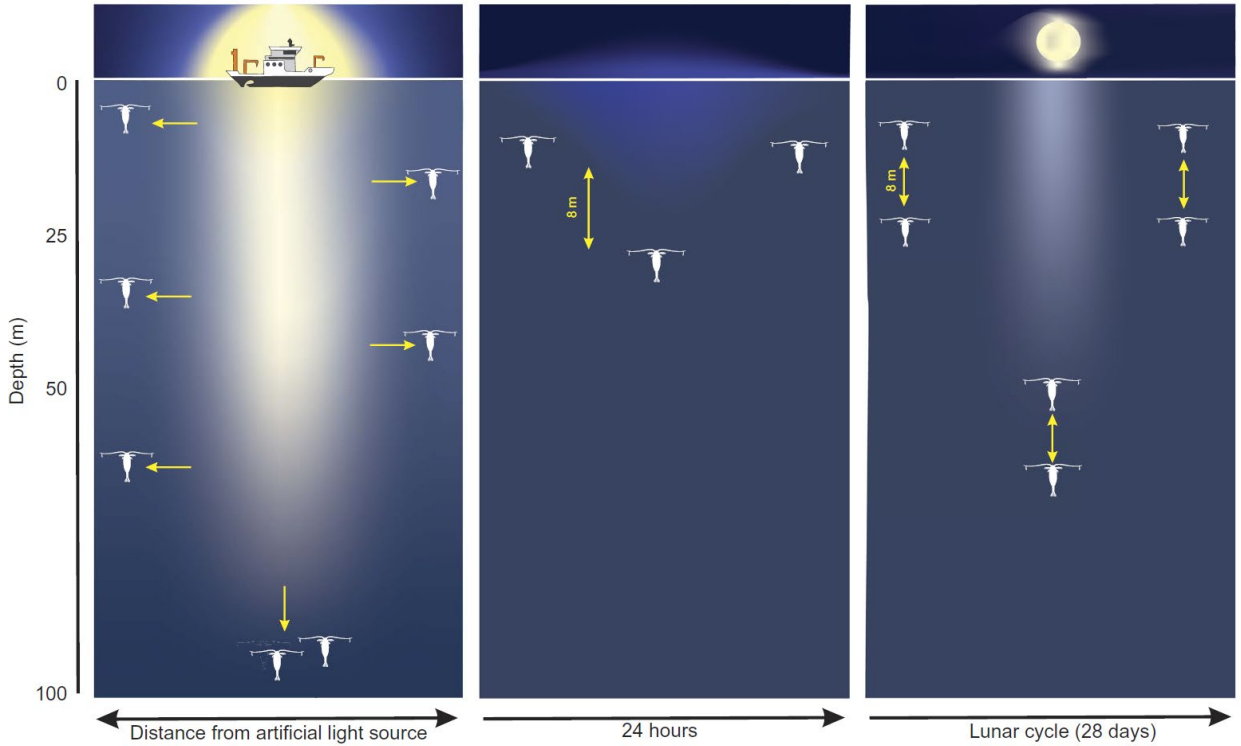
Movement





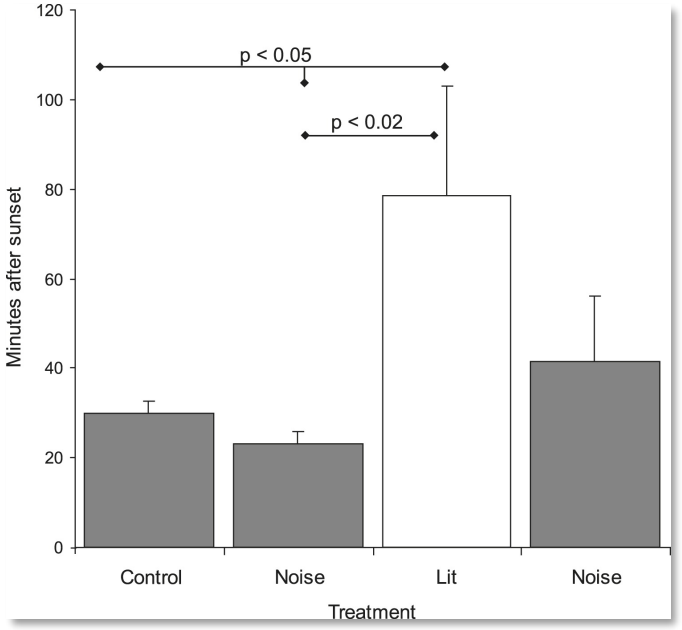
Ludvigsen et al. 2018

Functional Effects



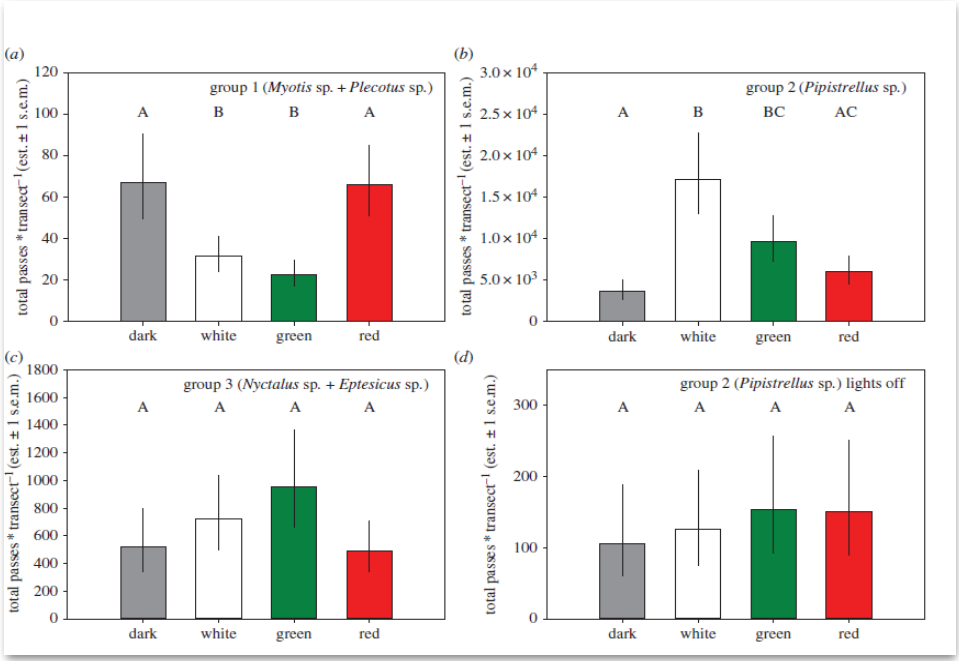
Ludvigsen et al. 2018

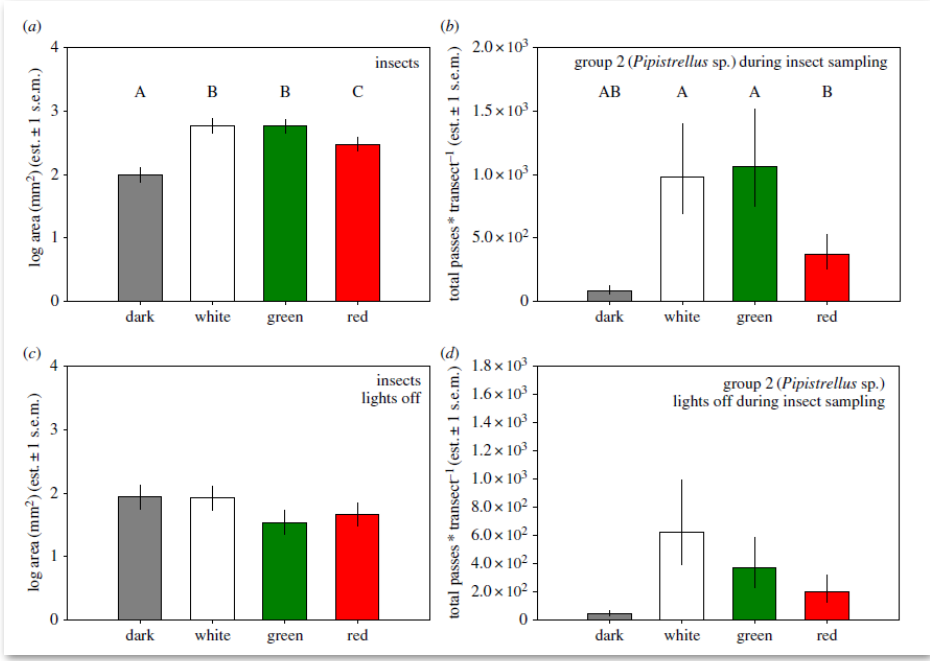
Functional Effects



Stone 2009

Experimental Approach





Spolestra et al.2015

In Summary

Natural sources of light at night are exceedingly dim and slightly red shifted

Animal vision varies across ecological realm, and habitat, niche, and even within species and is manifest in physiology, signal processing, and behavioral response.

Non-natural sources of light have altered the natural day night cycle spatially, temporally, spectrally, and in overall intensity

This novel pressure has effected wildlife cross all taxa at every stage in natural history

Spectra are important, but so is intensity, timing, duration, polarization, and flicker

Future Research

- Connecting spectral radiometry with visual ecology, behavioral ecology, and landscape ecology in controlled field and laboratory experiments
- Consistent approach to measuring and reporting light
- Thresholds and dose response of intensity, and spectrum
- Spectral tuning, spatial control, nuanced timing
- Ecological services (pollination, pest control, disease vector, agriculture)
- Population level effects

Thank You

Literature Cited

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