Coping with light pollution: sleep, stress, and sickness in city songbirds

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Background

- Sleep behavior is a mediator of a large number of important behavioral and physiological processes
- Urban birds tend to initiate dawn song earlier[1] and may therefore lose sleep in the process
- Anthropogenic light pollution in cities and suburbs may be an important driver of extended overnight activity and sleep loss (Fig 1.)
- Effects of overnight lighting on sleep behavior and associated stress, disease susceptibility, and oxidative balance in wild animals is largely unknown

Hypotheses and Predictions

- **Hypothesis:** Artificial night lighting will influence sleep, disease status, oxidative balance and stress physiology
  - **Predictions:** Artificial night-lighting will…
    - Interrupt sleeping behaviors
    - Increase severity of infection by *Isospora* spp. endoparasites
    - Increase glucocorticoids (stress hormones)
- **Hypothesis:** Birds of urban and rural origin will differ in their responses to artificial light at night
  - **Prediction:** Urban birds will be more resilient to night-lighting

Methods

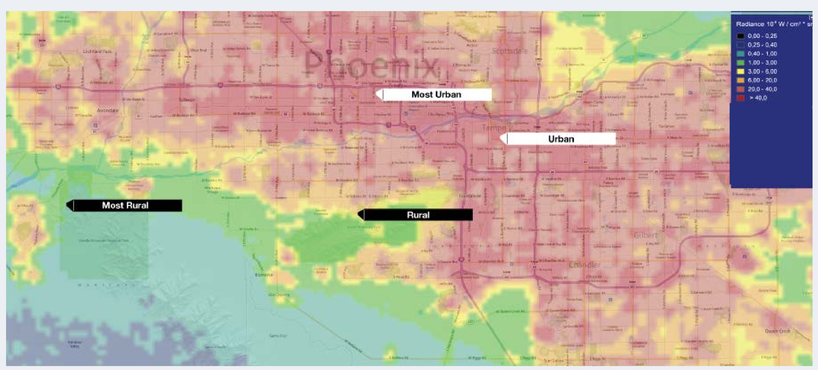


Figure 1. Geographical distribution of study sites in Phoenix, AZ overlaid with light pollution data. Light pollution data are from the NASA Suomi NPP VIIRS satellite (2015). Relative urbanization data is based on previous studies of satellite images (Giraudeau et al. 2014). The sites in order from most to least urbanized are: Downtown Phoenix, Arizona State University - Tempe Campus, South Mountain Regional Park, and Estrella Mountain Regional Park.

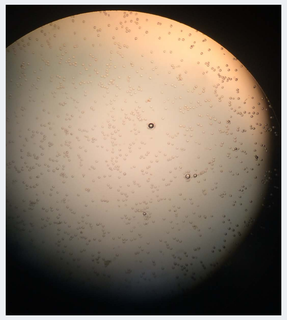


Figure 2. Left: A sample slide from a severely infected bird, filled with Isosporan oocysts which are voided though the feces in the afternoon. Right: A sample plasma chromatogram showing the absorbance spectra at λ = 448 nm, the wavelength of maximum absorbance for many xanthophyll carotenoids.

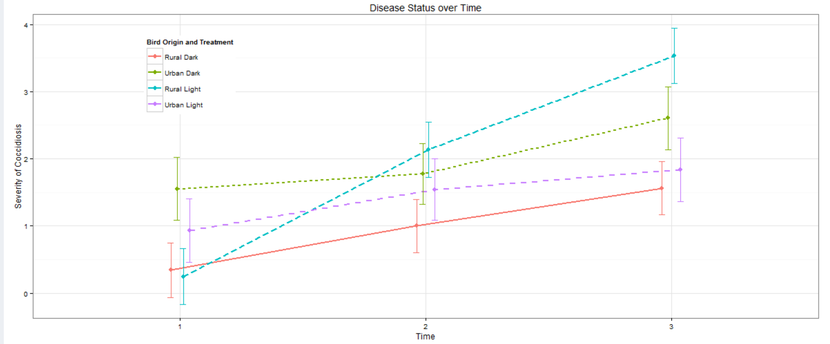
→Captive experiment which exposed (N = 64) house finches (*Haemorhous mexicanus*) of urban and rural origin to ecological low levels of artificial night-lighting over a 4 week period

→ We captured a mixture of ages (hatch-year, after hatch-year) and sexes

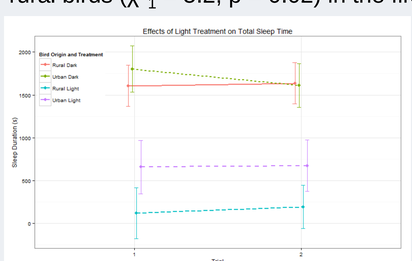
- → Birds were allowed to acclimate to captivity for two weeks before experimental treatment began
- → Night behaviors recorded with infrared cameras
- → We sampled feces for *Isospora* oocyts (see Fig. 2) at capture (Week 0), and beginning (Week 2), middle (Week 4) and end of experiment (Week 6)
- → A feather was plucked at the beginning of treatment and allowed to regrow for glucocorticoid (corticosterone) assays

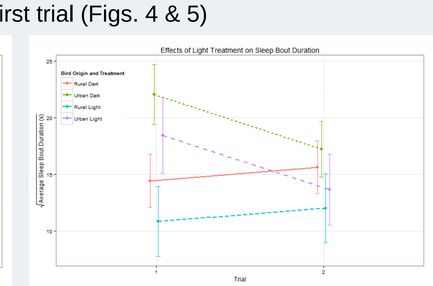
Results

DISEASE: Light-treated, and especially rural light-treated, birds became more severely infected. Rural light-treated birds had more rapid increases in infection severity (Fig. 3; Type III Wald χ^2: $\chi^2_1 = 4.12$, $p = 0.04$*)

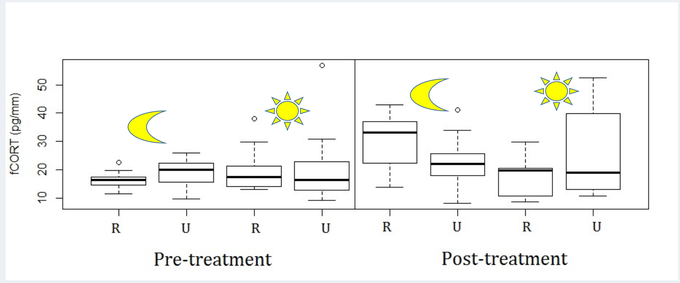


SLEEP: Light treatment reduced total sleep time ($\chi^2_1 = 15.8$, $p < 0.001$*), but did not affect urban and rural birds differently ($p > 0.4$). Light treatment did not affect sleep bout time ($p > 0.2$), but urban birds had longer sleep bouts than rural birds ($\chi^2_1 = 5.2$, $p = 0.02$) in the first trial (Figs. 4 & 5)





STRESS: Only rural birds kept under natural photoperiod increased in feather CORT (fCORT; $\chi^2_1 = 7.75$, $p = 0.005$*; Fig. 6)



Conclusions

- ***Urban birds appear to have plastically/adaptively responded to some consequences of light exposure, but not others***
- *When exposed to night-light, rural birds were more susceptible to disease than urban birds*
  - Melatonin secretion is dependent on exposure to darkness, and regulates immunity[2], so this may be the neuroendocrine mechanism underlying this effect
- *Light treated birds slept less, but did not differ in how long they slept once they were asleep*
  - Light may interrupt the ability to initiate sleep, as opposed to interrupting sleep once it has begun
  - Whether light-treated birds compensate for sleep loss during the day (i.e. via reduced activity, daytime napping) is unknown
- *Light treatment increased stress hormones only for rural birds under natural photoperiod*
  - Suggests light pollution interrupts normal stress physiology, and may reflect chronic stress in rural light-treated birds
  - Urban birds did not show the same trend, suggesting they have overcome the effects of light pollution on stress physiology

References and Acknowledgments

REFERENCES: 1. Kempenaers B. et al. 2010. Current Biology 20:1735-39. 2. Jones TM et al. 2015. Phil Trans B 370:20140122. 3. Hasegawa et al. 2014. Behavioral Ecology 25(3): 641-649. 4. Isaksson C et al. 2005. Ecohealth 2(2): 138-146. **Acknowledgements:** We thank Cole Dellisanti, Kyle Glew, Spencer Cahalan, and Jake Besch-Stokes for help with husbandry and analyses. We thank the DACT and IACUC staff for their help.

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