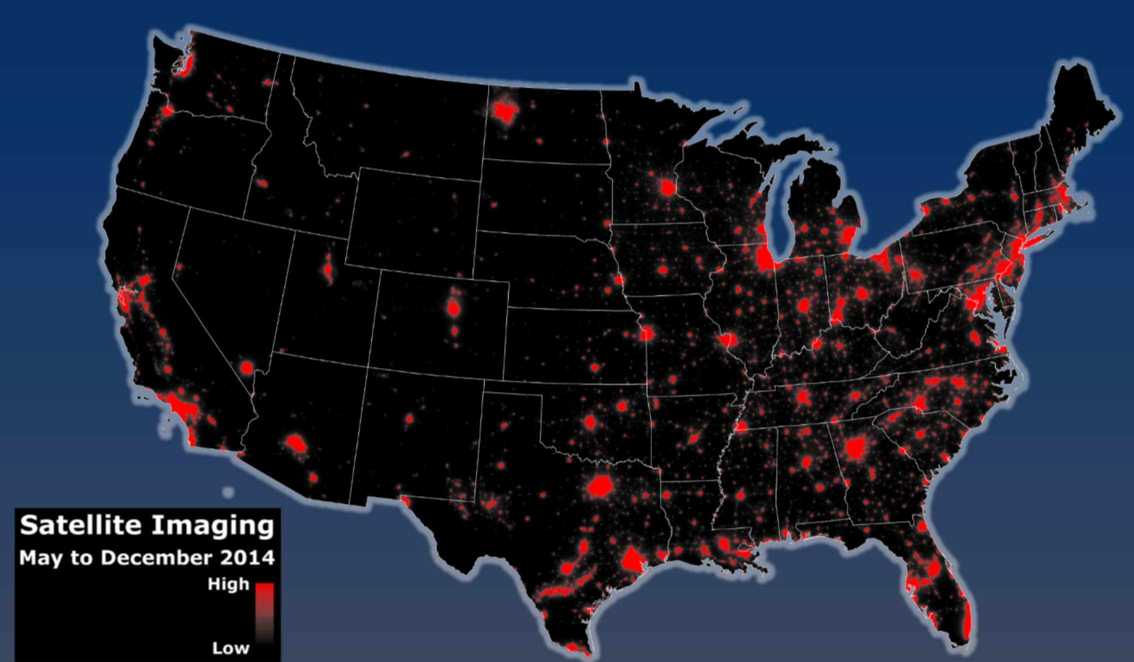
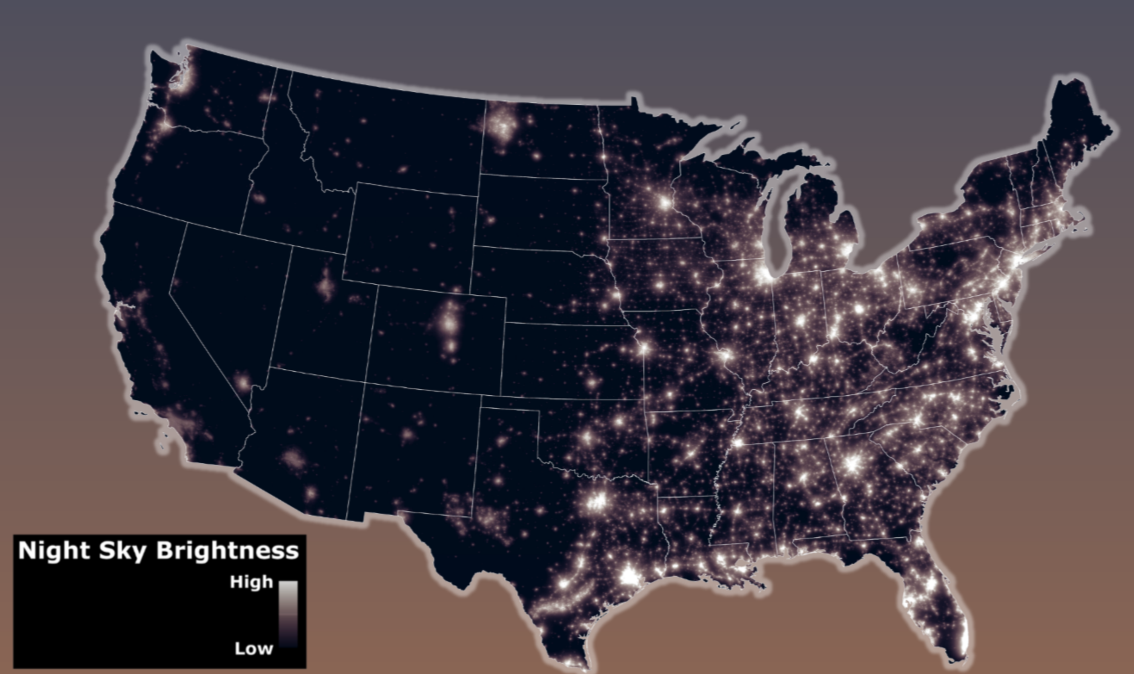
Does light pollution impact the flash color or activity time of *Photinus pyralis* fireflies?

INPUT MAPS

Average of 2000 to 2014 summer cloud cover data, assembled from satellite photographs. "Cloud cover" is the percentage of days cloudy enough to have been flagged as such by the MOD09 cloud algorithm.



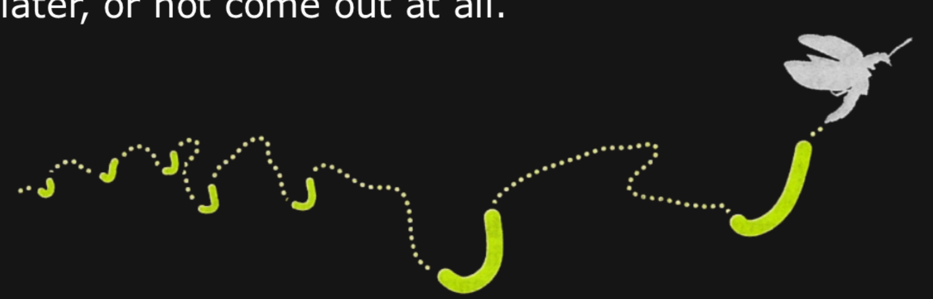
Estimates of zenith radiance given in mcd/m^2. Artificial light data comes from satellite photographs taken on cloud-free nights in 2014. Propagation of this light through the atmosphere has been estimated with a mathematical model calibrated by Sky Quality Meter measurements taken on the ground.



INTRODUCTION

Dusk-active fireflies, like the big dipper firefly, *Photinus pyralis*, emit yellower flashes than their exclusively nocturnal relatives (Lall *et al.* 1980); because green background foliage is more visible at dusk, yellow flashes stand out more than green ones. Average flash color varies between *P. pyralis* populations (Hall *et al.* 2016). The reason for this variation is not yet fully understood, but it may, again, have to do with ambient light conditions…

Street lamps, house lights, etc. artificial light sources may interfere with the exchange of firefly courtship signals by reducing visibility. In addition, illumination of the night sky ("skyglow") can alter the color and intensity of ambient light (Falchi *et al.* 2016), and the effect will be greatly enhanced in cloudy habitats (Kyba *et al.* 2011). If things get *too* bright, some fireflies may decide to come out later, or not come out at all.



METHODS

Clouds can increase skyglow by up to 10× in urban areas (Kyba *et al.* 2011). I used the raster calculator to combine the cloud cover raster on the top left, reclassed from 1 to 10, with the raster of artificial light on the left, to make a comprehensive raster of "relative summer night sky brightness" shown on the bottom left (also from 1 to 10).

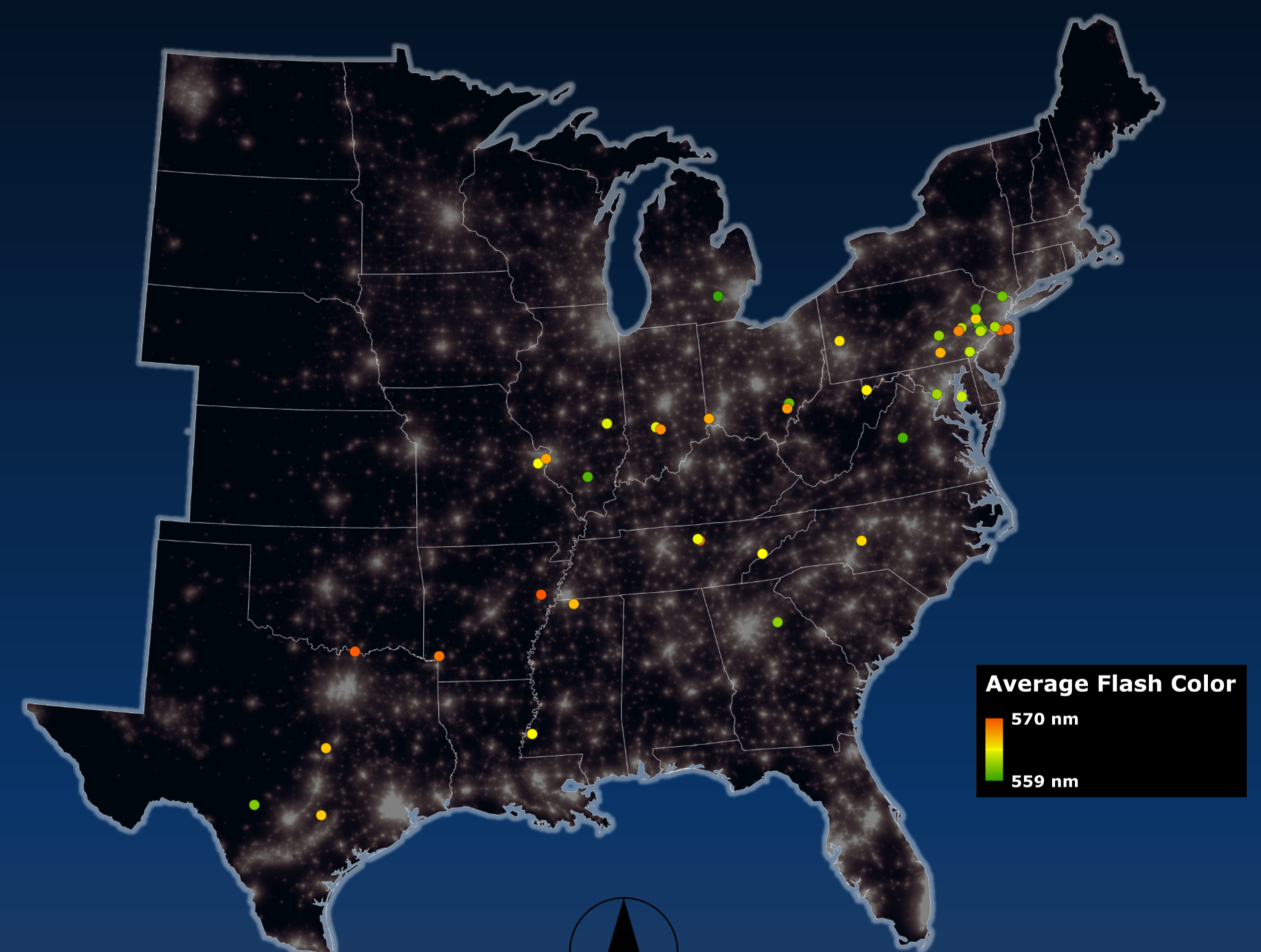
I then plotted two sets of *P. pyralis* data by their GPS coordinates: flash color by population (Hall *et al.* 2016), and the time of citizen science observations (Firefly Watch). To calculate relative night sky brightness around these areas, I made an undissolved 1 km buffer layer, and averaged the raster values within these buffers. I then joined the two resulting tables with the original data, and performed a linear regression, the results of which are displayed on the far right.

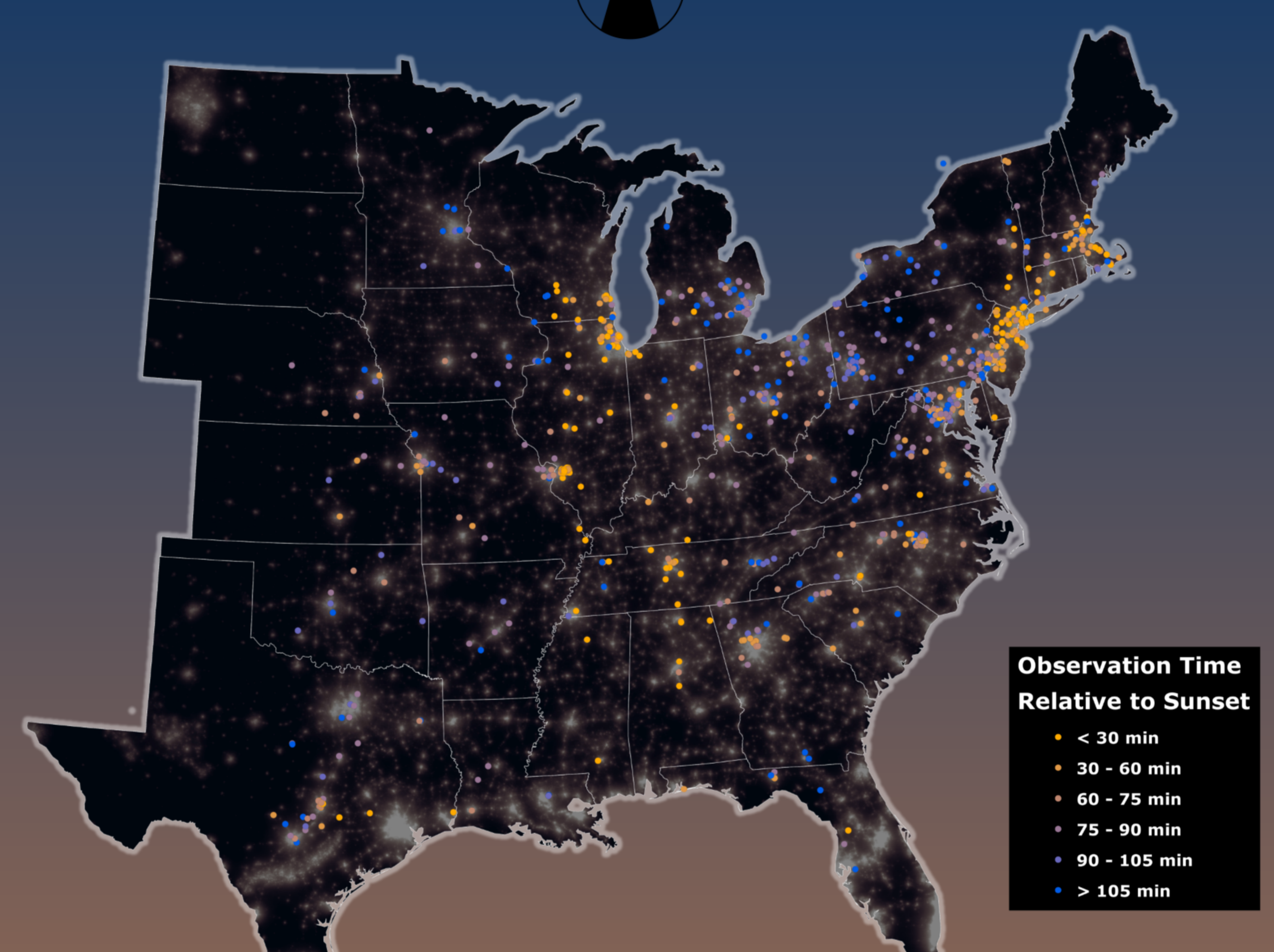
DISCUSSION

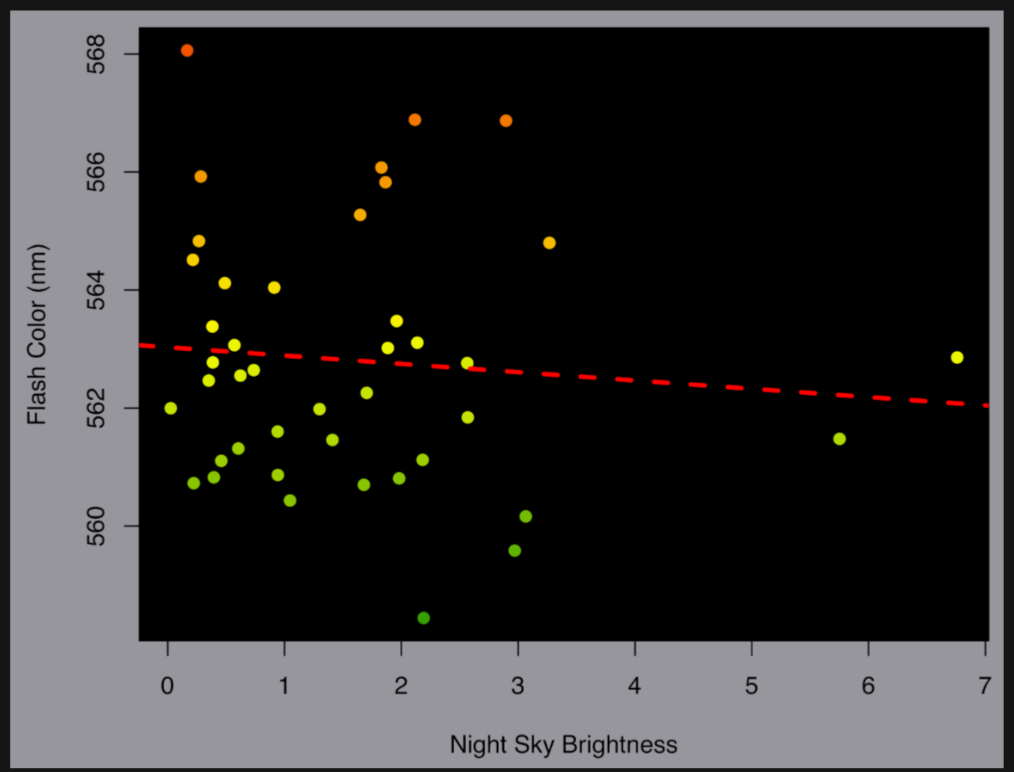
My analyses show that there is no significant effect of artificial night sky brightness on *P. pyralis* flash color or activity time. There is, however, a trend towards greener flashes in more illuminated areas, which makes sense: because light pollution is reddish in color, greener flashes would stand out more vividly against light polluted backgrounds.

The impact of artificial night sky brightness on activity time is completely insignificant. However, the map to the right does show some significant clustering of early observations. This may be due to species differences: though we tried to select for *P. pyralis*, many of the reports come from areas with no record of this species (such as Boston).

OUTPUT MAPS

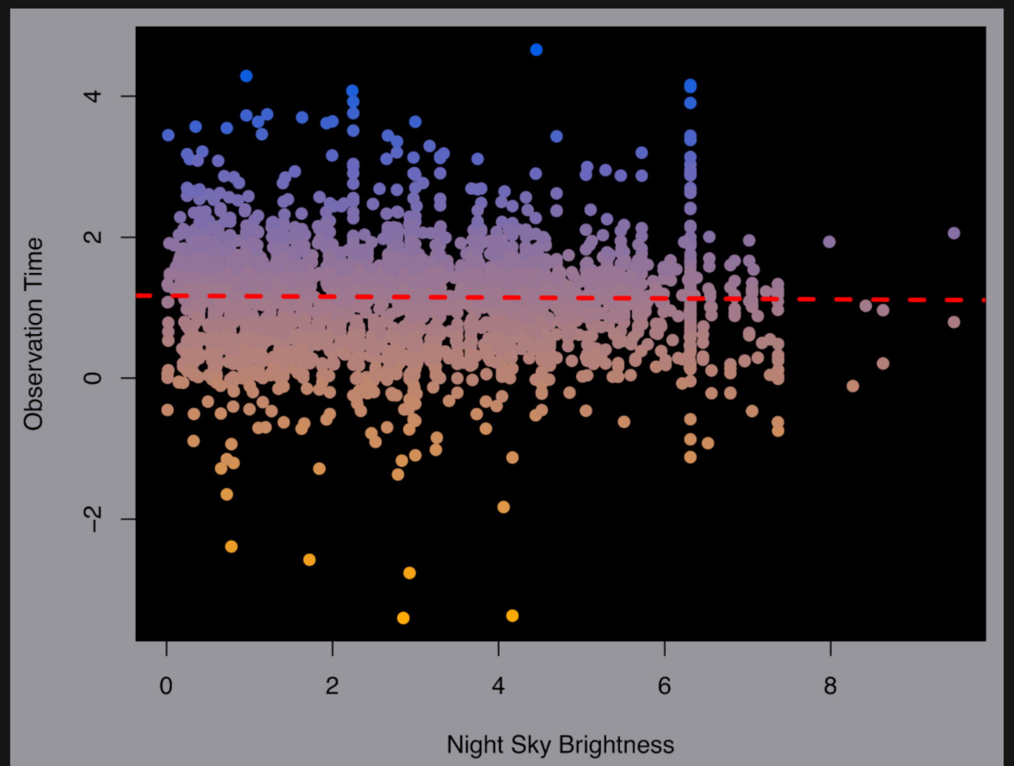






The average flash color of *P. pyralis* populations, measured by spectrophotometer during the 2012 and 2013 summer field seasons, is shown to the left. Each point represents an average of flash data taken from six or more males. The colors of these points are exaggerated to aid visualization, and do not reflect the colors as seen by the human eye.

The scatterplot above shows the relationship of flash color to relative night sky brightness within 1 km of the habitat. It shows a slight, insignificant trend towards greener flashes in more light polluted areas.



All observation data displayed to the left was collected by citizen scientists between 2008 and 2016. To narrow in on *P. pyralis*, I have only showed observations of "J"-shaped single flashes from flying individuals. The color corresponds to the time of the observation (and thus activity time of the fireflies observed) and is given in minutes post-sunset.

The scatterplot above shows the relationship of observation time to relative night sky brightness, again within 1 km, which is insignificant. Although the points to the left appear to be spatially clustered, it is not because of activity time is affected by night sky brightness.

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REFERENCES

1. Falchi F, Cinzano P, Duriscoe D, Kyba CM, Elvidge CD, Baugh K, Portnov BA, Rybnikova NA, Furgoni R. 2016. The New World Atlas of Artificial Night Sky Brightness. *Science Advances* 2 (6):e1600377.

2. Hall DW, Sander SE, Pallansch JC, Stanger-Hall KF. 2016. The Evolution of Adult Light Emission Color in North American Fireflies. *Evolution* 70 (9):2033–48.

3. Kyba CM, Ruhtz T, Fischer J, Hölker F. 2011. Cloud Coverage Acts as an Amplifier for Ecological Light Pollution in Urban Ecosystems. *PloS ONE* 6 (3):e17307.

4. Lall AB, Seliger HH, Biggley WH, Lloyd JE. 1980. Ecology of Colors of Firefly Bioluminescence."*Science* 210 (4469):560–62.

5. Wilson AM, Jetz W. 2016. Remotely Sensed High-Resolution Global Cloud Dynamics for Predicting Ecosystem and Biodiversity Distributions. *PLoS Biology* 14 (3):e1002415.

DATA SOURCES

1. The World Atlas of Artificial Night Sky Brightness (Falchi *et al.* 2016)
2. EarthEnv Global 1-km Cloud Frequency Version 1 (Wilson and Jetz 2016)
3. *Photinus pyralis* flash peak wavelength data (Hall *et al.* 2016)
4. *Photinus pyralis* citizen science data (Boston Museum of Science Firefly Watch)
5. 2010 U.S. census boundaries (ESRI)

PROJECTION: USA Contiguous Albers Equal Area Conic

COORDINATE SYSTEM: GCS WGS 1984