A Spatial Analysis Of Sky Brightness in International Dark Sky Association Designated United States National Parks

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Abstract

The purpose of my study is to determine the effectiveness and meaning of a Dark Sky Designation from the International Dark Sky Association (IDA). This study is important because depending on the results, it can be used to help certain areas attract stargazing tourists, or help decide a certain city whether going through the steps for a designation is worth it. The light pollution levels in similar areas, some with IDA Dark Sky designation and some without, will be compared using geographic information systems and ANOVA statistical analysis. I hypothesize that the areas with IDA designation will have higher light pollution levels. Data will be collected and put together using Geographic Information Systems. The data should indicate whether the designation has a correlation with light pollution levels.

Figure 1: The first Dark Sky Reserve in the United States, Central Idaho Dark Sky Reserve

Introduction

Light pollution is the presence of artificial light in the night time environment. It is mainly caused by excessive and misdirected use of light, but can be affected by moderated lighting as well. Artificial lighting has been used for thousands of years, and it can very easily accumulate over and light pollution is a problem that has only been brought to our attention recently; despite the increasing interest among scientists in fields such as ecology, astronomy,

healthcare, land use planning, light pollution lacks a current quantification of its magnitude on a global scale.

Light pollution can lead to grave ecological and health consequences. Along with decreased visibility of the night sky, light pollution disrupts ecosystems and can cause human health ailments. In 2004, Longcore and Rich published “Ecological light pollution” which supported the idea that light pollution could alter ecosystems and natural light routines for animals. This study was significant because it was the first to support hypothesized effects such as effects on animal migration patterns, seasonal behaviors, and reproduction. “Lighting for the human circadian clock: recent research indicates lighting has become a public health issue.” written by Pauley in 2004 supported the hypothesis that artificial light suppresses melatonin secretion, which could possibly have an effect on breast cancer rates.

The goal of my study is to find if there is a difference between similar state parks and public areas with and without IDA designation and the light pollution levels in those areas. This comparison will be done through geographic information systems, specifically QGIS. A geographic information system (GIS) is a framework for capturing and analyzing spatial data. I will then use QGIS statistics tools to find the mean, maximum, minimum, and standard deviations of the quantitative light pollution levels of each national park.

In 1973, Reigel published “Light pollution: Outdoor lighting is a growing threat to astronomy”. This article was used to explain that artificial outdoor light covers celestial objects like stars and planets, and to draw attention to the rapid growth rates of light pollution. In 2010, workers at the Royal Astronomical Society published “The Contribution of Street Lighting to Light Pollution” which found that street lighting has a large impact on sky brightness.

“Worldwide Variations in Artificial Skyglow” published by Kyba and colleagues in 2015 brought awareness to the disparities in light pollution levels in different countries.

If my hypothesis is supported and the areas with IDA designation have higher light pollution levels, the results of my study can be used as an insight into whether going through the designation process is worth it for certain cities or nature preserves to go through. The results could also help tourists decide whether IDA designation should be a deciding factor on where they go on vacation or for leisure activities.

Methodology

I will be using a Geographic Information System (GIS) called QGIS to map previously collected skyglow data onto two layers containing all U.S. National Parks, one layer including parks with IDA designation, one layer without. The collected skyglow data is the World Atlas of Artificial Night Sky Brightness from 2016. QGIS will offer statistics such as the mean, medium, minimum and maximum levels, and standard deviations for the two different layers.

References

Bagrov, A., Leonov, V., Attia, G., & Ghoneim, R. (2014). Modern problems of meteoric astronomy and possible ways of their solutions. *NRIAG Journal Of Astronomy And Geophysics*, *3*(1), 1-6. doi: 10.1016/j.nrjag.2014.01.001

Baker, B.J. & Richardson, J.M.L. (2006) The effect of artificial light on male breeding‐season behaviour in green frogs, *Rana clamitans melanota*. *Canadian Journal of Zoology*, 1528– 1532.

Benfield, J., Nutt, R., Taff, B., Miller, Z., Costigan, H., & Newman, P. (2018). A laboratory study of the psychological impact of light pollution in national parks. *Journal Of Environmental Psychology*, *57*, 67-72. doi: 10.1016/j.jenvp.2018.06.006

Bennie, J., Davies, T., Duffy, J., Inger, R., & Gaston, K. (2014). Contrasting trends in light pollution across Europe based on satellite observed night time lights. *Scientific Reports*, *4*(1). doi: 10.1038/srep03789

Bennie J, Davie TW, Cruse D, Gaston KJ. (2016). Ecological effects of artificial light on wild plants. *J. Ecol*. 104, 611–620.

Bennie, J., Duffy, J., Davies, T., Correa-Cano, M., & Gaston, K. (2015). Global Trends in Exposure to Light Pollution in Natural Terrestrial Ecosystems. *Remote Sensing*, *7*(3), 2715-2730. doi: 10.3390/rs70302715

Bertolotti, L. & Salmon, M. (2005) Do embedded roadway lights protect sea turtles? *Environmental Management*, 36, 702– 710.

Cinzano, P., & Falchi, F. (2014). Quantifying light pollution. *Journal Of Quantitative Spectroscopy And Radiative Transfer*, *139*, 13-20. doi: 10.1016/j.jqsrt.2013.11.020

Davies TW, Bennie J, Gaston KJ. (2012) Street lighting changes the composition of invertebrate communities. *Biol. Lett.* 8, 764–767.

ffrench-Constant, R., Somers-Yeates, R., Bennie, J., Economou, T., Hodgson, D., Spalding, A., & McGregor, P. (2016). Light pollution is associated with earlier tree budburst across the United Kingdom. *Proceedings Of The Royal Society B: Biological Sciences*, *283*(1833), 20160813. doi: 10.1098/rspb.2016.0813

Falchi, F., Cinzano, P., Elvidge, C., Keith, D., & Haim, A. (2011). Limiting the impact of light pollution on human health, environment and stellar visibility. *Journal Of Environmental Management*, *92*(10), 2714-2722. doi: 10.1016/j.jenvman.2011.06.029

Falchi, F., Furgoni, R., Gallaway, T., Rybnikova, N., Portnov, B., & Baugh, K. et al. (2019). Light pollution in USA and Europe: The good, the bad and the ugly. *Journal Of Environmental Management*, *248*, 109227. doi: 10.1016/j.jenvman.2019.06.128

Falchi, Fabio; Cinzano, Pierantonio; Duriscoe, Dan; Kyba, Christopher C. M.; Elvidge, Christopher D.; Baugh, Kimberly; Portnov, Boris; Rybnikova, Nataliya A.; Furgoni, Riccardo (2016): Supplement to: The New World Atlas of Artificial Night Sky Brightness. V. 1.1. GFZ Data Services. https://doi.org/10.5880/GFZ.1.4.2016.001

Gallaway, T., Olsen, R., & Mitchell, D. (2010). The economics of global light pollution. *Ecological Economics*, *69*(3), 658-665. doi: 10.1016/j.ecolecon.2009.10.003

Garrett, J., Donald, P., & Gaston, K. (2019). Skyglow extends into the world's Key Biodiversity Areas. *Animal Conservation*. doi: 10.1111/acv.12480

Gaston KJ, Davies TW, Bennie J, Hopkins J. 2012Reducing the ecological consequences of night-time light pollution: options and developments. *J. Appl. Ecol.* 49, 1256–1266. (doi:10.1111/j.1365-2664.2012.02212.x)

Heidmann, J. (1998). SETI from the Moon: Avoiding Radio Pollution for Future Radio-Astronomy. *Highlights Of Astronomy*, *11*(2), 996-999. doi: 10.1017/s1539299600019419

Hölker, F., Wolter, C., Perkin, E.K. & Tockner, K. (2010a) Light pollution as a biodiversity threat. *Trends in Ecology and Evolution*, 25, 681– 682.

Hölker, F., Moss, T., Griefahn, B., Kloas, W., Voigt, C., & Henckel, D. et al. (2010). The Dark Side of Light: A Transdisciplinary Research Agenda for Light Pollution Policy. *Ecology And Society*, *15*(4). doi: 10.5751/es-03685-150413

Kuechly, H., Kyba, C., Ruhtz, T., Lindemann, C., Wolter, C., Fischer, J., & Hölker, F. (2012). Aerial survey and spatial analysis of sources of light pollution in Berlin, Germany. *Remote Sensing Of Environment*, *126*, 39-50. doi: 10.1016/j.rse.2012.08.008

Kyba, C., 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. doi: 10.1371/journal.pone.0017307

Kyba, C. C. M., Tong, K. P., Bennie, J., Birriel, I., Birriel, J. J., Cool, A., … Gaston, K. J. (2015). Worldwide variations in artificial skyglow. *Scientific Reports*, *5*(1). https://doi.org/10.1038/srep08409

Marchant, P.R. (2004) A demonstration that the claim that brighter lighting reduces crime is unfounded. *British Journal of Criminology*, 44, 441– 447.

Ouyang, J., de Jong, M., van Grunsven, R., Matson, K., Haussmann, M., & Meerlo, P. et al. (2017). Restless roosts: Light pollution affects behavior, sleep, and physiology in a free-living songbird. *Global Change Biology*, *23*(11), 4987-4994. doi: 10.1111/gcb.13756

Paul, N.D. & Gwynn‐Jones, D. (2003) Ecological roles of solar UV radiation: towards an integrated approach. *Trends in Ecology & Evolution*, 18, 48– 55.

Pawson, S., & Bader, M. (2014). LED lighting increases the ecological impact of light pollution irrespective of color temperature. *Ecological Applications*, *24*(7), 1561-1568. doi: 10.1890/14-0468.1