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National Park Service, Fish & Wildlife Service, and DOE Solid-State Lighting Program:

Wildlife Responses to Light R&D Meeting

December 2022

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Disclaimer

DOE Solid-State Lighting Program, "Wildlife Responses to Light Meeting" December 2022

This report was prepared for:

Solid-State Lighting Program
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And

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Comments

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Jesse Barber	Boise State University
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Shigetomo Hirama	Florida Fish and Wildlife Conservation Commission
Travis Longcore	University of California, Los Angeles
Lynn Martin	University of South Florida
Avalon Owens	Harvard University
Jay Penniman	University of Hawaii
Liz Perkin	Native Fish Society
Willem Sillevis Smitt	Lumileds
Yash Sondhi	Florida International University
Rick Utting	Clanton & Associates, Inc.
Jeremy White	National Park Service

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1 Introduction

On December 15, 2022, experts in the field of wildlife responses to light gathered at the invitation of the Fish & Wildlife Service, the National Park Service (NPS), and the Department of Energy (DOE) Solid-State Lighting (SSL) Program for a virtual meeting with four objectives:

1. Highlight research and development (R&D) opportunities for LEDs and animal responses to light
2. Bridge R&D efforts among animal researchers and LED technologists
3. Facilitate collaboration
4. Provide guidance to R&D agencies on this topic

The U.S. DOE SSL Program, National Park Service, and Fish & Wildlife Service have aligned interests in this topic because LED lighting technology provides the opportunity to not only reduce lighting energy consumption but to also reduce the ecological impacts of light. In particular, with LED technology, light at night can be reduced, better targeted, dimmed or turned off when unnecessary, and spectrally tuned to reduce energy consumption and ecological impacts. These considerations and technical capabilities did not exist with previous lighting technologies.

This report summarizes the R&D themes and the discussions. Overviews of the participants' presentations and related remarks are included in Appendix A of the report.

2 Key Findings

The meeting format asked each of the participants to present findings and research directions from their own activities. The presentations and the subsequent discussions identified four key gaps in R&D: research funding and coordination, lighting stimulus characterization, animal responses to light, and human considerations.

2.1 Research Funding and Coordination

Despite the massive growth in the urban footprint and the use of lighting at night over the past several decades, there is relatively little research funding, and thus research, available on animal responses to light. Many factors play into this. One is that research on animal responses to light may be just a small portion of the total research portfolio of animal researchers who are looking at a broad range of physiological and behavioral responses in targeted species. In addition, research on this topic can be isolated since researchers often group themselves by specific animal species or orders rather than by the type of stimulus. Furthermore, animal researchers may be unfamiliar with lighting technology capabilities and characterization of lighting stimulus. Understanding of animal responses to light can be accelerated by coordinating research and comparing understanding across species and orders, including among researchers of human and domesticated animal responses to light.

Improved understanding of natural and anthropogenic light delivery and atmospheric propagation can also highlight linkages between light stimulus and the resulting animal physiological responses. Participants suggested that additional funding opportunities and increased funding levels could accelerate understanding of animal responses to light as well as the means to mitigate the large-scale ecological impacts of anthropogenic light at night. Ongoing coordination activities, such as this meeting, would also provide opportunities to interact with other animal and light researchers and technologists developing lighting technologies.

Action: Identify and share light R&D funding opportunities to understand animal responses, ecological-scale impacts, and implications of increased use at night; continue to coordinate collaborative discussions such as this roundtable.

2.2 Lighting Stimulus Characterization

Often, physiological impacts of light at night are studied at human-based lighting standards. Light levels are characterized in terms of human-based distillations (lumen, lux, footcandles) of the basic lighting properties. When lighting is characterized just in terms of human-based metrics, important basic properties of the lighting stimulus are lost. These include the total irradiance or radiance and spectral power distribution which can better relate to resulting animal responses.

Animals respond to wavelength, intensity, duration, frequency, and timing of light stimuli. At night, naturally occurring light stimuli are typically dim and colorless – according to human perception. However, characterization of nighttime light, including anthropogenic light, at biologically relevant levels and with absolute radiant or photon-based metrics rather than human-based metrics, is critical to relate the lighting stimulus to the animal response and to enable replication of the research.

Natural and anthropogenic night light levels are typically very low compared to daytime and indoor light levels. Specialized tools are often required to directly measure irradiance and spectral power distribution at these light levels. New sensing and spectrometer tools are becoming available but may be expensive, hard to find, and difficult to use.

Action: Support absolute radiometric or photon-metric characterization at biologically relevant light levels to enable replicable studies of light stimulus-animal response relationships. Train and support to animal researchers on measurement and use of absolute metrics at nighttime light levels.

2.3 Animal Responses to Light

There is an ongoing need to improve the understanding of animal responses to light. Studies that explore epidemiological type responses, basic visual perception, navigation and orientation, predator-prey relationships, mating responses, and hormonal responses for a range of species all add to the understanding of animal responses to particular aspects of light – intensity, spectral power distribution, optical distribution, and polarization. Often animal responses to light are characterized solely in terms of response to the spectral distribution of light. There is also a relationship between intensity and spectral power distribution with the resulting animal response. This is why it is critical to characterize the full spectral power distribution as well as the intensity of the light stimuli.

There can be important timing elements with animal responses to light as well. Responses may be different based on the phase of life of the animal. Animals also perceive environment signals based on diel, monthly, and seasonal changes in lighting that can have less direct influence their behaviors. Anthropogenic lighting can obscure these natural light signals which can have intensities well below human perception levels.

Action: Organize animal response to light research results in terms of 1) direct or indirect responses, where direct responses are related to visual activities and indirect responses are related to environmental sensing, and 2) types of responses – basic visual sensitivity, navigation, mating, predator/prey, and hormonal responses.

2.4 Human Considerations

Electric lighting is installed to meet human needs of safety, productivity, reassurance, information display, and more. So, when considering the mitigation of ecological impacts of anthropogenic light at night, the intended function must be considered as well. For example, using monochromatic light might benefit certain animal species, but could degrade the intended function of the light for humans to the point where it is little better than no light at all. It can be difficult to ascertain the extent to which changes to mitigate ecological impacts affect the intended function of lighting. Similar to the need for improved understanding of animal responses to light, research is needed on the human function of light to improve understanding of safety and productivity benefits. This will clarify how human benefits can be balanced against ecological impacts.

In addition to functionality, human reassurance and perception also need to be considered with lighting installations and changes. Not only is it important that lighting changes made to mitigate ecological impacts be safe, but it is also imperative that human users of the relevant systems understand and accept they are safe. If human users feel that their safety or productivity is being harmed for the sake of environmental protection, lighting changes may face resistance.

Action: Support more precise understanding of safety, productivity, reassurance, and security functions under different lighting conditions to determine trade-offs between the intended human function and the ecological impacts.

Appendix A: Participant Presentations

Jeremy White, National Park Service: Wildlife and Lighting

NPS has been very active in external review of onshore and offshore windfarm projects with a goal to help mitigate and minimize anthropogenic light. Turbines are required to have lighting systems for safety reasons, so the NPS has been advocating for the use of aircraft detection lighting systems (ADLS) that minimize the impact of required lighting on wind turbines. The ADLS systems are one of the best mitigation tools for reducing total light output. The NPS has also been successful in requesting the use of monochromatic red blinking lights instead of steady burn lights, which has helped mitigate the light impact on national parks. NPS is also working with the Deep Water Horizon Recovery Fund to restore night sky resources at Gulf Islands National Seashore in Florida and Bon Secour National Wildlife Refuge in Alabama. Work includes baselining and modeling skyglow in Phase I and providing targeted lighting plans for adjacent communities and lighting retrofit incentives in Phase II. A third activity of NPS involves assessing outdoor lighting in regions affecting the Northern Long-Eared bats, which are now listed as an endangered species.

Joelle Gehring, Fish & Wildlife Service: Lighting and Migratory Birds

Population losses in migratory birds in the past 50 years are staggering, with a 28% population loss since 1970. In the same timeframe, grassland bird populations have decreased 53%. The largest contributor to fatalities is glass collisions, which kill nearly 1 billion birds every year. Congress is addressing bird collisions on federal property, requiring that interior lights be turned off at night and films be applied to glass windows to reduce collisions. Further guidance indicates that interior plants should be moved away from windows, exterior lighting should be minimized and directed downwards, and timers or motion sensors on lighting should be installed. Another contributor to bird mortality is communications towers. Research indicates that eliminating non-flashing lights on towers saves nearly 7 million birds in the USA and Canada every year.

Travis Longcore, University of California, Los Angeles: 2022 Animal Responses to Light Research Update

Travis Longcore discussed the topic of light pollution and its impact on wildlife, including animal movement and animals' ability to connect across landscapes. Longcore worked on the design of an overpass over a Southern California freeway. The project includes strategies to reduce light pollution and takes into consideration the impact of LED lights on wildlife. He also presented research funded by Caltrans that looks into the impacts of light pollution on wildlife and how LED lights can impact different species. Longcore summarized his talk by noting that the sensitivity to different spectra varies greatly among species and that it may be challenging to produce a general strategy for mitigating light pollution.

Jesse Barber, University of Idaho: Mitigating the costs of light pollution for people and wildlife

Barber discussed two active projects, one focused on solar-powered streetlights in the Pioneer Mountains and the other in Grand Teton National Park. The first project examines the effects of light pollution on moth and bat populations, while the second project is aimed at reducing light pollution in the national park by converting streetlights to more insect-friendly lights. The Grand Teton project has taken many years due to funding challenges and is still ongoing, but the results of the street light conversion project have shown promise in reducing insect attraction and altering bat behavior.

Lynn Martin, University of South Florida: Does artificial light at night (ALAN) affect responses to West Nile virus in a wild bird? YES!

Artificial light at night (ALAN) affects West Nile virus responses in wild birds. Experiments show that birds exposed to artificial light for a period of several days before exposure to West Nile had higher viral loads and remained infectious for several days longer than controls. However, in examining chicken populations across Florida, light pollution appeared to be a strong predictor of West Nile virus exposure. Essentially, as radiance levels increase, West Nile virus cases decrease.

Avalon Owens, Harvard University: The Owens laboratory studies how organisms & ecosystems cope with artificial light at night

Avalon Owens presented research on the impacts of light pollution on fireflies. Fireflies are becoming a larger source of tourism and funding for national parks. They motivate people to visit these parks at night. The impact of artificial light sources on fireflies has been studied. Findings show that males are more likely to respond to real females in darkness, rather than those lit up by streetlights. The delay in mating caused by artificial light sources has been found to be costly, as it affects the number of fireflies that can thrive in an area and the length of time they survive.

Yash Sondhi: The effects of light pollution on circadian activity of moths

Sondhi discussed the impact of light pollution on the circadian biology of insects, specifically moths. Variations in external light can affect the behavior of animals, such as their food, mating, and sleeping patterns. However, it is difficult to measure non-model species' circadian rhythms, as the tools that exist today are expensive and mostly designed for lab use. Sondhi presented a low-cost and portable solution developed to measure the motion of insects in the field. The system is comprised of a small camera that uses infrared light and has low power requirements. The camera allows observation of the activity of insects in a localized area with or without external light. It was found that moth activity is influenced by ALAN and while spectrum matters, intensity is more important.

Eric Abelson, University of Texas, Austin

Abelson works at the intersection of sensory ecology, animal behavior, and wildlife conservation, with a focus on large body terrestrial animals. His research looks at the effects of nighttime light on wildlife, specifically pumas and their road crossings. Wildlife-vehicle collisions have serious consequences, including billions of dollars in property damage, hundreds of hospitalizations, and a high number of animal fatalities. Many of the species affected are federally listed.

Abelson has used radio-collar data to track the movements of 17 pumas in the Santa Monica Mountains to identify their road-crossing locations. Findings showed that most road crossings occur at night. The research aims to understand the impact of various environmental factors, such as olfactory perception, visual perception, and nighttime light pollution, on the behavior of wildlife in human-altered landscapes.

Liz Perkin, Native Fish Society: River Ecosystems & Light

Perkin focuses on aquatic ecosystems, particularly on insects like mayflies, caddisflies, and stoneflies and the fish that feed on them. Aquatic insects are important food sources for other species like birds and bats when the insects emerge as adults. In her research, she has added artificial lights to forest streams in British Columbia to study their effect on the insect and fish behavior in the aquatic environment. The results showed that the presence of lights significantly reduced the number of insects drifting at night, affecting food webs and fish populations.

Jay Penniman, University of Hawaii: Seabirds

Penniman discussed the impact of artificial light on seabirds and turtles, including their navigation by the stars, moon, and earth's magnetic field. Fledglings are vulnerable to being overwhelmed by lights used by humans at night. Turtles are also distracted by short wavelength light. Penniman noted the impact of different light spectra on seabirds, with petrels, shearwaters, and storm-petrels being the most impacted species. Some successful examples of reducing light pollution include the implementation of low spectral red light in the North Sea and the adoption of the standard in Chile. More research is needed to clearly identify the role of spectral content in seabird distraction, but the general recommendation based on available evidence is reducing short wavelength spectral content.

Shigetomo Hirama, Florida Fish and Wildlife Conservation Committee: Environmental factors predicting the orientation of sea turtle hatchlings on natural and lighted beaches

Shigetomo Hirama discussed the environmental factors that affect sea turtle hatchling disorientation along the Florida coastline. Data was collected from four different beaches, including both light and dark beaches. Variables such as distance from nest to dune, humidity, slope, angle from nest to top of dune, and light were measured. The results show that the distance from the nest to the dune was the most significant factor in all the top models for both light and dark beaches, and light was less important to hatchling disorientation than expected.

Rick Utting, Clanton & Associates: Lighting Zone Updates

Rick Utting is working with cities and counties to help draft and adopt lighting ordinances to help developers make better lighting choices. The purpose of lighting zones is to protect the natural environment from unintended consequences of excessive or misapplied anthropogenic light. He is leading a task group to evaluate the current lighting zone definitions within the International Dark-Sky Association (IDA) and recommend improvements to make it easier for users to adopt and apply lighting standards. The task group is focusing on aligning the IDA lighting zone definitions with the International Commission on Illumination (CIE) standards. They are also adding a purpose statement to explain the reasoning behind lighting zones.

Willem Sillevis Smitt, Lumileds: Reducing impacts for Wildlife

Smitt discussed spectral distributions in the LED lighting industry. Reviewing a subset of commercially available spectral distributions, he noted the difference in spectrum and perceived white. He also noted the importance of response curves, including the melanopic curve for human circadian rhythms and the scotopic curve for human night vision. In the melanopic curve, there is a clear trend that the higher the CCT, the higher the melanopic ratio in the light. Also, lower color rendering index (CRI) lights have lower melanopic ratios. Some specifications for lighting require a blue content of less than 2%, but the LED lights shown do not meet this requirement.

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