

2023 Spring Experimental Analysis of Light Pollution Impacts on Glow-worm and Moths Using Machine Learning and XAI

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Abstract

There is a well-known issue with light pollution, which has negative effects on the well-being of humans, animals, and plants. One of the major consequences of this is the attraction of nocturnal insects to artificial light sources, which can be fatal to them. Glow worms and moths are two of the nocturnal insects that show a maladaptive response to artificial light. To evaluate the effects of light pollution on insects, we did an experimental analysis of the data of glow worms and moths using different machine learning and deep learning algorithm. we have also included Explainable AI to explain and interpret the models' predictions.

1 Introduction

A type of light source that is produced by humans and utilized for a number of reasons is known as artificial light. Contrary to natural light sources like the sun, artificial lights can be turned on and off at will, and their brightness and color temperature can be changed to accommodate a variety of requirements and tastes. Typical kinds of artificial lighting include halogen lamps, LEDs, fluorescent tubes, and incandescent bulbs. Artificial lights play a significant role in modern society by allowing us to work and live peacefully at all hours of the day and night. They are widely used in homes, workplaces, public spaces, and industrial settings to provide illumination for various tasks and activities.

Despite being a benefit to modern civilization, artificial light is a growing environmental issue. Light pollution, which has negative effects on the ecosystem, has been caused by the proliferation of streetlights, business buildings, and residential properties that are illuminated at all hours of the day and night. Numerous species and ecosystems are affected by light pollution, which alters the

cycles of life and poses a serious danger to biodiversity. Animal existence is disrupted by light pollution, which is one of its most serious effects. The sudden appearance of artificial light can have a disruptive effect on the behavior of many species because they are adapted to survive and flourish in the dark. For instance, it's been observed that marine turtles can become confused by lights along the shoreline, leading them to stray from the ocean and risk getting trapped or hurt. Similar to nocturnal creatures, bright lights attract nocturnal creatures like bats and moths, which can make them disorientated and susceptible to predators.

Environmental harm from manufactured light is referred to as ecological light pollution. Ecological light pollution can have widespread impacts on a variety of species and ecosystems. Animal behavior modifications, changes to the rhythms of life, and effects on human health are some of the most notable effects of ecological light pollution. Animal behavior disruption is one of ecological light pollution's most important impacts. When artificial light is suddenly introduced to a species that has evolved to exist in the dark, it can have a significant effect on how they behave. Artificial light, for instance, can throw off a bird's internal navigation systems and cause it to fly off course. Birds, for instance, are known to migrate based on shifts in light patterns. Similar to nocturnal creatures, bright lights attract nocturnal creatures like bats and moths, which can make them disorientated and more susceptible to predators.

An example of a bioluminescent insect is the glow-worm, which is distinguished by its unique glow. Both the mature females and the larvae of specific species of fireflies and beetles that have the ability to emit light are referred to as "glow-worms." In addition to forests, meadows, and gardens, glow-worms can be found in a variety of habitats. They are most active at night.

The mature female glow worm has no wings and a soft, elongated body that can grow to a maximum length of 20 millimeters. The distinctive glowing abdomen of the female glow-worm, which produces a greenish-yellow light, is what makes it so well-known. In the insect's body, an enzyme called luciferase and a substance called luciferin undergo a chemical process that results in the glow. The female glow-worm uses the light to entice men for mating. It's critical to preserve and safeguard glow-worms' natural environments. Sustainable land management techniques, like agroforestry and conservation plowing, can be used to accomplish this. Additionally, the use of non-toxic pest management techniques like biological control and integrated pest management can aid in shielding populations of glow-worms from the negative impacts of pesticides.

2 Literature Review

This research (Elgert et al., 2020) emphasizes how nocturnal animal behavior is being impacted by the rise of artificial nighttime lighting worldwide. However, it is not fully known how these behavioral responses affect population survival and individual fitness. The study explores whether female common glow-worms may alter the timing and position of their shining in order to reduce the detrimental effects of artificial light on mate attractiveness. The results show that females delay or abstain from shining instead of moving away from the light, which is ultimately maladaptive since it lowers their capacity to attract mates. According to the study, one reason for glow-worms' global decrease may be that they are unable to adapt to spatial variations in artificial light. The findings therefore validate the idea that animals frequently fail to adjust their behavior to environmental changes caused by humans, emphasizing the significance of taking behavioral responses into account when researching how human activities affect wildlife.

In this paper (Van den Broeck et al., 2021), everyday individual female glow-worms (*Lampyrus noctiluca* L.) were observed in artificially lit and unlit surroundings over the course of a complete mating season, with the aim to determine whether street lighting (low pressure sodium (LPS; monochromatic orange) affects female mate-attraction success. Additionally, in order to demonstrate that any changes on mating

success were induced only by ALAN and not by variations in female quality or attractiveness between locations with more or less light, they exposed field-collected and captive-raised females to various light settings. Females in dark environments tended to quit glowing after one night, signifying that they had mated, but females in lit environments glowed for noticeably longer periods of time, sometimes up to 15 nights. This research [1] supports earlier results and predictions that females exposed to artificial light have lower mate attraction success, which has a detrimental effect on populations.

The researchers (Keinath et al., 2021) conducted a study in the Berlin-Brandenburg region of Germany to examine how artificial light affects the moth species *Agrotis exclamationis*. They focused on traits such as body length, eye size, and forewing length, and hypothesized that increasing light pollution would lead to a decrease in these traits. The researchers used a "light pollution map" to categorize artificial light at night (ALAN) levels at different sites and years. They analyzed moths collected over the past 137 years and found that while there were no differences in traits across different locations, there were changes over time that were dependent on sex and trait. They observed a trend of decreasing eye size in female moths in areas with higher levels of light pollution, indicating that the morphological traits of these moths are being impacted by artificial light.

A model by collecting glow worms (Bird and Parker, 2014) came to an interpretation that Artificial lights effects the ability of male glow worms to locate female glow worms (Bird and Parker, 2014). According to their study, for females, a student T test showed that the LED illumination on the canes had no impact on how long the female bioluminescence lasted. However, there was a tendency for females to stop glowing when around fake females. However, the ability of males to locate the artificial females was greatly hampered by very low levels of light pollution. At 0.3 or 0.18 lux, no males were drawn to the imitation females, whereas 33 males were drawn to each of the two matched controls. For these data, a custom model with a 95% confidence limit was created in order to better illustrate how light pollution affects males.

In another study (Kivelä et al., 2023) on 2022, Linnea et al. experimented over 624 individual

glow worms. A total of 57% of the traps during the experiment were effective in capturing at least one male, with 170 instances of one or more males being captured and 129 instances of no males being caught. Therefore, other than the fact that the difference between the blue and white light treatments was no longer significant, the findings of the binary analysis were consistent with those obtained from the analysis using the number of males. According to their laboratory experiment, despite attempts to mitigate this, the artificial light intensity may have had an impact on the success of the illuminated traps in attracting males. This is because the artificial light intensity varied between treatments due to the color filters used, which had an impact on the light output. It was not possible to include the intensity of each light hue as a factor in the statistical analyses because it was only measured once and not individually for each observation. However, there is no discernible correlation between artificial light intensity and male catch size independent of artificial light color when comparing the quantities of males caught in each treatment and their corresponding light intensities. Lastly they came to a conclusion that, the artificial light intensity alone cannot account for the variations in male attraction effectiveness between treatments; light color also must be a factor.

3 Methodology

4 Implementation and Result

5 Conclusion and Future Work

Light pollution is a well-known problem that has detrimental impacts on the health of people, animals, and plants. The attraction of nocturnal insects to artificial light sources, which can be fatal to them, is one of the main effects of this. Two nocturnal insects that exhibit a maladaptive reaction to artificial light are glow worms and moths. We conducted an experimental analysis of data from glow worms and moths using various machine learning and deep learning algorithms in order to assess the impacts of light pollution on insects. To interpret and describe the predictions made by the models, we have also included Explainable AI.

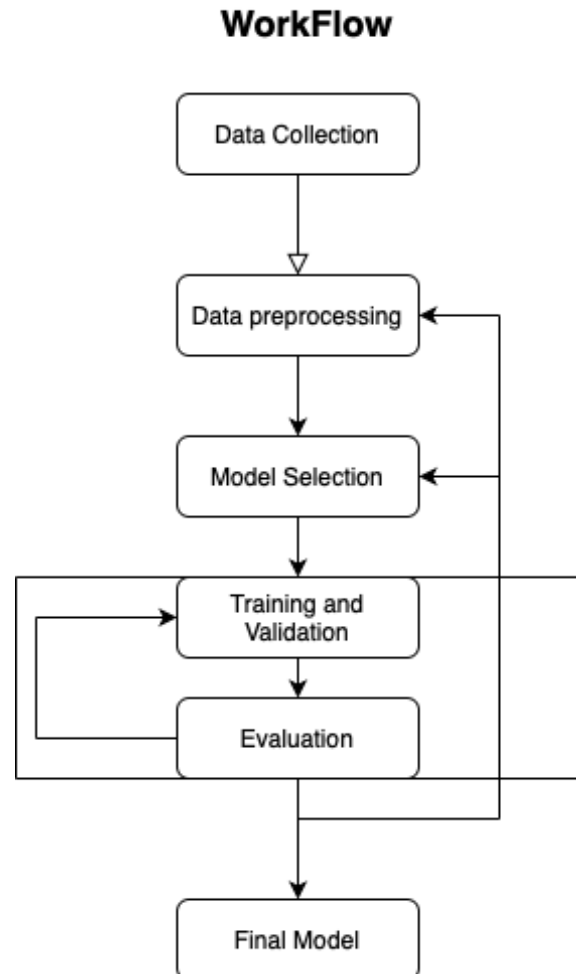


Figure 1: Workflow

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