

Unveiling the Impact of Environmental Variables on Moth (Lepidoptera) Abundance: A Comprehensive Study within a Dark Sky Reserve

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Introduction

For millennia, Earth's life, notably the class *Insecta*, has adapted to reliable photic cycles, including day-night and lunar cycles (Tierney et al., 2017). Anthropogenic light, however, disrupts these cycles, impacting ecosystems from molecular to community levels (Seymoure et al., 2019; Robinson et al., 2021). With an estimated 60% of invertebrates being nocturnal and up to 85% of Lepidoptera species, these positive phototaxis species will be some of the most at risk of the impacts of artificial light (Boyes et al., 2021). Macro-moth populations have declined in Great Britain; "State of Nature 2019" reported a 34% decline in 390 species from 1970 to 2016 (Hayhow et al., 2019). However, the exact causes remain unclear, and light pollution may often be mistakenly implicated (Boyes et al., 2021).

Aims & Objectives

Aim: To elucidate the true drivers of moth abundance survey data within a low light pollution dark sky reserve.

Objectives:

- Investigate the various factors influencing moth abundance using light trapping.
- Survey a series of microhabitats near the village of Hebden in the Yorkshire Dales National Park.
- Use statistical tests to assess the relationship between environmental factors (wind speed, temperature, humidity, and precipitation) and moth abundance.

Hypotheses

H0: No significant association exists between (environmental factors 1,2,3,4) and moth abundance within the dark sky reserve.

H1: A significant negative association exists between (environmental factors 1,2,3,4) and moth abundance within the dark sky reserve.

Environmental Factors:

- Precipitation
- Wind Speed
- Humidity
- Temperature

Method

This study was conducted near Hebden village in the Yorkshire Dales National Park. The author's cabin, located by Hebden Beck near Scala Falls, served as the research base (see Figure 1). Six locations were sampled for two nights each in December 2023, generating twelve datasets. Multiple microhabitats were sampled to allow for insights into the factors influencing distribution patterns and community structures of moth species based on microhabitat preferences (Niermann & Brehm, 2022)

Light trapping was employed for moth capture using portable compact heath traps with high UV fluorescent tubes and 12V battery packs (see Figure 2) (Watkins & Doncaster, 2024). Traps were set up at dusk, protected from weather, and retrieved at dawn to avoid sunlight interference. Weather data were logged using an iPhone's internal app. Moths were photographed, identified using Butterfly Conservation's aid (2024), and released at the collection sites after assessment.



Figure 2: Light trap in situ (Author's own, 2023)



Figure 1: Satellite view of survey sites and the basecamp along Hebden Beck (Google Earth, 2024)

Results

Moth Abundance

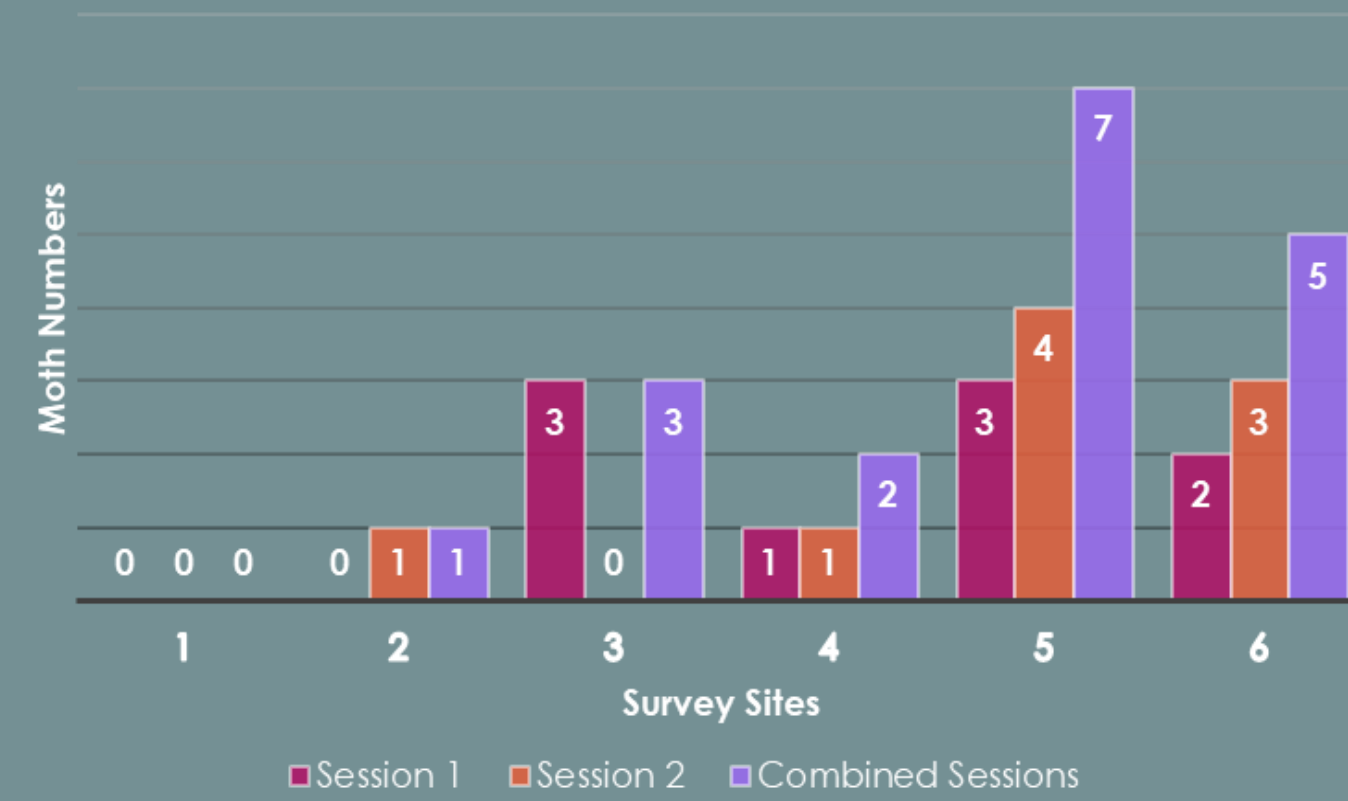


Figure 3: Number of moths trapped per survey site (Author's Own, 2024)

Species Richness

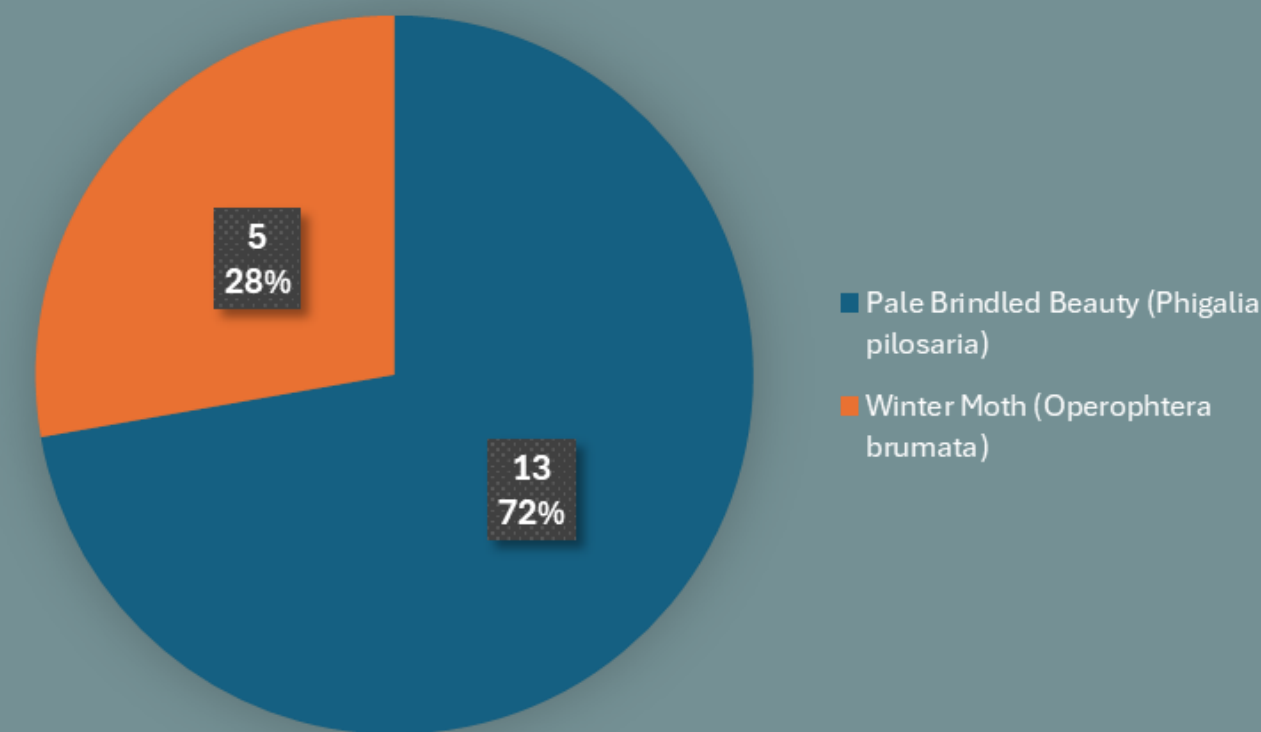


Figure 4: Abundance and percentage of total captured moths (Simpson's Diversity Index $D = 0.43$) (Author's Own, 2024)



Figure 5: A captured Pale Brindled Beauty (left) and a captured Winter Moth (right) (Author's Own, 2024)

Environmental Variables Associations

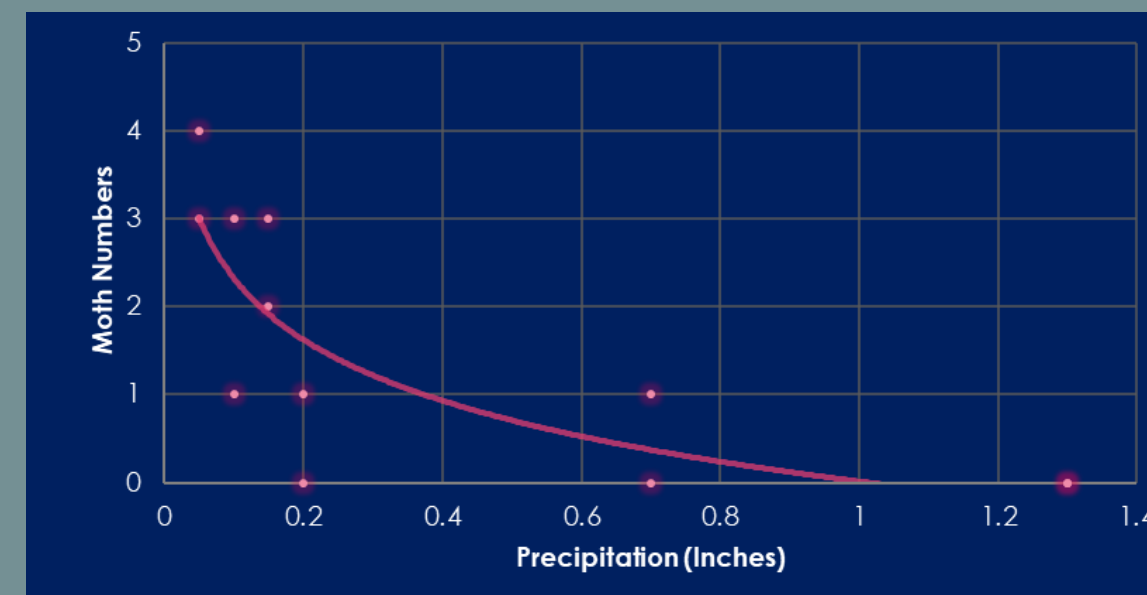


Figure 6: Precipitation had a highly significant negative association with moth numbers (Spearman's Rank Correlation, $r = -0.854$, $N=12$, $p=0.0004$) (Author's Own, 2024).

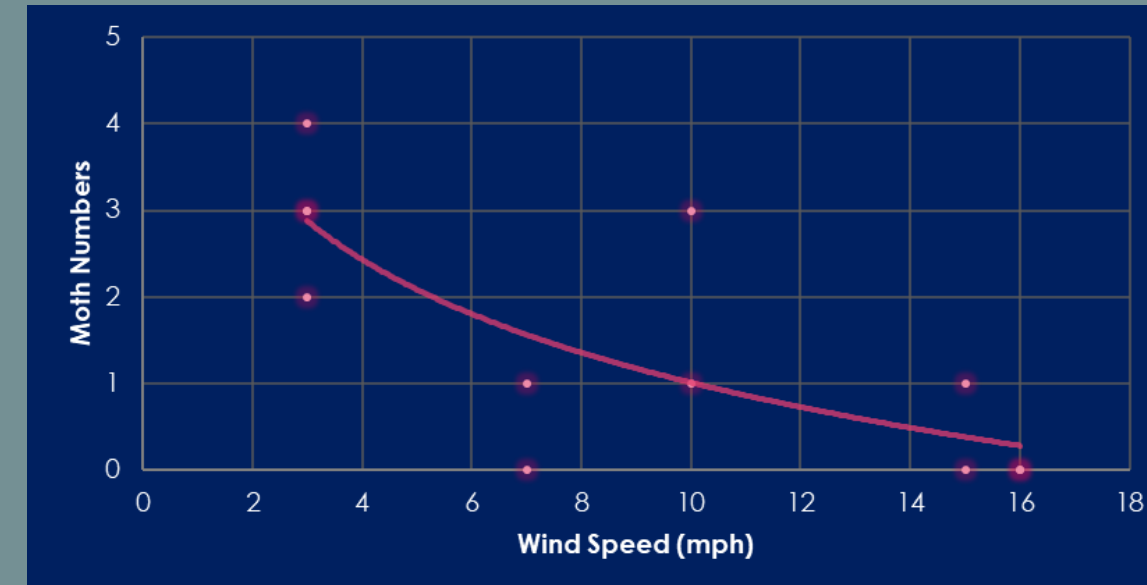


Figure 7: Wind speed had a very significant negative association with moth numbers (Pearson's Correlation: $r = -0.741$, $N=12$, $p=0.006$) (Author's Own, 2024).

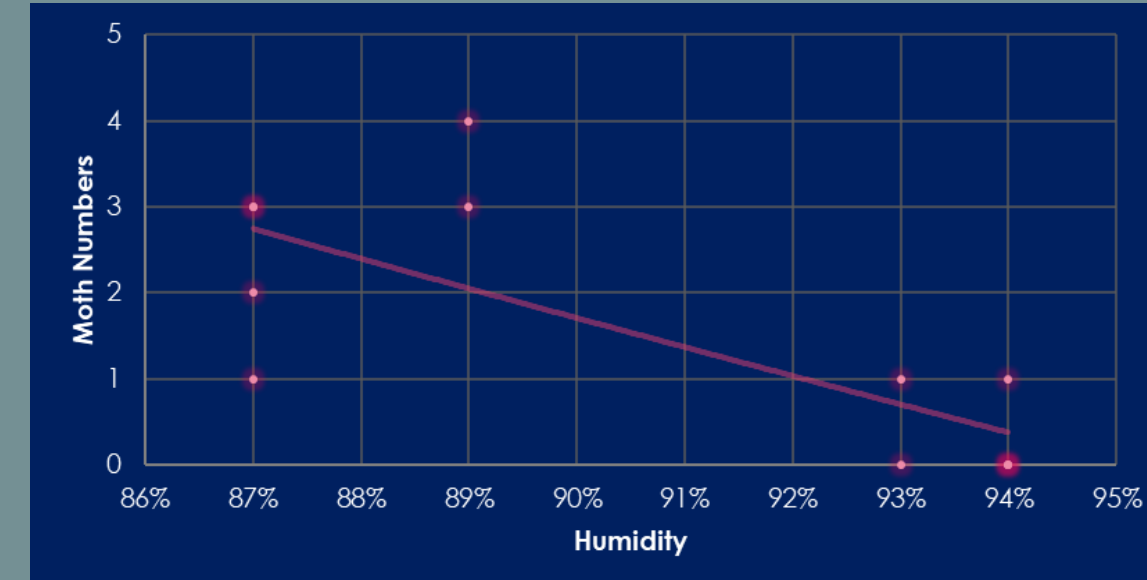


Figure 8: Humidity had a very significant negative association with moth numbers (Spearman's Rank Correlation, $r = -0.718$, $N=12$, $p=0.009$) (Author's Own, 2024).

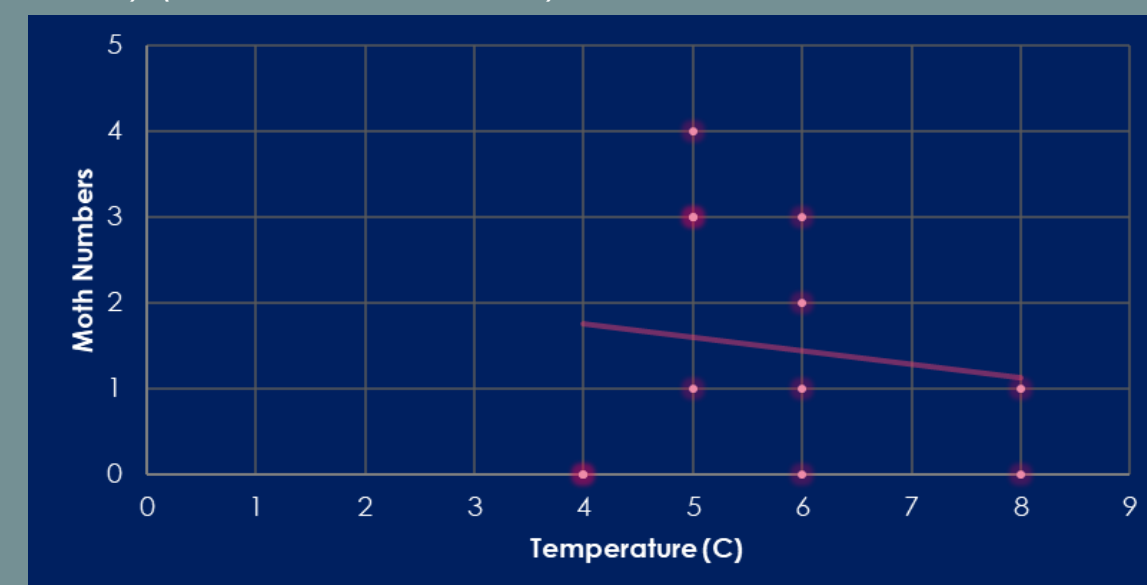


Figure 9: Temperature had no significant association with moth numbers (Pearson's Correlation: $r = -0.145$, $N=12$, $p=0.653$) (Author's Own, 2024).

Discussion

Precipitation: A strong negative association was observed between precipitation and moth abundance. This finding is consistent with broader research on various flying organisms. For example, studies on hummingbirds have highlighted the mechanical difficulties of flight in the rain, suggesting that precipitation imposes similar challenges for moths (Ortega-Jimenez & Dudley, 2012). Moreover, rainfall can dilute or wash away nectar resources, crucial for moth foraging behaviour, as evidenced in studies on other nectar-feeding insects (Cnaani et al., 2006). This suggests that precipitation may affect moths directly by hindering their flight and indirectly by reducing their food availability, thereby influencing their overall abundance.

Wind Speed: A significant negative association was found between wind speed and moth abundance. High wind speeds are known to damage the delicate wings of moths physically and can lead to behavioural changes, such as migration away from approaching weather fronts (Ortega-Jimenez et al., 2013). This aligns with broader ecological studies indicating that many flying insects, including moths, exhibit reduced activity and increased vulnerability in high wind conditions. This factor is crucial in understanding the spatial and temporal distribution of moth populations, especially in regions prone to high winds.

Humidity: A significant negative association was observed between humidity and moth abundance. Increased humidity raises air density, making flight more energetically costly for moths, a phenomenon also noted in studies on other insects (Contreras et al., 2013). Additionally, high humidity can cause condensation on flowers, potentially reducing nectar accessibility and thus impacting moth foraging efficiency. This relationship highlights the complex interplay between environmental factors and moth physiology and behaviour, contributing to our broader understanding of how climate variables influence insect ecology.

Temperature: Contrary to expectations, no significant association was found between temperature and moth abundance within the observed narrow temperature range. However, the study's minimal temperature fluctuations might explain this lack of significance. Broader research has shown that substantial temperature changes can significantly affect moth behaviour, including metabolic rates, flight activity, and reproductive cycles (Leith et al., 2021). This finding suggests that while temperature may not have been a limiting factor in this study, it remains a critical variable in other contexts and warrants further investigation across more extensive and varied temperature ranges.

Limitations & Recommendations

Limitations:

- Limited Data Sets:** Only twelve data sets were used, restricting the robustness of conclusions.
- Unclear Microhabitat Role:** Focus on weather conditions left the influence of microhabitats unexplored.
- Survey Methodology:** Only two light traps were used, limiting the survey's scope and scale.
- Seasonal Bias:** Winter surveys are biased towards winter-active species, skewing overall results.

Recommendations:

- Longitudinal Studies:** Conduct across multiple seasons and locations within the Dark Sky Reserve.
- Year-round surveys:** Capture temporal dynamics and responses to environmental changes.
- Microhabitat Sampling:** Sample multiple habitats simultaneously using more light traps for broader coverage.
- Enhanced Survey Tools:** Deploy additional light traps to improve data comprehensiveness and representativeness.

References

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