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MOUNTING LIGHT, DIMINISHING INSECTS: THE GROWING CONCERN OF INCREASED URBAN LIGHTING – AN OBSERVATION IN HUMAN HABITATS

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ABSTRACT

Light pollution, a consequence of excessive and misdirected artificial illumination, has emerged as a pressing environmental concern with far-reaching impacts on various ecosystems. As urbanization and industrialization continue to expand, the encroachment of artificial light into natural habitats escalates, altering the behaviours and ecological dynamics of nocturnal organisms. In particular, the effects of Artificial Light at Night (ALAN) on insect populations have drawn significant attention due to their crucial role in ecosystem functioning. This study seeks to investigate the impact of ALAN on insect mortality, recognizing the urgent need to address the detrimental effects of light pollution on essential insect populations. To study the impact of Artificial light at Night (ALAN) on insect mortality. The study spanned 90 days, with observations conducted over 30 days in each of three distinct locations. Dead insects were collected early morning each day. During the experiment, the insects were attracted to the light source circling it, ultimately losing their way, and meeting a tragic end. Over the course of our study, we collected a total of 1,650 insect corpses. These casualties were most pronounced in hotels/eateries/ commercial establishments, where an average of 31 insects per day succumbed to light-induced attraction. ATM locations saw an average of 17 insect casualties daily, while houses registered approximately 7 insect fatalities daily. Insects experience increased night deaths from artificial light, necessitating urgent scientific investigation, given the crucial ecological role of insects and their alarming decline in numbers in recent times. Night-time artificial light disrupts insect behaviour, reproduction and survival, affecting foraging, mating and navigation of the insects, making insects prey to unusual predators, disturbing life cycles and causing a severe decline in insect biomass in natural habitat. The increased insect mortality disrupts pollination, nutrient cycles, food chains and several vital ecological processes. So, assessing this insect loss is crucial for predicting its profound impact on ecosystem stability, prompting targeted conservation strategies to counter the detrimental effects of light pollution on these indispensable insect populations.

KEYWORDS: Artificial Light at Night (ALAN), Biodiversity, Toxicology and Conservation.

INTRODUCTION

The explosion of the human populace has precipitated the establishment of new human habitation, engendering the metamorphosis of pristine landscapes into urbanized ecosystems characterized by an augmented prevalence of artificial illumination. This artificial luminance exhibits a spectrum of attributes, encompassing variations in luminosity, frequencies, and chromatic compositions, thus culminating in an upsurge of light pollution, which, in turn, heightens the attraction of insects to these lights. To combat pests, the use of devices like "Light Traps" and "Pest Smashers" has become widespread, as documented in U.S. Patent 4808 (Owens et al., 2020). Nevertheless, it remains salient to acknowledge that these light traps lack the capacity to discriminate between pest species and the indispensable community of pollinators.

With the declining cost of lighting and the improvement in both the quality and quantity of artificial light installations worldwide, this has further exacerbated the attraction of insects to artificial light sources (Owens et al., 2020). Unfortunately, there has been limited research on the impact of light pollution on the death of pollinators, even though approximately 87% of major food crops rely on animal pollinators for reproduction (Van der Sluijis et al., 2016). The loss of pollinators poses a significant threat to global food security.

If the death of pollinators adversely affects food production, it's important to recognize that the broader decline in insect populations poses a threat to insect diversity, which in turn affects the stability of ecosystems. Insects provide numerous ecological services (Stork 2018; Wilson and Fox 2021), the loss of which has largely gone understudied. It's estimated that within the next decade, approximately 10 million species, including 40% of insects, may face extinction (Owens et al., 2020). A systematic analysis of the food web can yield profound insights. If we study the decrease in different types of insects in the food web, we can predict what might happen to ecosystems in the future. It gives us insights into how different species work together to keep a balance in the ecosystem.

The attraction of insects toward artificial light leads to disruptions in their natural daily solar and lunar light cycles, increasing their mobility towards these artificial light sources. As a consequence, these insects often lose their wings and gradually die (Eisenbeis 2013; Frank 2006; Yoon et al., 2010). Some insects attracted to lights become trapped, unable to return to their natural environment, creating what can be described as "fatal traps." In this context, we conducted a preliminary 90-day observation as a precursor to a more comprehensive study on the loss of insect populations due to artificial light at night (ALAN).

This research emphasizes the critical need to study the impact of artificial light on insect populations, as it has far-reaching consequences for both pollinators and insect diversity, with potential implications for ecosystem stability and global food security. Understanding these ecological dynamics is essential for making wise decisions and the development of strategies to mitigate the adverse effects of light pollution.

MATERIALS AND METHOD

We employed a rigorous approach to conduct our study on light measurement and the collection of insect carcasses attracted to Artificial Light at Night (ALAN). Firstly, the light was quantified using a lux meter, a device that measures luminance in lux units. To further validate our measurements, we cross-referenced the data with the luminous app on an Apple phone. Subsequently, we turned our attention to the collection of insect carcasses. Our study encompassed various types of locations, including ATM site, hotel/commercial establishments, and residential house. This survey was conducted daily over a span of 90 days that is 30 days in each location to comprehensively understand the extent to which insects were being attracted to artificial light sources, becoming trapped, and ultimately perishing.

In our data collection process, we intentionally maintained non-uniform sample stations to mirror the natural diversity of human habitats. Every morning, as the sun rose, we meticulously gathered and counted the collected insects. This method allowed us to gain insights into the patterns and impact of artificial light on insect mortality, while also considering the diverse urban environments in which these insects were found.

SAMPLING SITE

Mandya is a unique region that seamlessly integrates rural and urban characteristics, with a strong focus on both agriculture and commerce. Traditional farming methods coexist with modern techniques, fostering sustainable and diverse crop production. Additionally, Mandya has become a thriving hub for commercial endeavours, serving as a dynamic marketplace where the region's agricultural richness intersects with the needs of a lively urban economy. In Mandya, three strategic locations were carefully selected, including a residence with GPS coordinates 12°31'57.1"N 76°54'46.5"E, a commercial establishments/hotel with GPS coordinates 12°31'52.4"N 76°54'29.9"E, and an ATM facility with GPS coordinates 12°31'46.7"N 76°54'21.3"E.

RESULT AND DISCUSSION

In the various sampling locations, the house exhibited the lowest light intensity, ranging from 21 to 1927 lux units, followed by the ATM, which registered a range of 1927 to 2585 lux units. In contrast, commercial place/hotel demonstrated the highest illumination, ranging from 2585 to 10,000 lux units.

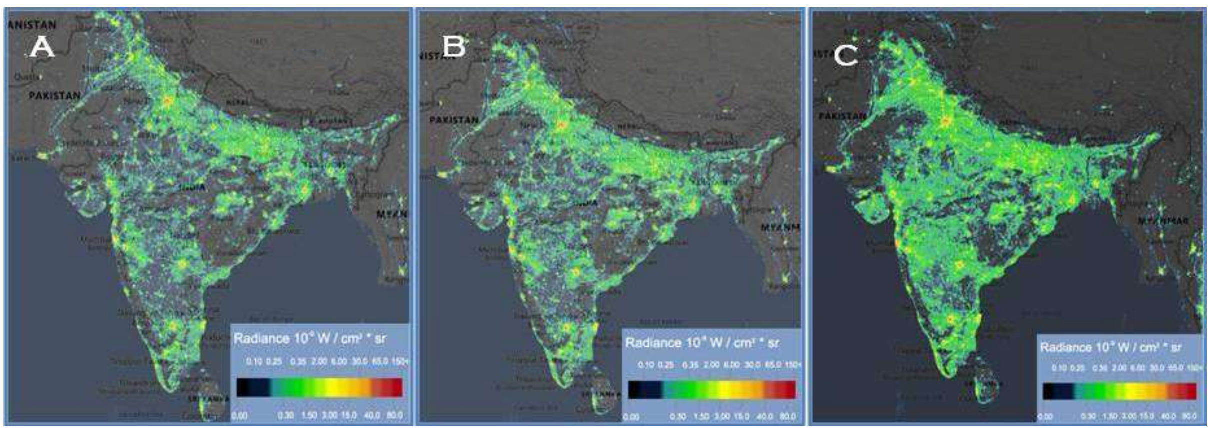

Figure 1: (A) Light Pollution Map of India 2020
(B) Light Pollution Map of India 2021
(C) Light Pollution Map of India 2022

Light pollution in India shows a steady increase year after year, as indicated in **Figure 1**. Our investigation into the collection of insect cadavers and the assessment of the impact of artificial lighting on insects has provided valuable insights. Over the course of our observations at ATM sites, hotels/eateries/commercial establishments, and residences, we amassed a total of 1650 insect cadavers, averaging 55 per day. The data clearly demonstrates that hotels/eateries/other commercial venues exhibited the highest daily collection rate, with an average of 31 insects per day. ATM locations followed with 17 insects daily, while houses exhibited the lowest daily collection rate at 7 insects per day. This compelling evidence strongly underscores the adverse effects of artificial lighting on insect populations, underscoring its significance within our findings **Table 1 & Figures 2 and 3**.

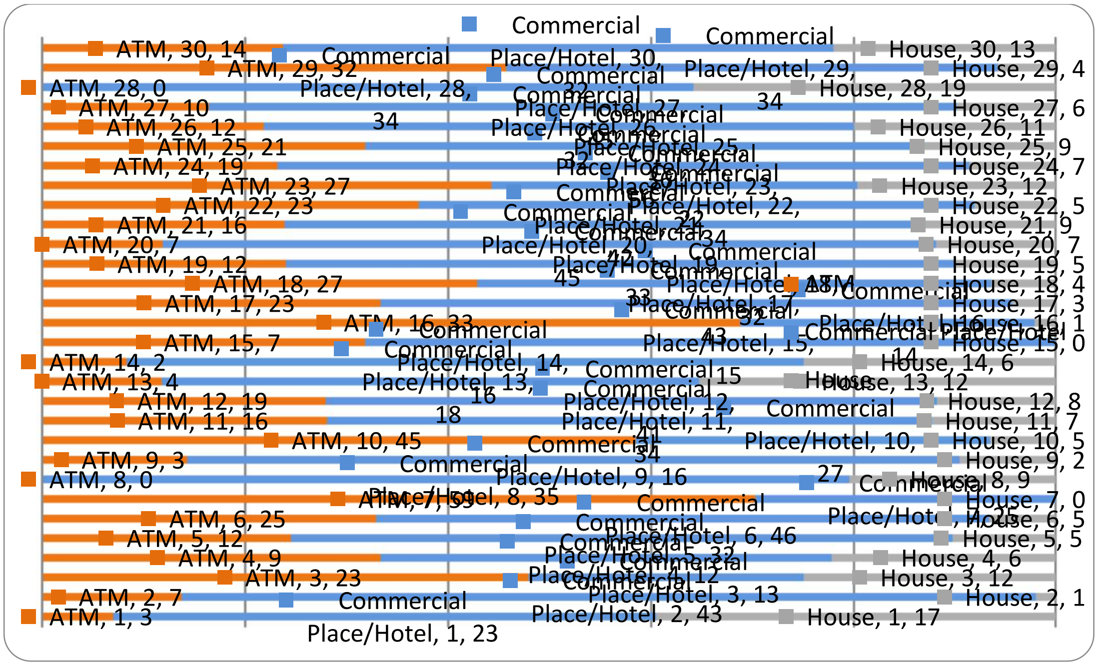

Figure 2: Number of Dead Insects Collected in Different Sampling Sites

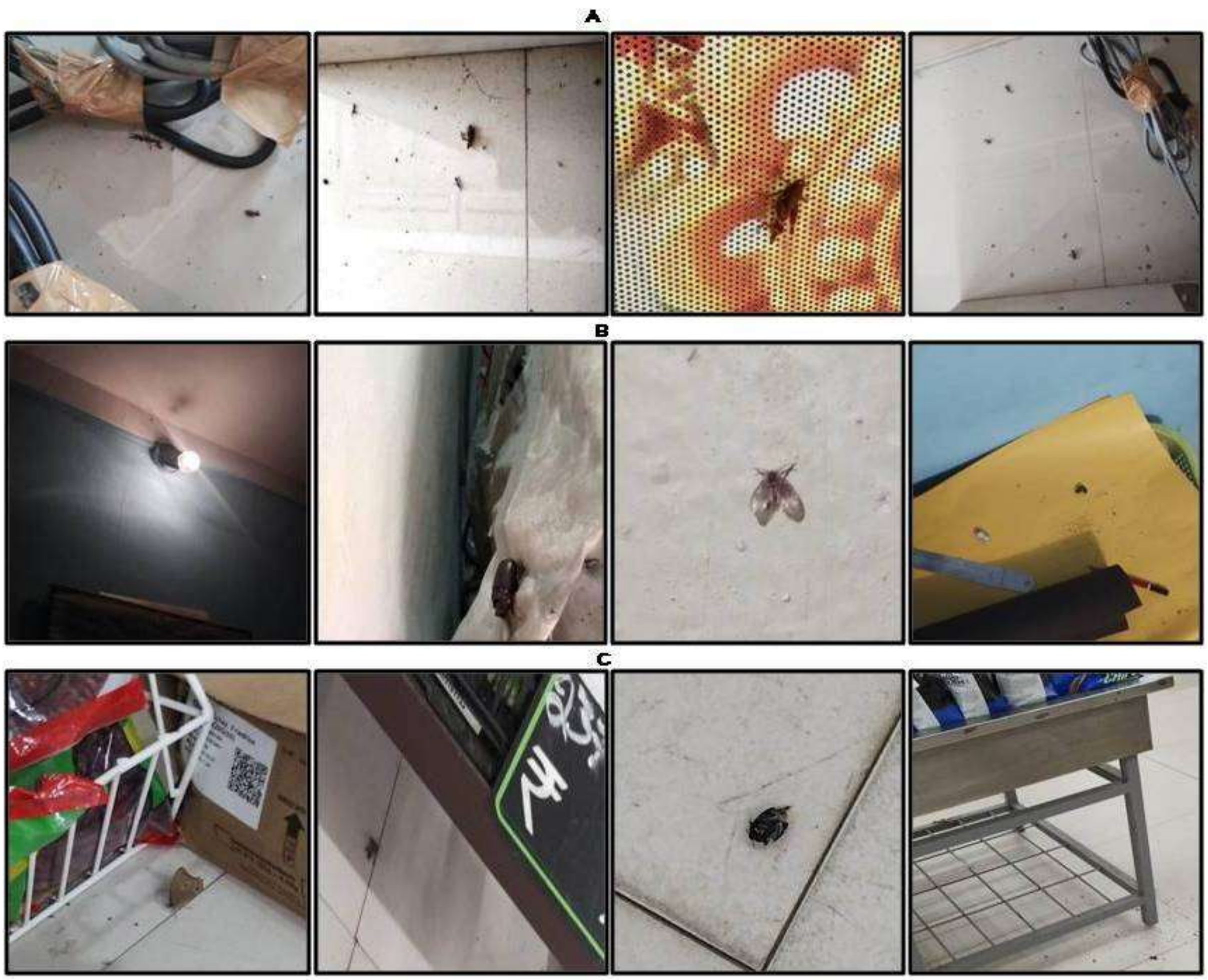

Figure 3: A. Insects Attracted by Artificial Light at Night in ATM
B. Insects Attracted to Light at House
C. Insects Attracted to Light in Commercial Place

Table 1: Insect Carcasses Collected during Observation in Different Sampling Sites

Number of Trials	**Number of days of observation**	**Number of Insects collected in each sampling site**		
Sl. No.	**Date**	**ATM**	**Commercial Place/Hotel**	**House**
1	Day 1	3	23	17
2	Day 2	7	43	1
3	Day 3	23	13	12
4	Day 4	9	12	6
5	Day 5	12	32	5
6	Day 6	25	46	5
7	Day 7	59	25	0
8	Day 8	0	35	9
9	Day 9	3	16	2
10	Day 10	45	27	5
11	Day 11	16	34	7
12	Day 12	19	41	8
13	Day 13	4	18	12
14	Day 14	2	16	6
15	Day 15	7	15	0
16	Day 16	33	14	1
17	Day 17	23	43	3
18	Day 18	27	32	4
19	Day 19	12	33	5
20	Day 20	7	45	7
21	Day 21	16	42	9

22	Day 22	23	34	5
23	Day 23	27	22	12
24	Day 24	19	56	7
25	Day 25	21	36	9
26	Day 26	12	32	11
27	Day 27	10	45	6
28	Day 28	0	34	19
29	Day 29	32	34	4
30	Day30	14	32	13

Trends in ATM

The number of insect corpses collected in ATM varies considerably over the 30 days. The highest number of corpses collected is on Day 7, with 59 corpses. After Day 7, there is a general decline in the number of insect corpses, reaching zero on Day 8. The numbers then start to increase again, with fluctuations but never reaching the initial peak **Figure 2**.

Trends in Commercial Place/Hotel:

The number of insect corpses collected in commercial place/hotel is relatively stable, with some fluctuations. The highest number of corpses collected is on Day 7, with 46 corpses. There is a decline after Day 7, but the numbers remain consistently higher than in ATM and house throughout the 30 days **(Figure 2**).

Trends in House:

The number of insect corpses collected in house also varies but is generally lower than in ATM and commercial place. The highest number of corpses collected is on Day 7, with 17 corpses. Unlike ATM, there is no day with zero corpses collected, but the numbers remain relatively low throughout the 30 days (**Figure 2)**.

Comparative Analysis

The data suggests that artificial light at night has a significant impact on attracting insects, particularly in the initial days. In ATM, there is a clear pattern of decline in insect corpses after an initial peak, while in commercial place, the numbers remain more consistent. House has the lowest number of insect corpses, indicating that indoor artificial lighting has a relatively smaller impact compared to outdoor lighting (**Figure 2)**.

Interpretation

The spike in insect corpses on Day 7 could be due to factors such as seasonal changes, insect behaviour or light intensity. The decline in corpses in ATM and commercial place after Day 7 could be related to insects adapting to the artificial light source or changes in insect populations. The data suggests that commercial place may provide a more stable environment for insects due to continuous artificial lighting.

IMPLICATIONS

This data highlights the influence of artificial light at night on insect mortality and population dynamics. Understanding these trends is crucial for urban planning, outdoor lighting design, and ecological conservation efforts. Further research is needed to determine the specific causes of the observed patterns and their ecological implications (Yan and Tan 2023; Morgan-Taylor 2023).

The presence of insects within human habitats is the result of a complex interplay of multiple factors. Among these, the local flowering patterns of vegetation stand out as a significant influence on insect behaviour (Feeny., 1976). These flowering patterns dictate where and when insects can find their essential sources of nectar and pollen, effectively drawing them into human-inhabited areas.

However, it's important to recognize that when conducting surveys and research in this field, the results can exhibit substantial variation. The specific study area, the presence of various plant species (flora), and the availability of both natural and artificial light sources all play crucial roles. Indeed, artificial light stands as a prominent factor with the potential to significantly disrupt the balance of insect life (Rodrigo-Comino et al., 2023). This disruption is most notably seen in the crucial plant-pollinator interactions. Studies have shown that artificial light at night can reduce nocturnal visits by insects to plants by as much as 62% when compared to naturally dark areas, as highlighted in research conducted by (Knop et al., 2017). The challenges faced by insect populations extend beyond light pollution (Longcore et al., 2004). They are further compounded by numerous other factors, including habitat loss due to urbanisation, fragmentation of agricultural land, environmental degradation, deforestation, and the widespread use of conventional pesticide-intensive farming practices (Ortiz et al., 2021). Additionally, threats such as pest infestations, colony collapse disorders (Johnson et al.,2010), pathogens, and the introduction of invasive species (Stricker et al., 2016) all contribute to the declining populations of insects. In the context of these challenges, artificial light emerges as a significant contributor by attracting insects and, in many cases, leading them into a perilous trap, where they face certain demise **(Figure 4)**.

Figure 4: Insects Attracted to Light and Fallen Dead on The Ground

This phenomenon is not confined to specific areas. The impact of artificial lighting extends to a diverse range of settings. This includes recreational constructions, path lights in ecologically sensitive regions, ecotourism hotspots, rural areas, and agricultural farmlands. Artificial light pollution exacerbates the problem across all of these diverse environments.

An interesting aspect of the issue is how different types of artificial light sources have varying effects on insects. Traditional filament-based incandescent bulbs produce notable warmth, drawing and causing harm to insects, whereas contemporary LED luminaires emit ultrasonic waves that additionally detrimentally impact insect health. Even minimal-energy light sources such as incandescent bulbs, compact fluorescent lamps (CFLs), sodium or mercury vapor lamps, and 6-8 watt LEDs possess the capability to ensnare insects. Particularly, light sources emitting ultraviolet frequencies exhibit an increased propensity to allure insects and modify their behaviours. Despite these evident threats, it's crucial to recognize that the negative implications of artificial light on insect populations are an under-researched and underreported area on a global scale. The field of study is still in its nascent stages, with limited scientific data available regarding the enumeration of insect deaths due to light pollution. This issue is especially prominent in developing countries like India, where public awareness of the detrimental effects of excessive light pollution on the environment is often lacking.

In conclusion, the adverse effects of artificial light on insect populations and ecosystems represent a pressing and multifaceted concern for decades (Cotarelo-Valledor 1923; Gallaway et al., 2010). Increased awareness, expanded research efforts, and the implementation of mitigation strategies are all essential to address the challenges posed by light pollution. By doing so, we can better safeguard insect biodiversity and secure global food security (Dorey et al., 2021)

ALAN and Change in Vegetation Dynamics

The impact of artificial light at night (ALAN) on flowering patterns is a significant ecological concern. The introduction of artificial light sources in the natural environment has been shown to interrupt the innate circadian rhythms of plants, leading to alterations in their flowering patterns. This, in turn, affects the foraging and pollinating behaviour of a variety of pollinators, eventually resulting in a profound transformation of vegetation dynamics in affected regions.

The disruption of flowering patterns by ALAN can be attributed to several factors, including the interference with photoperiodic cues that plants use to regulate their flowering. Plants rely on the duration of daylight and darkness to time their flowering. ALAN can extend the photoperiod artificially, leading to the perception of longer days, which may cause plants to flower out of season or delay their flowering. This can have cascading effects on the availability of floral resources for pollinators (Shawan Chowdhury et al., 2023)

Many pollinators like bees and butterflies belonging to the order Hymenoptera and Lepidoptera rely on the timing and abundance of flowering plants to find nectar and pollen (Boom et al., 2020). When these plants flower at different times due to ALAN, pollinators may struggle to find the resources they need, potentially impacting their survival and reproductive success. Additionally, the disruption in flowering schedules can lead to a mismatch between the timing of pollinator activity and flowering, further reducing pollination efficiency.

Scientific studies have shown that the effects of ALAN on flowering patterns and pollinator behaviour can vary among different plant species and pollinator groups. For example, some plants may be more sensitive to ALAN-induced disruptions, while certain pollinators may exhibit greater adaptability (Heinen 2021) Nevertheless, the cumulative result of these changes is a significant shift in vegetation dynamics within illuminated regions.

As a result, areas affected by excessive artificial light at night may witness changes in their plant composition, diversity, and density. Some plant species may decline in abundance due to the reduced effectiveness of pollination; while others that are less dependent on pollinators or more adaptable to ALAN conditions may thrive. This shift in vegetation dynamics can have far-reaching consequences for ecosystems, impacting herbivores that rely on specific plant species and cascading through the food web.

In conclusion, artificial light at night disrupts natural flowering patterns, which, in turn, affects the behaviour of pollinators and results in substantial changes in vegetation dynamics. This phenomenon is supported by scientific research and has important implications for the conservation and management of ecosystems in the context of increasing urbanization and the spread of artificial lighting (Bennie et al., 2018). Efforts to mitigate the impact of ALAN on flowering patterns and pollinators are essential to maintain the ecological integrity of natural environments.

Habitat Fragmentation Caused by Artificial Light at Night (ALAN)

The phenomenon of habitat fragmentation induced by intermittent light sources within previously unaltered ecosystems triggers a spatial partitioning of regions into illuminated and non-illuminated zones, ultimately precipitating habitat fragmentation. Artificial light at night (ALAN) plays a contributory role in this ecological disturbance, manifesting as the disintegration of contiguous natural landscapes through the introduction of anthropogenic lighting. This fragmentation imposes restrictions on the movement of wildlife and imposes perturbations on their ecological niches, rendering them more susceptible to environmental vicissitudes while diminishing their genetic variability.

In a comprehensive synthesis, the multifaceted ramifications of artificial light at night on wildlife within untamed settings emerge. ALAN displays the propensity to disrupt behavioural patterns, reproductive dynamics, and survival strategies among various organisms, wielding the potential to propagate consequences across intricate ecosystems and impinge upon the stability of human food systems. Therefore, it becomes imperative to advance endeavours directed at the amelioration of light pollution and the advocacy of judicious outdoor lighting practices to curtail the adverse repercussions of ALAN on insect populations.

Light pollution exerts a significant influence on ecosystems, unsettling the customary behaviours of a diverse array of species, spanning from insects to mammals. This interference extends to the perturbation of their biological clocks, known as circadian rhythms. Creatures that primarily operate during the night, known as nocturnal beings, rely heavily on the cover of darkness for vital activities, including hunting for food, engaging in reproduction, and navigating their surroundings (Williams et al., 2020)

ALAN can cause confusion and turmoil in the fundamental behaviours of insects, culminating in alterations in their foraging patterns and the potential diminishment of their populations (Longcore et al., 2004).

Mitigation

Mitigating light pollution is an ongoing concern, and innovative techniques are continuously being developed. One novel mitigation technique is "Adaptive Lighting Systems." (Opfermann et al., 2008). These systems use smart technology to adjust the intensity and direction of artificial lighting in real-time, responding to the presence or absence of people, vehicles, and natural light levels. By dynamically dimming or redirecting light only where and when it's needed, adaptive lighting reduces light spill, glare, and sky glow while maintaining safety and visibility in urban areas. This approach not only conserves energy but also minimizes the overall impact of artificial light on the night-time environment, making it a promising solution for controlling light pollution in urban settings.

CONCLUSIONS

In our current studies, we have encountered a significant gap in research and observation concerning the impact of artificial light at night on insect populations. To better understand the intricate dynamics at play, it is imperative that we conduct a more comprehensive and in-depth study. This broader study should encompass not only the diminishing insect populations but also the broader consequences of their deaths on local vegetation and the ecology.

Understanding the consequences of ALAN on insect mortality is a pivotal aspect of this research. Insects play critical roles in pollination, nutrient cycling, and food chain dynamics, making them integral to the functioning of ecosystems. Therefore, the impact of their death on plant-pollinator interactions, nutrient distribution, and the broader ecological balance needs to be thoroughly assessed and cannot be detrimental by this simple observational study.

Our investigations reveal that light (ALAN) causes a decline in insect populations and this indeed may cause adverse effects on the ecology; it becomes increasingly evident that light pollution represents an emerging and substantial threat of ecological significance. This issue extends beyond the immediate effects of light pollution on insects and raises broader concerns about the stability and sustainability of our ecosystems. As such, the need for this research is not only crucial but also timely, given the expanding urbanization and the ever-increasing use of artificial light at night.

REFERENCES

1. Avalon C.S. Owens, PrécilliaCochard, Joanna Durrant, Bridgette Farnworth, Elizabeth K. Perkin, Brett Seymoure.: Light pollution is a driver of insect declines, L Biological Conservation,241, (2020).
2. Bennie J, Davies TW, Cruse D, Bell F, Gaston KJ.: Artificial light at night alters grassland vegetation species composition and phenology. Journal of applied ecology. Jan;55(1):442-50 (2018).
3. Boom, Michiel P., Kamiel Spoelstra, Arjen Biere, Eva Knop, and Marcel E. Visser.: Pollination and fruit infestation under artificial light at night:light colour matters. Sci Rep 10, 18389 (2020).
4. Cotarelo-Valledor, A., La chispam_agica: (The magic spark). Tip. El Eco de Santiago, Santiago de Compostela, Galicia (1923).
5. Dorey, J.B. et al.: Continental risk assessment for understudied taxa post-catastrophic wildfire

indicates severe impacts on the Australian bee fauna. Glob. Chang. Biol. 27, 6551–6567(2021).

6. Eisenbeis, G.: Artificial night lighting and insects: attraction of insects to streetlamps in a rural setting in Germany. In: Rich, C., Longcore, T. (Eds.), Ecological Consequences of Artificial Night Lighting. Island Press, Washington, D.C, pp. 281–304 (2013)

7. Feeny P., Plant apparency and chemical defense. InBiochemical interaction between plants and insects, Boston, MA: Springer US, pp. 1-40. (1976)

8. Frank, K.D.: Effects of artificial night lighting on moths. In: Rich, C., Longcore, T. (Eds.), Ecological Consequences of Artificial Night Lighting. Island Press, Washington, D.C, pp. 305–344(2006).

9. Gallaway, T., Olsen, R. N., & Mitchell, D. M.: The economics of global light pollution. Ecological Economics, 69(3), 658–665(2010).

10. Heinen, R.:. A spotlight on the phytobiome: Plant-mediated interactions in an illuminated world. Basic and Applied Ecology, 57, pp.146-158 (2021).

11. Johnson, Renée.: Honey bee colony collapse disorder. Washington: Congressional Research Service, (2010).

12. Knop, E., Zoller, L., Ryser, R. et al.: Artificial light at night as a new threat to pollination. Nature 548, 206–209 (2017).

13. Longcore, Travis, and Catherine Rich.:"Ecological light pollution." Frontiers in Ecology and the Environment, 2.4: 191-198 (2004).

14. Morgan-Taylor, M.: Regulating light pollution: More than just the night sky. Science, 380(6650), 1118-1120 (2023).

15. Opfermann, A., et al.:"A new hardware-in-the-loop platform for the evaluation of adaptive lighting systems." IFAC Proceedings Volumes 41,2, 4446-4451(2008).

16. Ortiz, Diana I., et al.: "The impact of deforestation, urbanization, and changing land use patterns on the ecology of mosquito and tick-borne diseases in Central America." Insects 13,1 , 20 (2021).

17. Rodrigo-Comino, Jesús, et al.: "Light pollution: A review of the scientific literature." The Anthropocene Review 10,2, 367-392 (2023).

18. Shawan Chowdhury, Michael D. Jennions , Myron P. Zalucki , Martine Maron, James E.M. Watson , and Richard A. Fuller.: Trends in Ecology & Evolution, January 2023, 38 (2023)

19. Stork, N.E.: How many species of insects and other terrestrial arthropods are there on Earth? Annu. Rev. Entomol. 63, 31–45 (2018).

20. Stricker, Kerry Bohl, et al.: "Emergence and accumulation of novel pathogens suppress an invasive species." Ecology Letters 19,4, 469-477 (2016).

21. Van der Sluijis., Vaage,N.S.:Pollinators and Global Food Security:the Need for Holistic Global Stewardship.Food ethics 1,75-91 (2016).

22. Williams, B.A. et al.: Change in terrestrial human footprint drives continued loss of intact ecosystems. One Earth 3, 371–382 (2020)

23. Wilson, R.J. and Fox, R.: Insect responses to global change offer signposts for biodiversity and conservation. Ecol. Entomol. 46, 699–717 (2021).

24. Yan, Z., & Tan, M.: Changes in light pollution in the Pan-Third Pole's protected areas from 1992 to 2021. Ecological Informatics, 75, 102016 (2023).

25. Yoon, T.J., Kim, D.G., Kim, S.Y., Jo, S.I., Bae, Y.J: Light-attraction flight of the giant water bug, Lethocerusdeyrolli (Hemiptera: belostomatidae), an endangered wetland insect in East Asia. Aquat. Insects 32, 195–203 (2010).