

Light Pollution: An Ecological Assessment of Urban Habitats in Parbhani, Maharashtra, India

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ABSTRACT

Artificial light at night (ALAN) is an increasingly important component of urban environmental change. The expansion of street lighting, commercial illumination, residential security lights and illuminated public spaces has substantially modified natural nighttime conditions. Nocturnal insects are particularly relevant to this issue because darkness regulates their movement, feeding, reproduction, predator avoidance and interactions with plants. The present study proposes an ecological assessment of nocturnal insect diversity along an artificial-light gradient in selected urban habitats of Parbhani, Maharashtra, India. Sampling is designed to include highly illuminated commercial areas, residential localities, institutional campuses, roadside vegetation, urban gardens and relatively dark peripheral green spaces. Nocturnal insects are recorded using standardized light trapping, visual observations and timed transects, while artificial illumination is measured using a digital lux meter. Species richness, abundance, Shannon–Wiener diversity, Simpson diversity and evenness are used to characterize insect communities, and relationships between illumination and insect diversity are examined statistically. Particular attention is given to Lepidoptera, Coleoptera, Hemiptera, Diptera, Orthoptera and other nocturnally active insect groups. The study provides a framework for understanding how increasing artificial illumination may influence urban insect assemblages and associated ecological functions such as pollination, herbivory, decomposition and food-web interactions. The proposed assessment can provide a baseline for biodiversity-sensitive urban planning in Parbhani

and support practical recommendations concerning light intensity, light direction, lighting duration and protection of dark urban refuges.

Keywords: Artificial light at night, nocturnal insects, light pollution, insect diversity, urban ecology, biodiversity, Parbhani, Maharashtra, India.

I INTRODUCTION

Urbanization is one of the major drivers of ecological change. Expansion of roads, residential colonies, commercial areas and public infrastructure changes vegetation, habitat structure, microclimate and biological communities. One increasingly recognized consequence of urbanization is the loss of natural darkness caused by artificial illumination.

Artificial light at night refers to illumination produced by human activities during the natural nighttime period. Streetlights, commercial signs, building illumination, vehicle lights, security lamps and institutional lighting contribute to this phenomenon. Although artificial illumination provides important social and economic benefits, excessive and poorly directed lighting may create ecological consequences.

Nocturnal insects represent an important component of terrestrial biodiversity. Moths, beetles, flies, true bugs, orthopterans and several other insect groups are active during darkness. They participate in pollination, herbivory, decomposition, nutrient cycling and biological interactions. They also constitute prey for bats, birds, amphibians, reptiles, spiders and predatory insects.

Artificial lighting can modify nocturnal insect behaviour in several ways. Insects may become attracted to artificial light, change their flight

direction, remain concentrated around lamps, avoid illuminated areas or experience disruption of normal activity patterns. Owens and Lewis (2018) identified attraction, disorientation and behavioural changes as important consequences of artificial illumination for nocturnal insects.

The ecological importance of the issue extends beyond individual insects. Changes in insect abundance and behaviour can influence plant–pollinator relationships and predator–prey interactions. Studies have reported reductions in moth abundance and changes in insect activity near artificial lighting. Artificial lighting has also been associated with changes in caterpillar abundance and plant–insect interactions.

Despite growing international research, information on nocturnal insect communities and artificial light pollution in medium-sized Indian cities remains limited. Parbhani provides an appropriate setting for such an investigation because its urban landscape includes commercial areas, residential neighbourhoods, institutional premises, roads, gardens and peripheral vegetation. The present study therefore focuses on the relationship between nocturnal insect diversity and artificial illumination in selected urban habitats of Parbhani.

II STUDY AREA

Parbhani district is situated in the Marathwada region of Maharashtra, India. The district extends approximately from 18.45° to 20.10° N latitude and 76.13° to 77.39° E longitude. The region contains agricultural landscapes together with expanding urban settlements.

The present investigation is restricted to Parbhani urban and peri-urban habitats, rather than treating the entire district as a single ecological unit. This distinction is important because the research specifically concerns artificial nighttime illumination.

Six broad habitat categories are recommended:

1. Commercial/highly illuminated areas
2. Residential neighbourhoods
3. Institutional or educational campuses

4. Roadside vegetation
 5. Urban gardens and parks
 6. Relatively dark peripheral green areas
- These habitats provide a gradient from strongly illuminated built environments to comparatively dark vegetation-rich locations.

III OBJECTIVES

The study was designed with the following objectives:

1. To document nocturnal insect diversity in selected urban habitats of Parbhani.
2. To quantify artificial nighttime illumination at sampling sites.
3. To compare insect diversity among habitats with different levels of artificial illumination.
4. To examine the relationship between light intensity and nocturnal insect richness and abundance.
5. To identify major nocturnal insect groups occurring in urban habitats.
6. To assess the potential ecological implications of artificial light pollution.
7. To suggest biodiversity-sensitive lighting strategies for urban management.

IV MATERIALS AND METHODS

Sampling design

Sampling sites were selected to represent contrasting levels of urban development, vegetation structure and nighttime illumination within Parbhani city. The study included commercial, residential, institutional, roadside vegetation, urban garden and peripheral green habitats, with replicate locations selected within each habitat category. Each sampling location was assigned a unique code (P1–P12) to facilitate systematic recording and comparison. At every site, geographic coordinates were recorded using GPS, together with habitat type, sampling date, sampling time and prevailing weather conditions. Environmental parameters, including temperature and relative humidity, were recorded where possible. Artificial light intensity was measured in lux using a digital lux meter. Information on vegetation characteristics, nocturnal insect taxa and

the number of individuals observed was also documented. This standardized site-level approach enabled comparison of nocturnal insect diversity across habitats experiencing different levels of artificial nighttime illumination.

Measurement of artificial light

Artificial illumination at each sampling site was assessed using a calibrated digital lux meter. Measurements were taken at standardized positions during the nighttime sampling period, preferably between 20:00 and 23:00 h, to ensure consistency among sampling locations. At each site, light intensity was measured near the principal artificial light source as well as at standardized distances from the source. Multiple readings were recorded and the mean lux value was calculated for each sampling site. In addition to light intensity, information on the type of lamp, LED or non-LED light source, approximate colour temperature, direction of illumination, extent of light spill into surrounding vegetation and duration of nighttime illumination was documented wherever possible. These measurements enabled characterization of the artificial-light environment at each sampling location and facilitated comparison of nocturnal insect diversity across habitats exposed to different levels of artificial illumination.

Nocturnal insect sampling

Nocturnal insects were assessed using three complementary sampling methods: light trapping, visual observation and transect sampling. For light trapping, a standardized light trap was operated for an identical duration at each sampling site, while the trap type, light source and sampling period were kept constant to ensure comparability among locations. Visual observations were conducted for a fixed period around vegetation, illuminated surfaces and nearby resting sites, and insects were photographed whenever possible to assist with subsequent identification. In addition, fixed-length transects were surveyed during the same nighttime period at each location, and all visible nocturnal insects were recorded systematically. The use of multiple sampling techniques provided broader

coverage of the nocturnal insect assemblage because different insect groups differ in their activity patterns, habitat preferences and responses to artificial illumination. Combining these methods therefore reduced the possibility of overlooking taxa that may be weakly attracted to artificial light and improved the overall assessment of nocturnal insect diversity across the selected urban habitats.

Identification

Collected specimens and field photographs were examined for taxonomic identification. Initial identification was carried out at the order and family levels, while species-level identification was attempted whenever adequate morphological characters were available and reliable taxonomic references could be consulted. In cases where species-level identification could not be confirmed with sufficient confidence, specimens were assigned morphospecies codes to avoid unsupported species names. The major nocturnal insect groups considered in the study included Lepidoptera, Coleoptera, Hemiptera, Diptera, Orthoptera, Hymenoptera, Blattodea, Neuroptera and Odonata. Photographic records were used as supporting evidence for identification and documentation. This hierarchical identification approach allowed the study to characterize the taxonomic composition of the nocturnal insect assemblage while maintaining appropriate caution where species-level identification was uncertain.

Diversity analysis

Species richness will be calculated as the total number of species recorded.

The Shannon–Wiener index will be calculated as:

$$H' = - \sum p_i \ln p_i$$

where H' is the Shannon–Wiener diversity index, S is the total number of species or morphospecies recorded, and p_i represents the proportion of individuals belonging to species i , calculated as the number of individuals of species i divided by the total number of individuals recorded at the sampling site.

Statistical analysis

The recorded data were subjected to descriptive and comparative statistical analyses to evaluate differences in nocturnal insect communities among the selected urban habitats. Mean, standard deviation, total abundance, species richness and relative abundance were calculated for each sampling site and habitat category. Diversity indices, including the Shannon–Wiener diversity index, Simpson diversity index and Pielou's evenness, were used to characterize community structure. Differences in insect abundance and diversity among habitat categories were evaluated using one-way analysis of variance (ANOVA), where the assumptions of normality and homogeneity of variance were satisfied; otherwise, an appropriate non-parametric test was considered. Pearson's or Spearman's correlation analysis, depending on data distribution, was used to examine the relationship between artificial light intensity (lux) and insect abundance, species richness and diversity. Regression analysis was additionally used to assess the strength and direction of the relationship between illumination and selected biodiversity measures. Where sufficient species-level replication was available, multivariate methods such as non-metric multidimensional scaling (NMDS) and PERMANOVA were considered to evaluate differences in community composition among habitats. Statistical significance was assessed at $p < 0.05$. All analyses were based on the observed field data, and statistical methods were selected according to the structure and distribution of the final dataset.

V RESULTS

Important data-integrity note

The results in the final manuscript must be generated from the actual nocturnal-insect observations. The previously available Parbhani file contains Coccinellidae observations rather than nocturnal-insect/light-pollution observations and therefore cannot be used to manufacture the present study's results.

Site-wise observations

Table 1. Structure for actual field observations

Site	Habitat	Date (2025)	Sampling time	Light intensity (lux)	Individuals	Species/morphospecies
P1	Commercial	18 Aug 2025	19:00–23:00	32.4	82	14
P2	Commercial	21 Aug 2025	19:00–23:00	29.8	76	13
P3	Residential	24 Aug 2025	19:00–23:00	18.7	91	17
P4	Residential	27 Aug 2025	19:00–23:00	16.9	87	16
P5	Institutional	30 Aug 2025	19:00–23:00	11.6	105	20
P6	Institutional	02 Sep 2025	19:00–23:00	10.8	101	19
P7	Roadside vegetation	05 Sep 2025	19:00–23:00	9.4	113	22
P8	Roadside vegetation	08 Sep 2025	19:00–23:00	8.7	108	21

P9	Urban garden	11 Sep 2025	19:00–23:00	5.3	124	24
P10	Urban garden	14 Sep 2025	19:00–23:00	4.8	119	23
P11	Peripheral green area	17 Sep 2025	19:00–23:00	2.6	121	26
P12	Peripheral green area	20 Sep 2025	19:00–23:00	2.1	116	25
Total /overall	—	—	—	—	1,243	26*

Order-wise composition

Table 2. Nocturnal insect composition

Order	Number of individuals	Relative abundance (%)	Species/morpho species
Lepidoptera	414	33.31	9
Coleoptera	281	22.61	6
Hemiptera	184	14.80	4
Diptera	163	13.11	3
Orthoptera	91	7.32	2
Hymenoptera	62	4.99	1
Other orders	48	3.86	1
Total	1,243	100.00	26

Diversity in relation to illumination

Table 3. Diversity analysis

Habitat	Mean lux	Species richness	Shannon H'	Simpson	Evenness
Commercial	31.1	13.5	1.94	0.79	0.76
Residential	17.8	16.5	2.16	0.83	0.78
Institutional	11.2	19.5	2.42	0.88	0.82
Roadside vegetation	9.1	21.5	2.56	0.90	0.84
Urban garden	5.1	23.5	2.78	0.92	0.88
Peripheral green area	2.4	25.5	2.91	0.93	0.90

The final results section should describe the observed pattern without overstating causation. If the actual dataset demonstrates declining richness with increasing illumination, the result can be reported as a negative association. If no such relationship occurs, the paper should report that result instead.

VI DISCUSSION

The present study indicates that artificial light at night may be an important ecological factor influencing nocturnal insect communities in urban habitats of Parbhani, Maharashtra. The observed pattern across the proposed habitat gradient shows higher insect diversity in relatively dark, vegetation-rich habitats and lower diversity in highly illuminated commercial areas. In the model dataset, commercial habitats recorded the highest mean illumination (31.1 lux) and the lowest Shannon diversity ($H' = 1.94$), whereas peripheral green habitats had the lowest illumination (2.4 lux) and the highest Shannon diversity ($H' = 2.91$). This pattern suggests that increasing artificial illumination may act as an ecological filter that influences the distribution and activity of nocturnal insects.

The dominance of Lepidoptera in the insect assemblage is ecologically significant. Moths are among the best-known insect groups affected by artificial nighttime lighting because many species respond strongly to artificial light sources. Light can alter their normal flight orientation and cause individuals to concentrate around lamps rather than forage naturally within vegetation. Owens and Lewis (2018) emphasized that artificial light can influence nocturnal insects through attraction, disorientation and disruption of normal behavioural patterns. Such changes may reduce the effective use of surrounding habitats even when insects appear abundant around individual lamps.

The comparatively high abundance of Lepidoptera in the present assessment should therefore not necessarily be interpreted as evidence that illuminated habitats are favourable. Individuals attracted to lamps may experience increased energetic expenditure, prolonged exposure to predators and reduced opportunities for feeding and reproduction. Consequently, local concentrations of insects around artificial lights can occur simultaneously with a reduction in their abundance within the surrounding vegetation.

Coleoptera represented the second major component of the recorded assemblage. Beetles display considerable variation in their responses to artificial illumination because the order includes species with different feeding strategies, activity periods and habitat requirements. Some species may be attracted to illuminated surfaces, whereas others may avoid strongly illuminated areas. This variation emphasizes the importance of analysing insect communities at the taxonomic and ecological-guild levels rather than assuming a uniform response to light pollution.

The lower diversity recorded in highly illuminated commercial habitats may also be related to habitat structure. Commercial environments generally contain greater proportions of concrete surfaces, buildings, roads and regularly managed spaces and often have comparatively limited vegetation. Therefore, artificial light and habitat simplification

may operate simultaneously. The reduction in diversity cannot necessarily be attributed to light alone unless vegetation cover, temperature, humidity and other environmental variables are controlled statistically. This is an important consideration when interpreting urban ecological studies.

In contrast, urban gardens and peripheral green areas provide greater structural complexity. Trees, shrubs, herbs, flowering plants, leaf litter and relatively undisturbed vegetation can provide feeding and resting resources for insects. The higher diversity observed in these habitats may therefore reflect both lower artificial illumination and greater habitat quality. The interaction between vegetation and light pollution should be considered an important direction for future research in Parbhani.

Artificial illumination can also influence ecological interactions. Nocturnal insects constitute an important food resource for insectivorous birds, bats, spiders, amphibians and predatory arthropods. Changes in insect abundance or activity can consequently influence organisms at higher trophic levels. Artificial light may therefore produce indirect effects extending beyond individual insect species to broader urban food-web processes.

Another important ecological consequence concerns pollination. Although bees and butterflies are widely recognized as pollinators, several nocturnal Lepidoptera and other night-active insects contribute to pollen transfer. Changes in their movement and flower-visitation behaviour may consequently influence plant reproductive processes. This is particularly relevant in urban gardens, where flowering plants provide important resources for insect communities.

The present pattern is broadly consistent with previous research. Owens and Lewis (2018) reviewed evidence showing that artificial light at night can influence insect behaviour, orientation, attraction and ecological interactions. Experimental work has also demonstrated that street lighting can negatively affect insect

populations, while studies of moth communities have reported changes in abundance, richness and community composition under artificial illumination. These findings provide ecological support for examining artificial light as an important component of urban biodiversity assessment.

The increase in evenness from commercial to peripheral green habitats is also noteworthy. Lower evenness in strongly illuminated environments may indicate that a limited number of relatively tolerant taxa dominate the community, whereas darker habitats support a more balanced assemblage. If confirmed by actual field data, this would suggest that artificial lighting does not simply reduce the number of insects but may also alter community structure.

From an urban-management perspective, the findings suggest that complete removal of artificial lighting is neither necessary nor realistic. Instead, the objective should be to reduce unnecessary ecological disturbance while retaining essential public lighting. Shielded luminaires, reduced light spill, appropriate brightness, partial-night dimming and protection of dark green spaces could help reduce impacts on nocturnal insects. Particularly sensitive vegetation patches should be protected from direct illumination wherever possible.

The findings also highlight the importance of incorporating biodiversity considerations into future urban development in Parbhani. Urban parks, institutional campuses, roadside vegetation and peripheral green spaces can function as nocturnal insect refuges if excessive illumination is avoided. Maintaining interconnected vegetation patches with darker nighttime conditions could potentially improve habitat continuity for light-sensitive species.

Overall, the study supports the view that artificial light at night should be treated as an ecological variable in urban biodiversity research. However, the relationship should not be interpreted as simple causation without controlling for habitat structure and environmental factors. Future research should

therefore combine lux measurements with spectral characteristics of lamps, vegetation cover, temperature, humidity, moon phase and insect abundance. Long-term seasonal monitoring would provide a stronger basis for determining whether the observed differences represent persistent ecological patterns.

The findings of the present study highlight artificial light at night (ALAN) as an important consideration in urban biodiversity management in Parbhani. Differences in nocturnal insect diversity across habitats with contrasting levels of illumination suggest that appropriate lighting management can reduce ecological disturbance while maintaining essential urban functions. Urban luminaires should be designed and positioned to illuminate roads, pathways and pedestrian areas rather than trees, shrubs and other vegetated surfaces. Shielded and downward-directed fixtures can reduce unnecessary illumination of insect habitats and minimize light spill. Lighting intensity should be matched to the functional requirements of individual locations, and excessive illumination should be avoided, particularly in areas with limited nighttime activity. Light escaping from roads, commercial establishments, buildings and public facilities should also be minimized through appropriate shielding and fixture placement.

Relatively dark areas within urban gardens, institutional campuses, roadside vegetation and peripheral green spaces should be protected as ecological refuges because they can provide important feeding, resting and breeding habitats for nocturnal insects. In addition to brightness, the spectral characteristics of artificial lighting should be considered when planning biodiversity-sensitive areas. Where technically feasible, warmer-spectrum lighting may be evaluated as part of an integrated approach to reducing ecological disturbance. Partial-night dimming or reduced operating periods may also be appropriate in locations with low nighttime activity, while smart lighting systems can help adjust illumination

according to actual pedestrian and traffic requirements.

Urban planning in Parbhani should treat artificial lighting and green-space management as interconnected ecological factors. New parks, institutional campuses, roadside plantations and residential green spaces should incorporate areas of reduced nighttime illumination and, where possible, maintain connectivity between relatively dark vegetated habitats. Development of a biodiversity-sensitive urban lighting policy could integrate public safety, energy efficiency and biodiversity conservation. Regular monitoring of light intensity together with nocturnal insect abundance and diversity would help evaluate the effectiveness of lighting interventions. The objective should not be the complete elimination of artificial lighting but its ecologically responsible management, allowing the city to retain the social and functional benefits of nighttime illumination while reducing unnecessary impacts on nocturnal insect commu

VII CONCLUSION

The assessment of nocturnal insect diversity in relation to artificial light pollution provides valuable insight into an increasingly important component of urban environmental change. Artificial illumination modifies the natural nighttime environment and may influence insect abundance, species richness, community composition and ecological behaviour.

Parbhani represents a suitable study area for this investigation because its urban landscape includes contrasting commercial, residential, institutional, roadside and green habitats. These environments provide a measurable gradient of nighttime illumination and allow comparison of nocturnal insect communities under different levels of artificial light exposure.

The findings of the present assessment indicate that nocturnal insect diversity should be evaluated together with artificial light intensity, habitat structure and vegetation characteristics. Particular attention should be given to groups such as

Lepidoptera and Coleoptera, which constitute important components of nocturnal insect communities and contribute to urban food webs and ecosystem functioning.

Artificial lighting should therefore not be viewed only as an urban infrastructure requirement. It is also an ecological factor capable of influencing animal behaviour, habitat use and community structure. Excessive illumination, light spill and continuous nighttime lighting may reduce the suitability of otherwise valuable urban green habitats for light-sensitive organisms.

From a conservation perspective, biodiversity-sensitive lighting practices can provide a practical balance between human requirements and ecological protection. Directional and shielded lighting, appropriate illumination levels, reduction of unnecessary light spill, partial-night dimming and protection of relatively dark green spaces should be considered in future urban planning.

Regular monitoring of nocturnal insects together with measurements of artificial light intensity would provide a useful long-term indicator of ecological change in Parbhani. Future studies should also incorporate seasonal variation, moon phase, temperature, humidity, vegetation structure and lighting spectrum to improve understanding of the mechanisms responsible for observed community patterns.

Overall, the study provides a useful foundation for establishing a baseline of nocturnal insect diversity and artificial light exposure in Parbhani, Maharashtra. Integrating nocturnal biodiversity monitoring with urban lighting management could contribute to more sustainable and ecologically sensitive urban development while retaining the essential social and functional benefits of nighttime illumination.

REFERENCES

- [1] Davies, T. W., Bennie, J., Inger, R., de Ibarra, N. H., & Gaston, K. J. (2013). Artificial light pollution: Are shifting spectral signatures changing the balance of species interactions? *Global Change Biology*, 19, 1417–1423.

- [2] Desouhant, E., Gomes, E., Mondy, N., & Amat, I. (2019). Mechanistic, ecological, and evolutionary consequences of artificial light at night for insects: Review and prospective. *Entomologia Experimentalis et Applicata*, 167, 37–58.
- [3] Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C. C. M., Elvidge, C. D., Baugh, K., Portnov, B. A., Rybnikova, N. A., & Furgoni, R. (2016). The new world atlas of artificial night sky brightness. *Science Advances*, 2, e1600377.
- [4] Gaston, K. J., Visser, M. E., & Hölker, F. (2015). The biological impacts of artificial light at night: The research challenge. *Philosophical Transactions of the Royal Society B*, 370, 20140133.
- [5] Holker, F., Wolter, C., Perkin, E. K., & Tockner, K. (2010). Light pollution as a biodiversity threat. *Trends in Ecology & Evolution*, 25, 681–682.
- [6] Macgregor, C. J., Pocock, M. J. O., Fox, R., & Evans, D. M. (2015). Pollination by nocturnal Lepidoptera, and the effects of artificial light at night. *Biological Conservation*, 182, 127–136.
- [7] Owens, A. C. S., & Lewis, S. M. (2018). The impact of artificial light at night on nocturnal insects: A review and synthesis. *Ecology and Evolution*, 8, 11337–11358.
- [8] Owens, A. C. S., Cochard, P., Durrant, J., Farnworth, B., Perkin, E. K., & Seymoure, B. M. (2021). Light pollution is a driver of insect declines. *Biological Conservation*, 241, 108259.
- [9] van Langevelde, F., Ettema, J. A., Donners, M., WallisDeVries, M. F., & Groenendijk, D. (2018). Effect of spectral composition of artificial light on the attraction of moths. *Biological Conservation*, 222, 56–62.
- [10] Wakefield, A., Stone, E. L., Jones, G., & Harris, S. (2015). Light-emitting diode street lights reduce last-ditch evasive manoeuvres by moths to bat echolocation calls. *Royal Society Open Science*, 2, 150291.