Journal of Threatened Taxa

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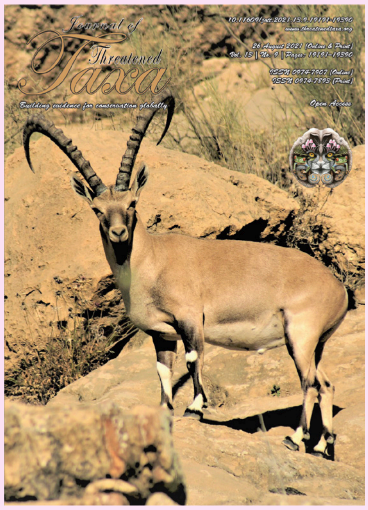
www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)



## Communication

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26 August 2021 | Vol. 13 | No. 9 | Pages: 19302–19309
DOI: 10.11609/jott.6412.13.9.19302-19309



Publisher & Host

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2021 | 13(9): 19302–19309
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6412.13.9.19302-19309
#6412 | Received 14 July 2020 | Final received 15 July 2021 | Finally accepted 14 August 2021
OPEN ACCESS
COMMUNICATION

# Is habitat heterogeneity effective for conservation of butterflies in urban landscapes of Delhi, India?

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**Abstract:** The present study which was conducted in 2015–16 and 2016–17 emphasizes the nine different types of habitats used by 40 listed butterflies in six different urban landscapes of Delhi. Assessment of flowerbeds, grasses, hedges/crops/bushes, artificial light, wet soil/damp patches/humus, trees, open spaces/grounds, bird droppings, and roads/pavements/concrete spaces in conserving butterfly diversity in highly urbanized landscapes by testing the hypothesis that diversity of butterflies across all the habitats are similar, was the focal point of the study. Except for the artificial light and the paved roads or concrete spaces, all other habitats were natural in surroundings. The families Lycaenidae and Nymphalidae had the largest habitat share (26%), whereas the family Hesperiidae had the minimum share (9%). Aravalli Biodiversity Park, New Delhi maintained the serenity of natural ones. Species richness and diversity was the highest at flowerbeds and lowest at the artificial light. The study highlights the choice of heterogeneous habitats by city butterflies to integrate the concept of the urban green spaces into a wide variety of urban development projects which in turn can help their own sustenance.

**Keywords:** Community, diversity, ecology, generalist, green space, heterogenous, lepidoptera, protected, semi-urban.

**Editor:** Monsoon J. Gogoi, Bombay Natural History Society, Mumbai, India. **Date of publication:** 26 August 2021 (online & print)

**Citation:** Paul, M. & A. Sultana (2021). Is habitat heterogeneity effective for conservation of butterflies in urban landscapes of Delhi, India? *Journal of Threatened Taxa* 13(9): 19302–19309. https://doi.org/10.11609/jott.6412.13.9.19302-19309



**Funding:** Guru Gobind Singh Indraprastha University, New Delhi through Indraprastha Research Fellowship (IPRF) vide letter no. 1426/2013 is the sole funding agency for this study.

**Competing interests:** The authors declare no competing interests.

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**Author contributions:** MP—research design, data collection, drafting manuscript, methodology design, critical review, revisions at different stages, editing. AS—conceptualization, data analysis and interpretation, map preparation, drafting manuscript, critical review, editing, revisions at different stages.

**Acknowledgements:** We thank Guru Gobind Singh Indraprastha University, New Delhi for financial assistance through Indraprastha Research Fellowship vide letter no. 1426/2013 and Indian Agricultural Research Institute, Pusa, New Delhi for giving the permission to conduct the research in their agricultural fields. We also thank Dr. M. Shah Hussain of Aravalli Biodiversity Park, New Delhi for his help. A special mention to Mr. Manish Joshi, Ms. Mandeep Kaur, Ms. Shubhi Malik and Mr. Somnath Sahoo of Guru Gobind Singh Indraprastha University, New Delhi is indispensable for timely suggestions that helped to improve the manuscript.

Aravalli Biodiversity Park

Guru Gobind Singh Indraprastha University

## INTRODUCTION

Studies on urban biodiversity are booming in recent years (Shwartz et al. 2014). Urban ecology is an integral part of such studies, and urban areas have become a research topic due to the recognition that conservation and management of urban habitats and species pose particular challenges (McDonnell et al. 1997; Angold et al. 2006). Butterflies, being diurnal, have often been the focus of urban ecosystems (Ramirez-Restrepo & McGregor-Fors 2017) because they are thought to react rapidly to environmental changes due to their high mobility and short generation time (McIntyre 2000). They are a fundamental part of urban ecology (Rebele 1994; McDonnell et al. 2009), providing important ecosystem and helping people reconnect with nature (Soga & Gaston 2016). Recent research has highlighted the positive role of urban green infrastructure in terms of urban ecology and ecosystem services (De Groot et al. 2002; Tratalos et al. 2007), keeping butterflies in the pivotal point of study as tropical butterflies are disappearing at the fastest rates due to loss of suitable habitat (Brook et al. 2003; Koh 2007) especially in southern Asia.

Delhi is the second largest megacity in the world (Tickell & Ranasinha 2018) and one of the largest contributors to the urban population (about 7.6%) of India, with about 16.8 million inhabitants distributed over 1,485 km$^2$ area (Chandramouli & General 2011). Over the last two decades, the population density has increased from nearly 9,340 people/km$^2$ in 2001 to 11,297 persons/km$^2$ in 2011. Rising urbanisation has a strong influence over the butterfly diversity of the city (Paul & Sultana 2020). The present study was undertaken to understand the importance of different habitat types in the urban landscape of Delhi.

## METHODS

### Study area

The study area is NCT (National Capital Territory) of Delhi (Figure 1) 28.42 to 28.87 N and 76.83 to 77.35 E which lies in the northern India and spreads over an area of 1,484 km$^2$ (573 mi$^2$). It borders the Indian states of Uttar Pradesh to the east and Haryana in the north, west, and south. Two prominent features of the geography of Delhi are the Yamuna flood plains and Delhi ridge. The present study includes six sampling sites: industrial area Mayapuri (MP) 28.64 N,77.13 E, Nehru Park (NP), a city park 28.59 N,77.19 E, agricultural area IARI Pusa (PU) 28.64 N, 77.16 E, suburban residential and institutional area Dwarka (DW) 28.59 N,77.02 E, Aravalli Biodiversity Park (ABP) 28.56 N, 77.15 E restored degraded area as a biodiversity park, and a city forest Northern ridge (NR) 28.69 N,77.22 E.

### Data collection

The butterfly sampling was done using the 'Pollard walk' method (Pollard et al. 1993). For each site, the selection of transects was in a random stratified manner depending on the size of the area. Each site was sampled once in a month and thrice in a season using random stratified transects based on the dimensions of the area. At all the sampling sites, three random transects of each 0.5–1 km was selected and every transect was covered in one hour, but at the different time slots of the day: 1000–1200 h,1200–0200 h, and 0200–0400 h. Identification was done using the field guides (Kehimkar 2013; Singh 2017; Smetacek 2017). The classification is based on Kunte et al. (2020). Butterflies were not collected but only photographed for the identification. Field sampling was carried out between April 2015 to March 2017. Data were collected in three distinct periods each year, i.e., (a) pre-monsoon (mid-February to mid-June: comprises spring and summer), (b) monsoon (mid-June to mid-September), and (c) post-monsoon (mid-September to mid-February: comprises autumn and winter). Each site was visited during ideal weather conditions only. Rainy and windy days were avoided. Meteorological data for monthly rainfall and the diurnal temperature were obtained from Regional Meteorological Department of the Indian Meteorological Department, Delhi. Nine different habitats such as flowerbeds, grasses, hedges/crops/bushes, artificial light, wet soil/damp patches/humus, trees, open spaces/grounds, bird droppings, and roads/pavements/concrete spaces were chosen at different landscapes of Delhi during this study.

### Data analysis

The relationships of complex habitats were depicted using Venn diagram (Figure 2). '∩' symbol denotes intersection between two independent habitats which will include the common species between them. Hedges, crops, and bushes had been clubbed together under a same category (H) because they constitute a collective green cover irrespective of their usage in terms of urban greenery. Likewise, roads, pavements and concrete spaces had been put together in a single group (R) as well as wet soil, damp patches, and humus (W) had been grouped together.

Data analyses were carried out in two phases. First,

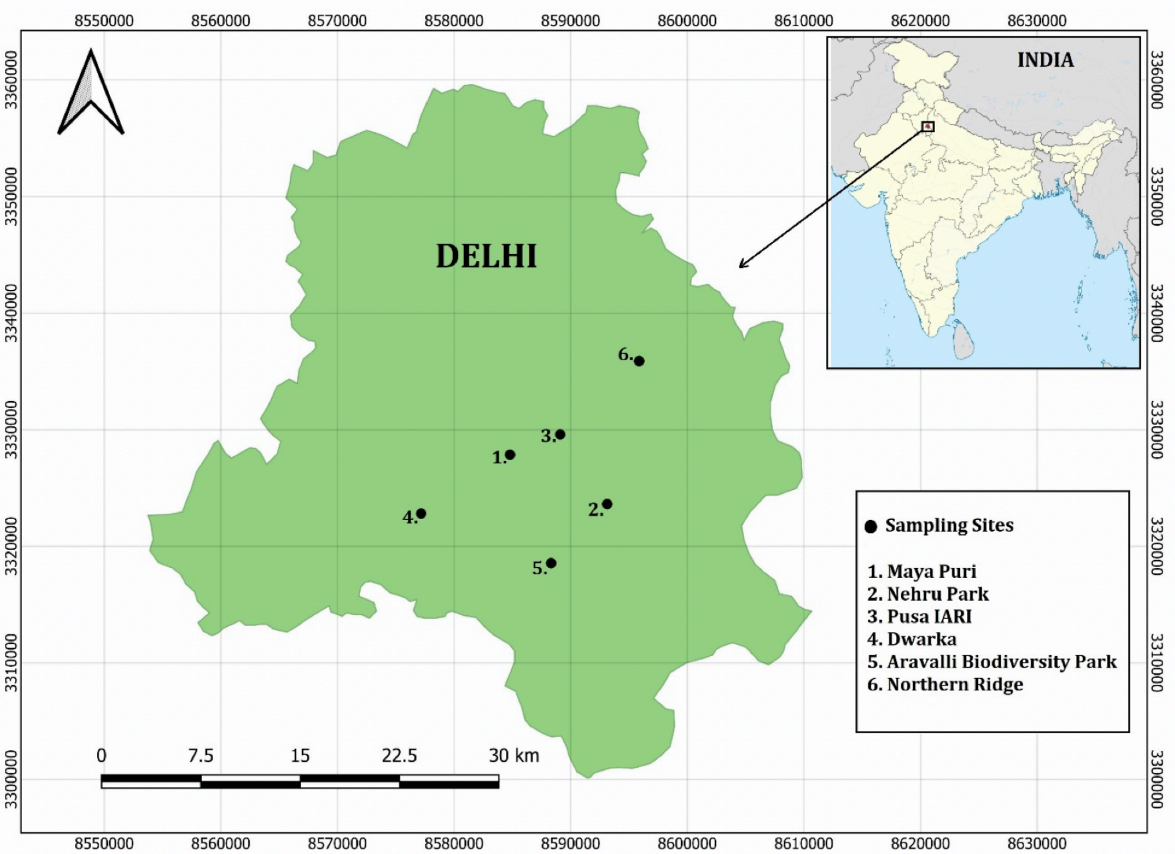


Figure 1. Map of study sites in Delhi.

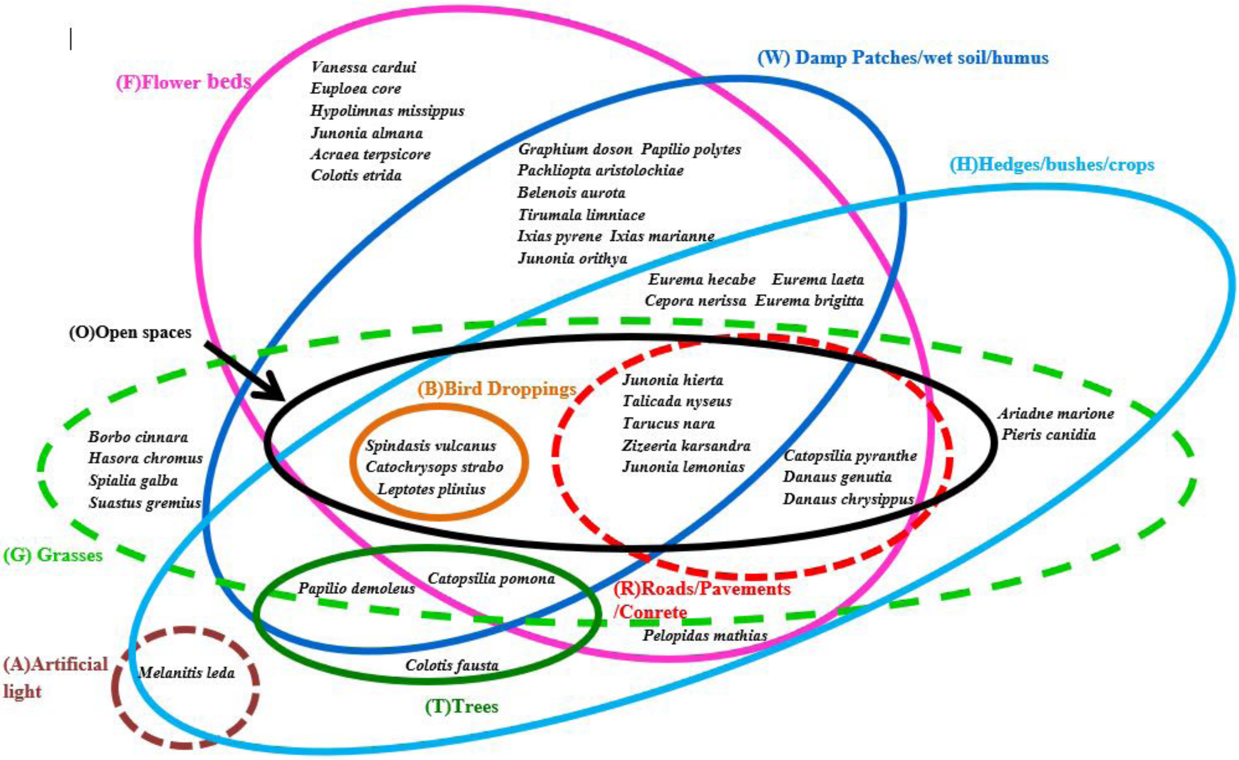


Figure 2. Venn diagram representing 40 species of butterflies in nine habitats across six urban landscapes.

to quantify the diversity of butterfly assemblage at nine different habitats, the following diversity indices, viz., Simpson index of diversity (1 – D) (Romos et al. 2006), Shannon-Wiener index (H′) (Henderson 2005; Romos et al. 2006), and Shannon J or evenness index (Henderson 2005; Romos et al. 2006; were calculated using Microsoft Excel 2010.

The second phase of analysis involves statistical interpretation of data. Shapiro-Wilk test and Kolmogorov-Smirnov test were used to check the normality of the data. Further a null hypothesis was proposed that the diversity of butterflies across all nine habitats is similar, i.e., H1= H2= H3= H4= H5= H6= H7= H8= H9, to check the variance between the habitats. ANOVA test was applied over the data set using the software SPSS 23.0 to check the null hypothesis and further post hoc Dunnett T3 test was conducted to check exactly where the difference lies as the variances were not equal for all habitats.

## RESULTS

With 11,943 overall sightings, 40 species of butterflies belonging to 30 genera and five families were recorded in nine different habitats (Table 1). The results are summarized in a Venn diagram (Figure 2). The groups of butterflies which lie at the innermost zone exploit the maximum number of habitats as compared to the butterflies lying at the outer periphery. Lycaenidae and Nymphalidae families have 26% of the total share and Hesperiidae family has the least share of 9%. *Hypolimnas misippus* (Schedule I) despite it is widespread in India*, Euploea core* (Schedule IV) though this schedule has little or no importance, and *Cepora nerissa* (Schedule II) though its subspecies *dapha* which is found in northeastern India, is only legally protected (Table 1).

*Catochrysops strabo, Leptotes plinius*, *Talicada nyseus*, *Tarucus nara*, *Spindasis vulcanus*, & *Zizeeria karsandra* (family Lycaenidae) and *Junonia lemonias* & *J. hiertha* (family Nymphalidae) are the species of butterflies which are placed at the core of the habitat ellipses, indicate that these species choose up to a maximum of six different habitats. Intricate overlapping of the habitats suggests wide range of habitat usage by a species of butterfly.

Flowerbeds alone carry 15% of the total habitat share (Table 2), followed by grasses with 10%, while 2.5% was observed overlapping among various habitats such as hedges, flowerbeds, trees, grasses, and wet soil. *Melanitis leda* (rice crop pest) is the single candidate for the artificial light source, having 2.5% of the independent share, which accidently got noticed during another type of field study at dusk. Overall, the result showed that the generalists can exploit a greater number of habitats compared specialists found only at selected sites. Dwarka has all the nine habitats, and the other five study sites are missing one or more of them (Table 3). Similarly, out of all the nine habitats, bird droppings, trees, grasses, open spaces, damp patches/wet soil/humus and crops/hedges/bushes were found in all six urban locations. Diversity indices for the habitats are shown in Table 4. The highest values for Simpson diversity index (0.96), Shannon-Wiener index (3.42), and Shannon evenness (0.94) were for the flowerbeds. The artificial light had just one species *Melanitis leda,* hence all diversity indices were 0.

Difference in the butterfly diversity between habitats was tested using ANOVA (SPSS version 23.0) where habitats were treated as independent variables and butterfly frequency as a dependent variable. This test showed that there was a statistically significant difference in butterfly diversity among nine habitats (F= 8.41, d.f.= 8, 450, p= 0.000). With p value </=0.05, it furthers rejects the null hypothesis of similar diversity of butterflies across all the nine habitats, hereby confirming the alternate hypothesis of considerable variation of butterfly diversity among habitats. Dunnett T3 test showed the pairwise comparisons of the habitats which rejected the null hypothesis (Table 5). Diversity in artificial light was significantly different with the flower beds, grass, hedges, and even with the roadside/pavements. Similarly, differences in the diversity among bird droppings, grasses, and flowerbeds are significant too. Butterfly diversity in trees was not significantly different from any other habitats (Table 5).

## DISCUSSION

Habitat heterogeneity is an important factor for the survival and reproduction of butterflies (Nielsen et al. 2014; Sing et al. 2016). *Danaus chrysippus*, being a generalist species thrived very well in the disturbed habitats and has shown successful colonization in West Africa (Larsen 2005). Generalist species tend to survive better in an urban ecosystem compared with specialist species (Lizée et al. 2015). The species which can extract multiple habitats are best in sustaining themselves in heterogeneous topography (Dapporto & Dennis 2013; Slancarova et al. 2014). *Melanitis leda*, among the forty listed butterflies, is the only one active during dusk and

**Table 1. List of 40 butterflies with their respective habitats.**

| | Scientific name | Habitats visited | WPA 1972 Schedules | IUCN Status |
|---|---|---|---|---|
| 1 | *Borbo cinnara* (Wallace, 1866*)* | G | _ | NA |
| 2 | *Hasora chromus*(Cramer, 1780) | G | _ | NA |
| 3 | *Pelopidas mathias* (Fabricius, 1798) | F, H | _ | NA |
| 4 | *Spialia galba* (Fabricius, 1793) | G | _ | NA |
| 5 | *Suastus gremius* Fabricius, 1798 | G | _ | NA |
| 6 | *Catochrysops strabo* Fabricius, 1793 | B, F, G, H, O, W | _ | NA |
| 7 | *Leptotes plinius* (Fabricius, 1793) | B, F, G, H, O, W | _ | NA |
| 8 | *Spindasis vulcanus* (Fabricius, 1775) | B, F, G, H, O, W | _ | NA |
| 9 | *Talicada nyseus* Guerin–Méneville, 1843 | F, G, H, O, R, W | _ | NA |
| 10 | *Tarucus nara* (Kollar, 1848) | F, G, H, O, R, W | _ | NA |
| 11 | *Zizeeria karsandra* (Moore, 1865) | F, G, H, O, R, W | _ | NA |
| 12 | *Acraea terpsicore* (Linnaeus,1758) | F | _ | NA |
| 13 | *Ariadne merione* (Cramer, 1777) | G, H | _ | NA |
| 14 | *Danaus chrysippus* (Linnaeus, 1758) | F, G, H, O, R | _ | LC |
| 15 | *Danaus genutia* (Cramer, 1779) | F, G, H, O, R | _ | NA |
| 16 | *Euploea core* (Cramer, 1780) | F | Schedule IV | LC |
| 17 | *Junonia almana* (Linnaeus, 1758) | F | _ | LC |
| 18 | *Junonia hierta* (Fabricius, 1798) | F, G, H, O, R, W | _ | LC |
| 19 | *Junonia lemonias* (Linnaeus, 1758) | F, G, H, O, R, W | _ | NA |
| 20 | *Junonia orithya* (Linnaeus, 1758) | F, W | _ | NA* |
| 21 | *Hypolimnas misippus* (Linnaeus, 1764) | F | Schedule I | NA |
| 22 | *Melanitis leda* (Linnaeus, 1758) | A, H | _ | NA |
| 23 | *Tirumala limniace* Cramer, 1775 | F, W | _ | NA |
| 24 | *Vanessa cardui* (Linnaeus, 1758) | F | _ | LC |
| 25 | *Graphium doson* Felder & Felder, 1864 | F, W | _ | NA |
| 26 | *Pachliopta aristolochiae* (Fabricius, 1775) | F, W | _ | LC |
| 27 | *Papilio demoleus* Linnaeus1758 | G, H, T, W | _ | NA* |
| 28 | *Papilio polytes* Linnaeus 1758 | F, W | _ | NA |
| 29 | *Belenois aurota* (Fabricius, 1793) | F, W | _ | NA |
| 30 | *Catopsilia pomona* Fabricius, 1775 | F, G, H, T, W | _ | NA |
| 31 | *Catopsilia pyranthe Linnaeus, 1758* | F, G, H, O, R | _ | NA |
| 32 | *Cepora nerissa* (Fabricius, 1775) | F, H, W | Schedule II | NA |
| 33 | *Colotis etrida* (Boisduval, 1836) | F | _ | NA |
| 34 | *Colotis fausta* Olivier, 1801 | H, T | _ | LC |
| 35 | *Eurema hecabe* (Linnaeus, 1758) | F, H, W | _ | NA |
| 36 | *Eurema brigitta* (Cramer, 1780) | F, H, W | _ | LC |
| 37 | *Eurema laeta* Boisduval, 1836 | F, H, W | _ | NA |
| 38 | *Ixias pyrene* Linnaeus, 1764 | F, W | _ | NA |
| 39 | *Ixias marianne* Cramer, 1779 | F, W | _ | NA |
| 40 | *Pieris canidia* (Sparrman, 1768) | G, H | _ | NA |

F—Flowerbeds | G—Grass | H—Hedges/Crops/Bushes | A—Artificial light | W—Wet soil/Damp patches/Humus | T—Tree | O—Open spaces | B—Bird droppings | R—Roads/Pavements/Concrete spaces
Scheduled under Indian Wildlife Protection Act,1972- Schedule I and II: Absolute protection with the highest penalty | Schedule III and IV: Protection with low penalty.
IUCN Red List Status: NA—Not yet been assessed | NA*— Not Applicable | LC—Least Concern

**Table2. Overlapping of habitats and their percentage of share.**

| Butterfly habitats | No. of butterfly species | % Share |
|---|---|---|
| F | 6 | 15.0% |
| G | 4 | 10.0% |
| F∩W | 8 | 20.0% |
| H ∩ A | 1 | 2.5% |
| H ∩ G | 2 | 5.0% |
| H∩T | 1 | 2.5% |
| H∩F | 1 | 2.5% |
| H∩F∩W | 4 | 10.0% |
| H∩T∩G∩W | 1 | 2.5% |
| H∩T∩G∩W∩F | 1 | 2.5% |
| R∩O∩G∩H∩F | 3 | 7.5% |
| B∩H∩O∩G∩W∩F | 3 | 7.5% |
| R∩O∩W∩G∩H∩F | 5 | 12.5% |

F—Flowerbeds | G—Grass | H—Hedges/Crops/Bushes | A—Artificial light | W—Wet soil/Damp patches/Humus | T—Tree | O—Open spaces | B—Bird droppings | R—Roads/Pavements/Concrete spaces | ∩—Intersection/overlapping of two or more habitats.

attracted to artificial light. It is also a rice pest; hence most were found in the rice fields at IARI Pusa during opportunistic search. *Eurema hecabe* is not a very strong flier and prefers open dry areas and thorny vegetation patches. *Belenois aurota* and *Catopsilia pomona* are fond of sun and flowers hence, their habitat ranges from meadows to gardens to damp patches (Kehimkar 2013).

Increasing urbanization brings challenges from environmental impacts. With the outbreak of COVID-19, as the sky and air are getting unadulterated by the automobile pollutants, there are chances for the more specialist species to cope with the changing environment. With further division of COVID-19 hotspot zones into red (areas where large outbreaks and symptoms of corona infection were seen), orange (areas where no new cases were registered in the last 14 days), and green (non-infected areas of the country) the chances of reviving city butterflies increase manifold. Dwarka came under red zone according to the list of Delhi government containment areas, 2020. Hence, further investigation at the various sectors of Dwarka pertaining to different habitats of butterflies could be an interesting comparative study. Dwarka is a sub city which is planned in a way to accommodate surplus population of one million people by building residential societies that constitute 49% of total land use distribution. Hence, because of semi-urban developments, man-made habitats like paved roads or concrete spaces came along with the natural habitats. Similarly, Mayapuri, an industrial and commercial landscape has all the eight habitats except for the flowerbeds which are very prominent in attracting the butterflies for nectaring. Aravalli Biodiversity Park on the other end has been a protected area which minimizes the usage of non-natural manifestations to protect the serenity of the place. It is rich with lush green native vegetation and native nectar rich flowers suitable to act as butterfly attractants. Northern ridge being a city forest also share the similar kind of environment as of Aravalli Biodiversity Park but due to human encroachment and trespassing, flowerbeds were missing. IARI Pusa is an agricultural setup where crops were abundant. Seasonal flower beds of the ongoing crops were regularly seen. Concrete spaces were completely curtailed. Likewise,

**Table 3. Distribution of habitats across urban landscapes of Delhi.**

| Urban Landscapes / Habitats | Dwarka (DW) | IARI Pusa (PU) | Nehru Park (NP) | Mayapuri (MP) | Northern Ridge (NR) | Aravalli Biodiversity Park (ABP) |
|---|---|---|---|---|---|---|
| Tree | √ | √ | √ | √ | √ | √ |
| Flower beds | √ | √ | X | x | X | √ |
| Grass | √ | √ | √ | √ | √ | √ |
| Open Spaces | √ | √ | √ | √ | √ | √ |
| Roads/Pavements/ Concrete spaces | √ | X | √ | √ | X | X |
| Damp patches/ Wet soil/Humus | √ | √ | √ | √ | √ | √ |
| Artificial light | √ | √ | √ | √ | X | X |
| Crops/ Hedges/ Bushes | √ | √ | √ | √ | √ | √ |
| Bird Droppings | √ | √ | √ | √ | √ | √ |
| **Total number of butterflies recorded per site** | **3050** | **1456** | **1298** | **630** | **967** | **4542** |

Table 4. Various diversity indexes for the habitats.

| Diversity indices | F | G | H | A* | W | T | O | B | R |
|---|---|---|---|---|---|---|---|---|---|
| Shannon' | **3.42** | 3.3 | 3.23 | **0** | 3.08 | 2.75 | 2.84 | 2.37 | 3.03 |
| Shannon J | **0.94** | 0.92 | 0.93 | **0** | 0.94 | 0.88 | 0.94 | 0.87 | 0.91 |
| Simpson 1-D | **0.96** | 0.95 | 0.95 | **0** | 0.95 | 0.92 | 0.93 | 0.91 | 0.93 |

F—Flowerbeds | G—Grass | H—Hedges/Crops/Bushes | A—Artificial light | W—Wet soil/Damp patches/Humus | T—Tree, O—Open spaces | B—Bird droppings | R—Roads/Pavements/Concrete spaces | A*—Artificial light had only single species reported hence the diversity index is 0.

Table 5. Pairwise comparison of habitats at alpha =0.05.

| Habitats | Dunnett T3 value | Significance value |
|---|---|---|
| F and A | 5.227 | p = 0.000 |
| F and O | 3.57 | p = 0.003 |
| F and B | 4.609 | p = 0.000 |
| G and A | 4.661 | p = 0.000 |
| G and O | 3.003 | p = 0.029 |
| G and B | 4.042 | p = 0.000 |
| H and A | 3.74 | p = 0.001 |
| H and B | 3.122 | p = 0.010 |
| A and R | 4.205 | p = 0.000 |
| B and R | 3.586 | p = 0.004 |

F—Flowerbeds | G—Grass | H—Hedges/Crops/Bushes | A—Artificial light | W—Wet soil/Damp patches/Humus | T—Tree | O-Open spaces | B—Bird droppings | R—Roads/Pavements/Concrete spaces | Significant values are marked in red.

Nehru Park is a city park in the heart of Lutyen's Delhi. Though, lush green grass sheets and other eight habitats were suitably present, but flower beds were completely missing from such a park. Park adoption schemes by Delhi Developmental Authority (DDA) in 2019 envisages adoption of certain DDA parks by willing agencies for development and maintenance as per the norms of urban green belt. Municipal Corporation of Delhi (MCD) reports Delhi to have 18,000 parks constituting 20% of green cover that is further planned to increase to 33% in coming years. Hence, preservation of natural landscapes adjoining the city will likely to be crucial for effective urban butterfly conservation (Koh & Sodhi 2004). A well-researched land use planning should be done to ensure sustainability of urban green spaces and the habitats.

## CONCLUSION

During a two-year survey and examination of Lepidoptera from Delhi, it is enigmatic to know about the habitats supporting butterflies in urban ecosystem. This lockdown effect is an opportunity not only for the butterfly experts but also for the amateurs to cultivate a butterfly garden at home. This will not only act as a screen free time (no use of electronic device like laptops, mobile phones or television sets) to the youngsters but also prove to be a quality family time to engage with the nature. Further investigations with respect to ecology of butterflies and urban habitats could enlarge the vision of conservation of butterfly communities and help in implementing stern government policies to regulate irresponsible conducts. Therefore, it is not only the prime responsibility of the civic bodies of the city to increase green cover of Delhi but also the residents to glorify terrace gardening, window nurseries and verandah horticulture, keeping in mind the requirements of nectar plants for adult butterflies as well as the larval host plants for the sustenance of this magnificent lepidopteran group in urban nooks of Delhi.

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**ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)**

**August 2021 | Vol. 13 | No. 9 | Pages: 19191–19390**
**Date of Publication: 26 August 2021 (Online & Print)**
**DOI: 10.11609/jott.2021.13.9.19191-19390**

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## Review



## Viewpoint



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