Seasonal Dynamics and Diversity of Butterflies in Urban Parks of the Yamuna River Floodplain Area in Haryana, India

Vidisha Gupta*, Parmesh Kumar

Department of Zoology, Institute of Integrated & Honors Studies, Kurukshetra University, Kurukshetra-136119, Haryana, India

*Corresponding author email: *mittalvidisha39@gmail.com*

Received: 4 July 2024 / Accepted: 29 July 2025

Abstract. Urban parks provide crucial refuges for biodiversity within densely developed areas, supporting diverse butterfly communities. This study, conducted from March 2022 to February 2023 in five urban parks of Yamunanagar, Haryana, India, documented 1,306 butterflies across 45 species, 37 genera, and 5 families using the Pollard Walk method. Family Nymphalidae (17 species) showed the highest species richness, while Lycaenidae (458 individuals) was the most abundant family. *Zizeeria karsandra* (Dark Grass Blue) was the dominant species, with the top five species comprising nearly half of the total abundance. Spatio-temporal analysis using Bray–Curtis dissimilarity and hierarchical clustering revealed distinct patterns in butterfly assemblages across parks and seasons. Species richness and abundance followed a pronounced bimodal distribution, with peaks occurring during the summer and post-monsoon periods. Significant differences ($P<0.05$) in species richness, abundance, and diversity were observed both seasonally and spatially. SIMPER analysis identified five generalist species as primary contributors to inter-park dissimilarities. Principal Component Analysis indicated a positive association of species richness with temperature, and negative correlations with rainfall and humidity. Among the recorded species, eight were categorized as abundant and twelve as rare, including one Schedule II protected species (*Euthalia aconthea*) and three species listed as Least Concern by the IUCN. These results emphasize the role of urban park heterogeneity and climate in shaping butterfly diversity and identify key species for urban ecological monitoring.

Keywords: Seasonal variations, Butterfly diversity, Urban parks, Species richness, Pollard Walk method, Yamunanagar.

1. Introduction

Urbanization stands as an one of primary driver of environmental change and biodiversity decline (Shih, 2018). It leads to the conversion of natural habitats into impervious built environments, resulting in the loss and fragmentation of native ecosystems (McKinney, 2006).

These landscape alterations disrupt ecological processes, reduce habitat connectivity, and displace native species that depend on specific vegetation types and microhabitats (Beardsley et al., 2009). Consequently, urban expansion has been consistently associated with declines in species richness and ecological function, particularly among taxa sensitive to habitat structure, such as butterflies.

Nevertheless, within these increasingly artificial landscapes, urban green spaces including home gardens, vacant plots, institutional campuses, and public parks can function as refuges and stepping stones for butterfly species (Concepcion et al., 2015). These patches often retain native or semi-natural vegetation and may provide key resources such as nectar plants, larval host species, and shelter. Their spatial distribution across urban matrices can also facilitate dispersal and genetic exchange between populations. However, the ecological value of such spaces is variable and depends greatly on vegetation composition, habitat complexity, and the intensity of human management (Aguilera et., 2019). Practices such as frequent mowing, use of pesticides, and preference for ornamental flora can limit the availability of resources critical for butterfly survival and reproduction (Goddard et al., 2010). Despite these limitations, well-managed urban green areas can support a notable diversity of butterfly species, particularly when designed with ecological principles in mind. Greenways, avenues, institutional compounds, and defence premises offer additional habitat opportunities and potential corridors for movement. Urban parks, in particular, have drawn increasing attention in urban ecology research due to their accessibility and potential for biodiversity conservation (Liu et al., 2021).

Butterflies, serving as potential bioindicators, exhibit sensitivity to changes in microclimate, temperature, solar radiation and the availability of host plants for ovipositing and larval development (Aneesh et al., 2013; Chowdhury et al., 2023). They have long been focal taxa for studying the impacts of urbanization, providing insight into the value of urban parks in harbouring biodiversity due to their well-documented taxonomy, status, and geographic distribution. Butterfly diversity often mirrors plant diversity within a given environment, as butterflies rely on various plants for egg laying, larval feeding, and nectar (Nair et al., 2014). Additionally, butterflies, alongside birds, represent one of the most charismatic and conspicuous groups, captivating the interest of both researchers and enthusiasts alike due to their vibrant colours, graceful flight, and charismatic aesthetics (Elanchezhyan et al., 2017; Saha, 2017).

Despite their potential, urban parks and other green spaces within urban landscapes have largely been overlooked as suitable butterfly habitats, even though they have the capacity to sustain diverse butterfly populations over time (Aguilera et al., 2019). Rapid environmental changes, resulting from reforestation and afforestation within built-up areas, have led to a lack of understanding regarding the butterfly diversity within newly established urban parks, despite their common occurrence in urban landscapes (Paul and Sultana, 2020). Thus, to explore the potential of parks s in sustaining butterfly populations, this study was undertaken for the first time to investigate the species richness, abundance and behaviour of butterfly fauna within the urban parks of Yamunanagar city, Haryana, India.

2.Materials and methods

2.1. Study area

The present study was conducted in selected urban parks located within the municipal limits of Yamunanagar city (approximately 30.130° N, 77.280° E), situated in the northeastern part of Haryana, India (Figure 1). The parks surveyed fall within a 5–7 km radius from the city center and were chosen based on criteria such as accessibility, vegetative cover, and representativeness of urban green infrastructure. Yamunanagar district covers an area of approximately 1,756 km^2 and is characterized by predominantly flat terrain, with an average elevation of 255 meters above sea level. The region experiences a subtropical climate with four distinct seasons: summer (April–June), monsoon (July–September), post-monsoon (October–November), and winter (December–February).During the scorching summer months, temperatures can soar to as high as 45°C, creating challenging conditions for both flora and fauna. Conversely, winter brings cooler temperatures, with lows dipping to 3°C, influencing the biodiversity and ecological dynamics of the region. The annual rainfall in Yamunanagar city ranges from 582 to 892 mm per year, with precipitation patterns playing a crucial role in shaping local ecosystems and habitat availability. Despite its rapid urbanization, Yamunanagar has managed to preserve pockets of greenery in the form of parks and gardens, which serve as vital refuges for diverse flora and fauna. These urban green spaces serve not only as recreational areas for city residents but also as important habitats that support a high diversity of species, including numerous butterfly taxa. Within this urban landscape, five specific urban parks were meticulously selected for butterfly surveys, taking into account their greenspace cover and accessibility. A comprehensive overview of the selected urban parks, highlighting key features such as size, vegetation composition, and proximity to urban infrastructure is presented in Table 1 and Figure 2.

2.2. Butterfly survey

The butterfly surveys were conducted bi-weekly from March 2022 to February 2023 in the five selected urban parks of Yamunanagar, Haryana. The Pollard Walk method (Pollard, 1977) was employed to record butterfly species, with fixed transect routes ranging between 350m to 500m established and followed for surveying the parks. Observations were made at 2.5m on both sides of the transects by moving at a slow and steady pace. Species number, population abundance, and r behavioural activities such as roosting, basking, nectaring, mating of adult butterflies were recorded using Nikon10x50 field binoculars during peak activity times from 07:00 to 11:00 or 14:00 to 16:00, progressing at a slow pace of about 1 km per hour.

Field visits were conducted only under suitable weather conditions (absence of rain and strong wind). Opportunistic observations of butterflies at other times were also recorded to prepare a comprehensive checklist of the study area. Photographs of butterflies were taken with a Nikon D5200 digital camera from different angles whenever possible for accurate identification, with no specimens collected. Butterflies were identified using the standard field guide (Smetacek, 2017) and classified according to Bhakare and Ogale (2018). Fast-flying or unclearly identifiable species were recorded to their confirmable genus or family. A local abundance status was assigned to each species based on sighting frequency, following Samanta et al. (2017) as abundant (A) – sighted on 75–100 % of survey days; common (C) sighted on 50–74.99 % of survey days; occasional (O)- sighted on 25–49.99 % of survey days and rare (R) - sighted on less than 25 % of survey days.

Seasonal variations in species richness, diversity and evenness were analysed by pooling data corresponding to four seasons: summer (March-May), monsoon (June-August), post-monsoon (September-November), and winter (December-February). Species richness was calculated as the total number of observed species. Temperature and humidity were recorded on each sampling date using a thermo hygrometer, while rainfall data was obtained from the Indian Meteorological Department. The conservation status of recorded butterfly species was assessed according to the Wildlife (Protection) Amendment Act (2022) and the International Union for Conservation of Nature (2023).

2.3. Data analysis

A species accumulation curve was plotted, showing the cumulative number of species recorded against sampling efforts, to assess the completeness of sampling efforts in the study area. To investigate the patterns in butterfly community composition across different urban parks and seasonal variations, we employed the Bray–Curtis dissimilarity index, based on square-root transformed abundance data. This approach facilitated a nuanced comparison of community structure by accounting for both species richness and abundance. A hierarchical cluster analysis, utilizing the Bray–Curtis dissimilarity matrix, was conducted to construct a dendrogram, offering a clear visual representation of the similarities and differences in butterfly assemblages between the surveyed parks and seasons. The clustering was performed using the unweighted pair-group method with arithmetic averages (UPGMA), allowing for an effective grouping of sites with similar community compositions. To further explore the species contributing most to the observed dissimilarities between parks, a SIMPER (Similarity Percentage) analysis was carried out using PAST version 3.26 software (Hammer et al., 2001).

To explore the relationships between butterfly community parameters (species richness and abundance) and environmental variables (average temperature, humidity and rainfall), Principal Component Analysis (PCA) was performed using PAST version 3.26 software.

3. Results and discussions

3.1. Results

A comprehensive survey yielded a total of 1,306 individual butterflies representing 45 species, 37 genera, 16 subfamilies, and 5 families across the five urban parks during the study period. A checklist of the recorded butterfly fauna, listing their common and scientific names, season of occurrence, local abundance status, and observed behaviours is presented in Table 2. Among the families, Nymphalidae exhibited the highest species richness with 17 species, followed by Lycaenidae (11 species), Pieridae (10 species), and Hesperiidae (4 species), Papilionidae was the least represented family, with records of three species. In terms of individual sightings, Lycaenidae emerged as the most abundant family, with 458 individuals observed, followed by Pieridae (439), Nymphalidae (200), Papilionidae (110), and Hesperiidae (99).

The genus *Junonia* emerged as the most diverse, represented by three species, while five genera (*Danaus, Pieris, Catopsilia, Eurema, Melanitis,* and *Papilio*) were each represented by two species. The remaining 30 genera were represented by a single species each. The ratio of species to genus in the recorded butterfly fauna was estimated to be 1.21. In the surveyed area, the Dark Grass Blue butterfly emerged as the most abundant species, boasting 165 individuals, followed by Lesser Grass Blue with 128 individuals, Pale Grass Blue with 116 individuals, Indian Cabbage White and the Small Branded Swift, tallying 103 and 95 individuals respectively. Collectively, these five dominant species comprised 46.7% of the total butterfly population observed. Applying Novotny and Basset's (2000) framework for identifying rare species within a community, the study revealed the presence of five 'Unique Singletons'—species represented by only one individual each. These solitary butterflies included the *Hypolimnas bolina*, *Euploea core*, *Melanitis leda*,., *Potanthus spp*. and *Spialia galba*.

Analysis of the species accumulation curve for the selected parks revealed a pattern where species richness initially started at a lower level, gradually increasing, and eventually approaching an asymptote. This trend was observed earlier in Tikona Park, Shaheed Bhagat Singh Park, and Jawahar Rose Garden. In contrast, the curves for Nehru Park and Town Park stabilized and reached an asymptote at the 19th sampling effort, suggesting the completeness of sampling efforts in these habitats (Figure 3). The rank abundance plot displayed a shallow slope, indicating an asymmetrical distribution of butterflies across various urban parks (Figure 4). The curve exhibited a steep gradient, suggesting low evenness in different parks, implying that high-ranking species have significantly higher abundances than low-ranking species. This portrayal of the butterfly fauna as an equilibrium community is influenced by various controlling factors.

Among the total identified species, 25 species (55.5%) were recorded from all five selected habitats, while 20 species (44.5%) were exclusively spotted at certain parks only. Town Park exhibited the highest species richness with the representation of 40 species, followed by Nehru Park (38), Shaheed Bhagat Singh Park (32), Tikona Park (27), and Jawahar Rose Garden (26). However, the maximum population abundance was recorded in Nehru Park (318), followed by Town Park (310), Shaheed Bhagat Singh Park (240), and Tikona Park (230), while the lowest number of individuals was observed in Jawahar Rose Garden (208).

Monthly variations in species richness of butterflies in the study area are depicted in Figure 5. A bi-annual peak in species richness was recorded during the study period, first in the month of October (35 species) and second in the month of April (33 species). The maximum species richness of butterfly fauna (n=39) was recorded in summer, followed by post-monsoon (n=40), monsoon (n=36), and winter seasons (n=24). Regarding the seasonal distribution of butterfly families, four families (Nymphalidae, Pieridae, Lycaenidae, and Papilionidae) were recorded in all four seasons, whereas the family Hesperiidae was encountered only during three seasons.

The species richness of butterflies during the four seasons exhibited significant differences (F=12.097, P < 0.05) and also varied significantly among the five urban parks (F=10.664, P < 0.05, Table 3). The average species richness of Town Park (38.29±2.52) was significantly higher (Tukey's HSD test, all P < 0.05) than that of the remaining four urban landscapes. Population abundance of butterflies also showed significant variation between seasons (F=16.653, P<0.05) as well as among the parks (F= 48.22, P< 0.05). The mean population abundance of Town Park (210.27±1.36) was significantly higher than in the other parks. Furthermore, the species diversity of butterflies varied significantly between the seasons (F=9.762, P<0.05) as well as among the five parks (F=10.00, P < 0.05). The mean species diversity of Town Park (2.89±0.14) was significantly higher than in the other four parks (Tukey's HSD test, all $P < 0.05$).

A hierarchical cluster analysis using Bray–Curtis similarity on square-root transformed abundance data revealed two main clusters of butterfly assemblages across five urban parks in Yamunanagar. Nehru Park and Town Park grouped closely, indicating similar species composition and abundance, while Tikona Park and Shaheed Bhagat Singh Park formed a second cluster. Jawahar Rose Garden occupied an intermediate position, showing moderate similarity with both groups (Fig. 6). Bray–Curtis dissimilarity values supported these groupings: Nehru and Town Parks had the highest similarity (dissimilarity = 0.63), whereas Bhagat Singh Park was the most distinct, particularly from Tikona Park (0.83) and Rose Garden (0.81) (Table 4).

SIMPER analysis identified five species, *Junonia lemonias*, *Catopsilia pomona*, *Eurema hecabe*, *Danaus chrysippus*, and *Pieris canidia* as the major contributors to over 65% of the total dissimilarity among parks. Although these species are widespread generalists, their site-specific abundance patterns reflect differences in habitat features such as host plants, nectar sources, and human disturbance, underscoring their value as indicators of urban environmental heterogeneity (Table 6).

Seasonal Bray–Curtis dissimilarity analysis showed the greatest similarity between summer and post-monsoon (0.10), followed by monsoon, which moderately overlapped with both (0.11–0.14). Winter stood out as the most distinct season, with dissimilarity values ranging from 0.14 to 0.18. The corresponding dendrogram confirmed these relationships, clustering summer and post-monsoon together, followed by monsoon, with winter joining at the highest dissimilarity level (~0.26) (Fig. 7, Table 5).

The PCA biplot reveals a positive association between species richness and average temperature, suggesting that butterfly diversity increases under warmer climatic conditions. Butterfly abundance also aligns moderately with temperature along the second principal component (PC2), indicating a similar, albeit less pronounced, relationship. In contrast, rainfall exhibits a negative correlation with both species richness and abundance, implying that higher precipitation levels may suppress butterfly diversity and population numbers. Humidity shows a weaker negative association with these metrics, indicating that increased moisture levels might have a subtle limiting effect on butterfly presence and diversity (Figure 8).The assessment of local abundance status revealed that 8 species were abundant, 12 species were common, 13 species were occasional, and 12 species were rare in the study area (Table 1). Two species, namely, Common Baron *Euthalia aconthea* and Common Silverline *Spindasis vulcanus*, were found to be very static, while the rest of the species were very active and swift in their recorded seasons in the study area.

Among all the recorded species, one species, the Common Baron (*Euthalia aconthea*), was found to be protected under Schedule II of the Wildlife (Protection) Amendment Act, 2022. Regarding International conservation status, the Peacock Pansy (*Junonia almana*), Dark Grass Blue (*Zizeeria karsandra*), and Small Grass Yellow (*Eurema briggitta*) are listed as Least Concern species in the Red List of IUCN (2023), while the remaining species are not yet evaluated. Analysis of the global population trend by IUCN in 2023 revealed that the Small Grass Yellow (*Eurema briggitta*) and Peacock Pansy (*Junonia almana*) have stable (→) global population trends, while the Dark Grass Blue (*Zizeeria karsandra*) has a declining (↓) global population trend.

3.2 Discussions

The findings of this study underscore the rich diversity of butterfly fauna present in urban parks within Yamunanagar city. A total of 45 species representing 37 genera, 15 subfamilies, and 5 families were recorded across the five parks surveyed. This observed richness aligns with previous studies conducted in various urban settings worldwide, including India. For instance, Nacua et al. (2020) reported 11 butterfly species in urban habitats in the Philippines, while Tam et al. (2016) documented 58 species in the urban parks of Hong Kong. Chowdhury et al. (2021) identified 137 butterfly species in urban areas of Dhaka, Bangladesh, and Sing et al. (2016) reported 60 species from urban parks in Southeast Asia. Similarly, Lee et al. (2015) recorded 59 species in urban areas of Seoul, while Sing et al. (2019) found 31 species in the capital city of China. In the context of urban landscapes in India, comparable findings were reported. Paul and Sultana (2020) documented 40 butterfly species in urban parks of New Delhi, while Alex (2023) identified 74 species across ten urban parks in the Kozhikode urban agglomeration of Kerala.

The dominance of the family Nymphalidae in the present study aligns with earlier records and reinforces its significance in Indian butterfly diversity (Kunte, 2000; Paul and Monalisa, 2023). Nymphalidae's prevalence in tropical regions is attributed to its members' polyphagous nature and active flight capabilities, enabling them to thrive across diverse habitats (Tiple, 2009).

Analysis of butterfly community assemblages across the surveyed urban parks revealed a considerable degree of similarity. Specifically, 51.2% of the observed 45 species were recorded in all five parks, with an additional 33.4% occurring in at least two parks. Several species, such as *Eurema hecabe, Papilio polytes,* and *Catopsilia pomona*, were commonly sighted across all the studied parks, suggesting their status as "Urban exploiters." These species demonstrate a high tolerance for urbanization and human disturbance (Aronson et al., 2016). In contrast, species like *Hypolimnas bolina, Melanitis phedima, M. leda, Mycalesis perseus,* *Euploea core, Hasora chromus, Spialia galba*, and *Potanthus spp.* were infrequently observed, appearing only once or twice during their respective seasons. This rarity suggests their classification as "Urban avoiders," indicating a lower likelihood of breeding in green spaces and potentially lacking adaptation to managed urban habitats.

Previous surveys in semi-natural and rural habitats outside Yamunanagar city, such as forested corridors around Kalesar National Park, Morni Hills, and the Shivalik foothills, have recorded relatively higher abundances of these species (Kumar & Sharma, 2020; Singh et al., 2018; Chowdhury et al., 2024). For instance, *Euploea core* and *Mycalesis perseus* are frequently encountered in the understory of mixed deciduous forests and along streamside vegetation in these areas, suggesting their preference for structurally complex habitats with microclimatic stability. These findings reinforce the interpretation that such species are more sensitive to habitat fragmentation, human presence, and simplified vegetation structures that dominate urban green spaces.

The results of our study unveiled the dynamic character of butterfly communities within the sub-tropical region under investigation, revealing notable fluctuations in species richness across different periods of the year. Notably, two distinct peaks in species richness were observed, one occurring in the post-monsoon season in October, with a recorded occurrence of 35 species, and an additional peak during the summer season in April, with 33 species identified. These results align closely with the observations of Gupta et al. (2019), who documented a similar bi-annual pattern of species richness in butterfly assemblages within a sub-tropical urban landscape in Delhi. In contrast to tropical insect communities, which tend to remain relatively stable throughout the year, our findings indicate that subtropical insect communities, such as those in our study area, exhibit more pronounced seasonal peaks in species richness. This variation likely arises from the marked dry and wet seasons characteristic of sub-tropical regions, along with greater climatic variability, including fluctuations in temperature, photoperiod, precipitation, and humidity (Wolda, 1988). Similar seasonal trends in insect diversity have been documented in other subtropical regions as well, such as in southeastern United States (Denlinger, 1980; Triplehorn & Johnson, 2005), parts of South America (Pinheiro et al., 2002) and Australia (Deguine et al., 2009) where shifts in abiotic factors strongly influence insect phenology and community composition.

Seasonality emerges as a critical factor shaping the distribution patterns of butterfly fauna within our study area. The observed fluctuations in species composition across different seasons highlight the dynamic responses of butterfly communities to changing environmental conditions. During the summer months, families Nymphalidae and Lycaenidae emerged as equally dominant, indicative of their preference for warmer temperatures and favourable breeding conditions. However, as winter sets in, a shift in dominance occurs, with Nymphalidae and Pieridae assuming equal prominence. This shift suggests a response to cooler temperatures and possibly altered resource availability during the winter season. The onset of the monsoon season sees a resurgence in the dominance of the Lycaenidae family, likely driven by increased moisture and vegetation growth. However, this dominance sharply declines in winter, indicating a sensitivity to temperature changes and perhaps a decrease in suitable habitat availability. (Nidup et al., 2014). Conversely, Pieridae experiences a decline during the monsoon season but resurges in winter, suggesting a nuanced response to fluctuating environmental conditions. Papilionidae, while displaying a relatively consistent distribution across seasons, declines in winter. This underscores the impact of seasonal changes on butterfly communities.The absence of Hesperiidae records during the summer season suggests a potential preference for specific environmental conditions or habitat types, indicating the importance of considering habitat heterogeneity in understanding butterfly distribution patterns (Lodh and Agarwala, 2016; Sharma and Sharma, 2021). These seasonal variations in distribution of butterfly fauna in the study area can be attributed to abiotic factors such as rainfall, temperature and humidity, timing of leaf and flower production by host and nectaring plants (Paul & Sultana, 2020).

In the present study, Town Park exhibited the highest butterfly species richness (40 species), followed by Nehru Park (38 species). This elevated diversity may be attributed to greater structural habitat heterogeneity, including a wider range of nectar sources and larval host plants. These parks also featured more varied microhabitats and lower levels of human disturbance compared to the other surveyed sites Reduced anthropogenic pressure such as minimal pruning, infrequent application of insecticides, and limited vegetation clearance likely contributes to the higher butterfly diversity recorded in these areas (Clark et al., 2007)

Conversely, the remaining three parks exhibited comparatively lower species richness. These sites appeared less diverse in terms of vegetation structure and composition and were subject to greater anthropogenic activity, including high visitor frequency and intensive park maintenance. Such disturbances can directly impact butterfly populations, particularly during vulnerable life stages such as egg, larva, and pupa, by removing host plants or introducing chemical stressors (Öckinger et al., 2006)

Although some scattered green features such as tree-lined roads, home gardens, and roadside vegetation occur between the parks, these potential ecological corridors are fragmented, narrow, and discontinuous. Such fragmentation likely constrains butterfly dispersal, particularly for habitat specialists (Bhardwaj et al., 2021). Generalist species like *Eurema hecabe* and *Catopsilia pomona* may utilize these corridors due to their higher mobility and broader habitat tolerance. In contrast, specialist and less mobile species such as *Euploea core* and *Mycalesis perseus* are likely restricted in their movement across urban matrices, limiting gene flow and increasing the risk of local extinctions in isolated green patches.

Although quantitative floristic data were not formally collected, qualitative observations during the survey period indicated marked differences in plant species composition and density across parks. Town Park and Nehru Park hosted a richer array of native and ornamental plant species, including several known nectar plants (e.g., *Lantana camara*, *Tagetes erecta*) and larval host plants (e.g., *Cassia spp.*, *Calotropis spp.*). These vegetative differences are likely key drivers of the observed patterns in butterfly diversity and distribution (Bonebrake et al., 2010; Thomas, 1995).

Our integrated application of Bray–Curtis dissimilarity, SIMPER, and PCA unveiled pronounced spatial and temporal variation in butterfly community composition, abundance, and richness across urban parks, shaped by both ecological and anthropogenic influences. Among the five parks surveyed, Nehru and Town Parks harbored the most similar butterfly assemblages (dissimilarity = 0.63), likely reflecting shared habitat characteristics such as diverse vegetation structure, abundant floral resources, and comparatively lower human disturbance. Tikona Park exhibited intermediate similarity to these sites, while Shaheed Bhagat Singh Park stood out as the most compositionally unique, possibly due to its isolation, reduced habitat quality, and distinct management regimes.

Hierarchical clustering corroborated these findings, with Nehru and Town Parks forming a cohesive cluster, Tikona Park and Rose Garden grouping separately, and Shaheed Bhagat Singh Park remaining ecologically isolated. SIMPER analysis highlighted a suite of generalist species—*Junonia lemonias*, *Catopsilia pomona*, *Eurema hecabe*, *Danaus chrysippus*, and *Pieris canidia*—as key drivers of inter-park dissimilarities. Their variable abundances likely reflect differences in host plant availability, floral diversity, and disturbance intensity, positioning these species as valuable bioindicators for urban habitat quality assessments.

Seasonal analyses revealed that butterfly assemblages in summer and post-monsoon periods were most alike (dissimilarity = 0.10), corresponding to favorable climatic conditions characterized by warm temperatures and plentiful nectar resources. The monsoon season showed moderate similarity to these periods, while winter emerged as distinctly divergent, driven by cooler temperatures and resource scarcity that constrain butterfly activity and reduce diversity. The seasonal clustering pattern aligns with well-documented phenological cycles, underscoring peaks in butterfly richness and abundance during warmer, wetter months (Bonebrake et al., 2010; Roy et al., 2001).

PCA provided further insight into environmental drivers, revealing a strong positive correlation between species richness and temperature, underscoring thermal conditions as pivotal in promoting floral productivity and butterfly activity. Abundance likewise demonstrated a moderate positive association with temperature. Conversely, rainfall negatively impacted both richness and abundance, likely through disruption of foraging behavior and increased larval mortality from pathogen pressure or host plant degradation. Humidity showed a subtle negative influence, suggesting a nuanced limiting role on butterfly populations.

Overall, these findings underscore the complex interplay between habitat characteristics, climatic variables, and anthropogenic pressures in shaping butterfly diversity in urban landscapes. The distinctiveness of certain parks and seasons calls for targeted conservation and management strategies. Enhancing floral diversity, reducing habitat fragmentation, and minimizing anthropogenic disturbance could promote more resilient and diverse butterfly communities. Given their sensitivity to environmental change, butterflies serve as effective indicators of urban ecosystem health, and continued monitoring could provide valuable insights into the ecological impacts of urbanization and climate variability in the region. These findings underscore the conservation significance of urban parks within the Yamunanagar district. Although comprehensive assessments of butterfly diversity around

Yamunanagar remain limited, studies from adjacent semi-natural and peri-urban areas suggest similar trends. Sethy and Ray (2010) recorded 35 species from Kalesar Wildlife Sanctuary, while Gupta and Kumar (2024) documented 66 species in the relatively undisturbed Hathnikund Barrage region. These findings highlight the biodiversity potential of less disturbed habitats. In contrast, urban green spaces despite their ecological value tend to support simplified butterfly assemblages dominated by generalist and urban-tolerant species, with habitat specialists underrepresented due to fragmentation and anthropogenic pressures.

Among the documented species, 13 are classified as Least Concern according to the IUCN Red List (2023). Additionally, one species is afforded protection under schedule II of the Wildlife (Protection) Amendment Act, 2022, while another species exhibits a declining global population trend. Presence of species listed as Least Concern by the IUCN, alongside those protected under wildlife legislation, highlights the biodiversity value of these urban green spaces. These parks serve as crucial habitats for various butterfly species, including those facing threats or population declines globally. Therefore, conservation efforts are imperative to ensure the preservation of butterfly diversity within urban environments.

4. Conclusions

This study assesses composition and distribution of butterfly fauna in the urban parks of Yamunanagar city, highlighting, the importance of local parks as a preferred habitat for butterflies in urban zones. The present study recorded the occurrence of 45 butterfly species distributed across five families of Lepidoptera. With 45 butterfly species identified across five families of Lepidoptera, the Nymphalidae family emerged as the most diverse, with Peridae being predominant in terms of individual counts. Seasonal variations were evident, with bi-annual peaks in species richness observed particularly in April-May and September-October. Importantly, the presence of species categorized as Least Concern by the IUCN, as well as those protected under wildlife legislation, underscores the biodiversity value of these urban green spaces. This study reaffirms the ecological importance of small urban parks and advocates for the introduction of more host plants and blooming flora to enhance both the diversity of butterflies and the aesthetic appeal of urban parks. Moreover, it highlights the critical need for further research and conservation efforts to protect biodiversity within cities and their surrounding ecosystems.

Acknowledgements

We are highly thankful to the department of Zoology Kurukshetra University, Kurukshetra for providing requisite research facilities. One of the authors, Vidisha Gupta is thankful to University Grants Commission (UGC), New Delhi, India for providing financial support in the form of SRF for this research work.

References

Aguilera G., Ekroos J., Anna S., Persson L., Pettersson B., Ockinger E., 2019, Intensive management reduces butterfly diversity over time in urban green spaces. *Urban Ecosystem* 22:335–344

Alex N.P., 2023, Urban Parks for Conservation of Butterflies: A case study of Butterfly Diversity of Urban Parks in Kozhikode urban agglomeration, Kerala.

Aronson M.F. et al., 2016, Hierarchical Filters Determine Community Assembly of Urban Species Pools, *Ecology* 97: 2952–63

Aneesh K.S., Adarsh C.K. & Nameer P.O., 2013, Butterflies of Kerala Agricultural University (KAU) campus, Thrissur, Kerala, India. *Journal of Threatened Taxa* 26:4422-40. http://dx.doi.org/10.11609/JoTT.o2870.4422-40

Beardsley K, Thorne J.H., Roth N.E., Gao S., McCoy M.C., 2009, Assessing the influence of rapid urban growth and regional policies on biological resources. *Landscape and Urban Planing* 93:172-183

Bhakare M, Ogale H., 2018. *A Guide to Butterflies of Western ghats (India) Includes Butterflies of Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra and Gujarat state. Satara & Sindhudurga*. pp x+496

Chowdhury S., Dubey V.K., Choudhury S., Das A., Jeengar D., Sujatha B., Kumar A., Kumar N., Semwal A. & Kumar V., 2023, Insects as bioindicator: A hidden gem for environmental monitoring. *Frontiers in Environmental Science* 11:273. https://doi.org/10.3389/fenvs.2023.1146052

Chowdhury S., Shahriar S.A., Bohm M., Jain A., Aich U., Zalucki M.P. and Fuller R.A., 2021, Urban green spaces in Dhaka, Bangladesh, harbour nearly half the country's butterfly diversity. Journal of Urban Ecology *7*: juab008.

Concepcion E.D., Moretti M., Altermatt F., Nobis M.P. & Obrist M.K., 2015, Impacts of urbanisation on biodiversity: the role of species mobility, degree of specialisation and spatial scale. *Oikos*, 124:1571-1582.

Deguine, J.P., Atiama-Nurbel, T., & Quilici, S., 2009, Protection and biodiversity in tropical agroecosystems: The case of the French island of La Réunion (Indian Ocean). *Fruits,* 64:343–354. https://doi.org/10.1051/fruits/2009027

Denlinger, D. L., 1980, Seasonal and annual variation of insect abundance and diapause. M. Rockstein (Ed.), *Biochemistry of insects* (pp. 431–478). New York, NY: Plenum Press.

Elanchezhyan K., Samraj J.M. & Reuolin S.J., 2017, Butterfly diversity at the agricultural college campus, Killikulam, Tami Nadu, India. *Journal of Entomology and Zoology Studies* 5:1389-400

Goddard M.A., Dougill A.J. & Benton T.G., 2010, Scaling up from gardens: biodiversity conservation in urban environments. Trends in Ecology & Evolution 25(2):90-98.

Gupta H., Tiwari C. & Diwakar S., 2019, Butterfly diversity and effect of temperature and humidity gradients on butterfly assemblages in a sub-tropical urban landscape. *Tropical Ecology* 60: 150-158. https://doi.org/10.1007/s42965-019-00019-y

Gupta, V., & Kumar, P. 2024, Butterfly Diversity and Seasonality at Hathnikund Barrage: Insights from a Natural Ecotone in Haryana, India. *Proceedings of the Zoological Society* 77:329-337.

Hammer, Ø., D.A.T., Harper and P.D. Ryan. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4(1):9.

IUCN 2022. The IUCN Red List of Threatened Species. Version 2023-2. Downloaded on 20 May 2023. https://www.iucnredlist.org

WPA 2022. http://www.wiienvis.nic.in/Database/ScheduleSpeciesDatabase_7969.aspx

Kunte K. 2000, *Butterflies of Peninsular India*. Hyderabad: Universities Press (India) Limited. p. 254.

Lodh R., Agarwala B.K., 2016, Rapid assessment of diversity and conservation of butterflies in Rowa Wildlife Sanctuary: an Indo-Burmese hotspot—Tripura, N.E. India. *Tropical Ecology* 57:231-242.

Lee C.M., Park J.W., Kwon T.S., Kim S.S., Ryu J.W., Jung S.J. & Lee SK., 2015, Diversity and density of butterfly communities in urban green areas: an analytical approach using GIS. *Zoological Studies* 54:1-12.

Liu J., Zhao Y., Si X., Feng G., Slik F.& Zhang J., 2021, University campuses as valuable resources for urban biodiversity research and conservation. Urban Forestry & Urban Greening 64, 127255.

McKinney M.L., 2006, Urbanization as a major cause of biotic homogenization. *Biological Conservation* 127:247–260. https://doi.org/10.1016/j. biocon.2005.09.005

Nacua A.E., Aranda H.P.U., Selda S.J.T. & Pascual A.B.M., 2020, Urban diversity of Rhopalocera (Butterflies) at cultural centre of the Philippines, Pasay city, metro manila, Philippines. *Journal of Entomology and Zoology* 8:1292-1296.

Nidup T., Dorji T. & Ugyen T., 2014, Taxon diversity of butterflies in different habitat types in Royal Manas National Park. *Journal of Entomology and Zoology Studies* 2:292-298

Novotny V. & Basset Y., 1998, Seasonality of sap-sucking insects (Auchenorrhyncha, Hemiptera) feeding on Ficus (Moraceae) in a lowland rain forest in New Guinea. *Oecologia* 115:514–522.

Paul M. & Sultana A., 2020, Studies on butterfly (Insecta: Lepidoptera) diversity across different urban landscapes of Delhi India. *Current Science* 118:819–827. https://doi.org/10.18520/cs/v118/ i5/819-827

Pollard E., 1977, A method for assessing changes in the abundance of butterflies. *Biological conservation* 12:115-134

Pinheiro. ,C.E.G., Dressler., R.L., & Papi, F., 2002, Seasonal pattern of butterfly abundance in a central Brazilian cerrado. *Journal of the New York Entomological Society*, 110:35–44.

Samanta S., Das D. & Mandal S., 2017, Butterfly fauna of Baghmundi, Purulia, West Bengal, India: a preliminary checklist. *Journal of Threatened Taxa* 9:10198-10207. http://doi.org/10.11609/jott

Sethy P.G.S. & S. Ray S., 2010**,** Preliminary observations on the butterfly fauna of Kalesar Wildlife Sanctuary, Haryana, India. *Records of the Zoological Survey of India* 110:131–134.

Shih W.Y., 2018, Bird diversity of greenspaces in the densely developed city centre of Taipei. *Urban ecosystems* 21: 379-393.

Sharma N. & Sharma S., 2021, Assemblages and seasonal patterns in butterflies across different ecosystems in a sub-tropical zone of Jammu Shiwaliks, Jammu and Kashmir, India. *Tropical Ecology* 62: 261-278. https://doi.org/10.1007/s42965-020-00139-w

Sing K.W., Jusoh W.F., Hashim N.R. & Wilson J.J., 2016, Urban parks: refuges for tropical butterflies in Southeast Asia? *Urban ecosystems* 19:1131-1147.

Sing, K.W., Luo, J., Wang, W., Jaturas, N., Soga, M., Yang, X., Dong, H. & Wilson, J.J., 2019, Ring roads and urban biodiversity: distribution of butterflies in urban parks in Beijing city and correlations with other indicator species. *Scientific reports*, *9*(1), p.7653.

Smetacek P., 2017, A Naturalist's Guide to the Butterflies of India Pakistan, Nepal, Bhutan, Bangladesh and Sri Lanka. John Beaufoy Publishing Limited and Prakash Books, Delhi, 117pp

Tam K.C., Bonebrake T.C., 2016, Butterfly diversity, habitat and vegetation usage in Hong Kong urban parks. *Urban ecosystems* 19:721-733.

Tiple A.D., 2009, Butterflies from Nagpur city, central India: Diversity, population, nectar and larval host plants and the implications for conservation, Ph.D. Thesis, RTM Nagpur University Nagpur India. 1-146.

Triplehorn, C. A., & Johnson, N. F., 2005, *Borror and DeLong's introduction to the study of insects* (7th ed.). Belmont, CA: Thomson Brooks/Cole.

Wolda H., 1988, Insect seasonality: why? *Annual Review of Ecology and Systematics* 19:1-18.

Table 1. Characteristic features of the selected urban parks of Yamunanagar, Haryana, India.

Habitat	Geo-coordinates	Area (m^2)	Transect length× number	Descriptions
Nehru Park	30°08'25''N 77°17'25''E	955.98	500m×1 450m×1	Centrally located amidst commercial buildings, Nehru Park features lush green lawns, pathways shaded by Palm, Mango, Black Plum trees and Ashoka trees along with many ornamental flowers and a central fountain, drawing visitors to its serene ambiance.
Town Park	30°09'05''N 77°16'50''E	1,508	350m×3	Situated in a residential area, Town Park offers well-maintained lawns surrounded by diverse plantings, providing ample nectar and habitat for various species of butterflies. Prominent shrubs include *Cassia javanica, Bougainvillea sp, Hibiscus rosa, Jasminium sp., Lantana camara, Amaranthus spinosus*
Shaheed Bhagat Singh Park	30°08'10''N 77°16'50''E	770.16	400m×1 350m×1	Adjacent to shopping centers and residential buildings, this park features thematic gardens, an open-air gym, and tree-lined pathways, making it a vibrant recreational space amidst urban hustle. Key vegetation includes *Hibiscus rosa*, *Cassia fistula*, Mango trees, Ashoka trees.
Jawahar Rose Garden	30°07'57''N 77°17'10'' E	400.38	350m×2	Positioned near educational institutions, Jawahar Rose Garden showcases well-kept lawns, shaded by a variety of trees, and ornamental flowers, enhancing the scenic beauty along its pathways. Key vegetation includes *Hibiscus rosa*, *Cassia fistula*, *Jasminium sp.*, Mango trees, Ashoka trees.
Tikona Park	30°07'50''N 77°16'30''E	435.82	350m×2	Nestled amidst residential estates and shops, Tikona Park boasts paved areas, lush plantings, and a distinct triangular shape, contributing to its unique appeal and charm. The vegetation inludes *Cassia javanica, Bougainvillea sp*, *Hibiscus rosa*, *Jasminium sp.*, Mango trees, Ashoka trees, Palm trees.

Table 2. List of butterfly species recorded across urban parks from district Yamunanagar, India.

Sr. no.	Family/Subfamily/Common name	Scientific name	Seasonality	Activity observed	Specialised features	IUCN status	Local status	Urban Parks					
								Nehru Park	Town Park	Shaheed Bhagat Singh Park	Tikona Park	Jawahar Rose Garden	Total
Family: Nymphalidae Subfamily: Nymphalinae													
1.	Peacock Pansy	*Junonia almana*	S, M, PM, W	Basking, sucking nectar	Pollination, Thermoregulation and basking	LC	C	18	7	2	5	9	41
2.	Blue Pansy	*Junonia orithya*	S, M, PM, W	Basking, sucking nectar	Pollination, Thermoregulation and basking	LC	O	2	1	2	0	1	06
3.	Chocolate Pansy	*Junonia iphita*	S, M, PM, W	Basking, roosting	Pollination, Thermoregulation	NE	O	10	6	1	3	0	20
4.	Common Castor	*Ariadne merione*	S, M, PM, W	Basking, sucking nectar	Pollination, Herbivory	NE	C	4	6	1	1	3	15
5.	Great Eggfly	*Hypolimnas bolina*	S, PM, W	Basking, roosting	Pollination	NE	R	1	0	0	0	0	01
6.	Painted Lady	*Vanessa carduii*	S, M	Basking, sucking nectar	Pollination, Migration	LC	C	4	7	2	0	0	13
7.	Common Leopard	*Phalanta phalantha*	PM, W	Basking	Pollination, Herbivory	LC	C	11	6	3	0	1	31
Subfamily: Danainae													
8.	Plain Tiger	*Danaus chrysippus*	S, M, PM, W	Basking, sucking nectar, mud puddling	Pollination, chemical defense, mimicry model	LC	A	9	20	5	8	4	46

9.	Striped Tiger	*Danaus genutia*	S, M, PM	Roosting, nectar sucking, basking	Pollination, mimicry model, group roosting	NE	R	2	0	0	0	0	02
10.	Common Crow	*Euploea core*	PM	Nectar sucking, Basking, resting	Pollination, Müllerian mimicry, unpalatability	LC	R	0	1	0	0	0	01
Subfamily: Satyrinae													
11.	Common Palmfly	*Elymnias hypermnestra*	S	Roosting	Shade-adapted, roosting in low light; Pollination	NE	O	2	1	1	3	2	09
12.	Dark Evening Brown	Melanitis phedima	PM, W	Roosting	Crepuscular activity	NE	R	0	2	0	0	0	02
13.	Common Evening Brown	Melanitis leda	S, M, PM, W	Roosting	Ground roosting, leaf-litter dwelling	LC	R	0	1	0	0	0	01
14.	Common Bushbrown	Mycalesis perseus	S, M, PM, W	Roosting	Shade and moisture lover	LC	R	0	3	0	0	0	03
Subfamily: Limenitidinae													
15.	Common Baron	*Euthalia aconthea*	S, M, PM, W	Basking in sun, Mud puddling	Pollination	NE	C	2	1	3	1	2	09
16.	Common Sailer	*Neptis hylas*	S, M, PM, W	Roosting, basking, mud puddling	Pollination	NE	O	2	1	1	0	1	05
17.	Commander	*Moduza procris*	PM	Territory guarding, basking	Pollination	NE	O	1	4	0	0	0	05
Family: Pieridae Subfamily: Pierinae													
18.	Indian cabbage white	*Pieris canidia*	S, PM, W	Roosting, basking, sucking nectar, mud puddling, patrolling, courtship	Pollination, crop pest (larvae on crucifers)	NE	C	20	34	16	19	14	103

19.	Large cabbage white	*Pieris brassicae*	S, W	Roosting, basking, sucking nectar, mud puddling, patrolling, courtship	Pollination, agricultural pest	NE	C	16	10	13	9	11	59
20.	Yellow Orange Tip	*Ixias pyrene*	S, M, PM, W	Roosting, basking, sucking nectar	Pollination	NE	O	2	5	1	1	0	09
21.	Common Gull	*Cepora nerissa*	S, M, PM	Basking, sucking nectar	Pollination	NE	C	7	15	10	5	9	46
22.	Pioneer	*Belenois aurota*	S, M, PM	Basking, roosting, patrolling.	Migratory pollinator, early colonizer species	LC	C	21	17	12	6	11	67
Subfamily: Coliadinae													
23.	Common Grass Yellow	*Eurema hecabe*	S, M, PM, W	Roosting, basking, sucking nectar, mud puddling, patrolling	Pollination	NE	A	8	6	10	9	5	38
24.	Small Grass Yellow	Eurema brigitta	S, M, PM, W	Mud puddling, resting, nectar sucking.	Pollination	LC	A	3	2	2	1	0	08
25.	Common Emigrant	*Catopsilia pomona*	S, M, PM, W	Mud puddling, roosting, sucking nectar, patrolling, courtship, flying around	Seasonal migration, pollination, fast colonizer of disturbed sites	NE	A	18	10	14	20	9	71

26.	Mottled Emigrant	*Catopsilia pyranthe*	S, M, PM, W	Mud puddling, roosting, sucking nectar, patrolling	Seasonal migration, pollination	NE	C	10	6	9	3	5	33
27.	Dark Clouded Yellow	*Colias feldii*	S	Resting, sucking nectar	Pollination	NE	R	0	5	0	0	0	05
Family: Lycanidae Subfamily: Polyommatinae													
28.	Dark Grass Blue	*Pseudozizeeria maha*	S, M, PM	Roosting, basking, patrolling, sucking nectar, flying around	Pollination	NE	A	36	48	29	22	30	165
29.	Lesser Grass Blue	*Zizina otis*	S, M, PM	Roosting, basking, patrolling, mating, sucking nectar, courtship, flying around	Pollination	LC	A	28	30	18	32	20	128
30.	Pale Grass Blue	*Zizeeria karsandra*	S, M, PM, W	Roosting, basking, patrolling, sucking nectar, courtship	Pollination	LC	A	19	27	22	30	18	116
31.	Zebra Blue	*Leptotes plinius*	S, M, PM	Roosting	Pollination	NE	C	10	4	3	1	1	19
32.	Pea Blue	*Lampides boeticus*	S, M	Roosting, basking	Pollination	LC	O	3	1	2	0	0	06

33.	Gram Blue	*Euchrysops cnejus*	S, M, PM	Roosting, basking, patrolling	Pollination	NE	O	1	2	4	7	5	19
34.	Common Pierrot	*Castalius rosimon*	S, M, PM, W	Roosting, nectar sucking	Pollination	NE	R	6	2	0	0	0	08
35.	Striped Pierrot	*Tarucus nara*	S, M, PM	Roosting	Pollination	NE	R	0	2	0	0	0	02
36.	Red Pierrot	Talicada nyseus	S, M, PM	Roosting, flying around	Pollination	NE	O	2	4	1	1	7	15
37.	Black Spotted Grass Jewel	Freyeria putli	S, M, PM	Roosting	Pollination	NE	O	1	2	3	1	0	07
Subfamily: Theclinae													
38.	Common Silverline	*Spindasis vulcanus*	S, M, PM	Roosting, basking	Pollination	NE	O	4	6	1	2	5	18
Family:Papilionidae Subfamily: Papilioninae													
39.	Common Jay	*Graphium doson*	S, M, PM	Mud puddling, sucking nectar	Pollination, herbivory	NE	C	6	2	4	7	3	22
40.	Lime Swallowtail	Papilio demoleus	S, M, PM, W	Roosting, basking, nectar sucking.	Pollination, herbivory	NE	O	2	1	3	4	3	13
41.	Common Mormon	*Papilio polytes*	S, M, PM,	Nectar sucking, mud puddling, patrolling, mating, courtship	Pollination, herbivory	NE	A	14	18	20	14	9	75
Family: Hesperiidae Subfamily: Hesperiinae													
42.	Small Branded Swift	Pelopidas mathias	M, PM, W	Roosting, Nectar sucking	Pollination, herbivory	LC	O	10	25	22	16	20	93

43.	Common Banded Awl	*Hasora chromus*	PM	Roosting	Pollination, herbivory	NE	R		4	0	0	0	04
44.	Dart spp.	*Potanthus spp.*	M, PM	Roosting	Pollination, herbivory	NE	R	1	0	0	0	0	01
Subfamily: Pyrginae													
45.	Asian Grizzled Skipper	*Spialia galba*	M, PM	Roosting	Pollination, herbivory	NE	R	1	0	0	0	0	01
Total individuals sighted								317	310	240	230	208	1306

Table 3. Species richness, abundance and species diversity of butterfly fauna in the selected urban parks of Yamunanagar, Haryana.

Urban Park	**Diversity index**														
	Species richness					**Population abundance**					**Species diversity**				
	S	**M**	**PM**	**W**	**Mean**	**S**	**M**	**PM**	**W**	**Mean**	**S**	**M**	**PM**	**W**	**Mean**
Nehru Park	36.25 ±2.41	28.32± 1.73	35.27± 2.03	21.25± 1.79	30.273^{b} ±1.98	233.40± 1.69	197.30± 0.82	230.20± 1.42	181.20± 1.52	210.27^{a}5 ±1.36	2.87±0 .20	2.79±0 .20	2.85±0 .20	2.12±0 .20	2.657^{b}± 0.20
Town Park	38.29 ±2.52	31.25± 2.79	36.21± 2.12	26.29± 2.01	33.01^{a}±2 .36	227.00± 1.72	185.15± 2.01	220.10± 1.58	145.20± 0.20	194.362^{b} ±1.37	2.98±0 .14	2.88±0 .14	2.97±0 .14	2.75±0 .14	2.89^{a}±0 .14
Bhagat S. Park	31.00 ±2.41	25.14± 2.61	27.41± 2.71	21.12± 1.65	26.168^{c}± 2.34	198.66± 1.72	188.54± 1.21	197.65± 1.72	178.47± 1.72	190.831^{bc} ±1.59	2.56±0 .16	2.49±0 .16	2.51±0 .16	2.41±0 .16	2.49^{c}±0 .16
Tikona Park	26.75 ±2.61	25.69± 2.49	25.71± 2.59	19.15± 1.41	23.825^{cd} ±2.28	193.33± 1.42	185.43± 1.25	191.33± 1.51	180.44± 1.71	187.632^{c} ±1.47	2.53±0 .20	2.47±0 .20	2.49±0 .20	2.40±0 .16	2.47^{cd}± 0.19
Jawahar Garden	23.25 ±2.41	20.17± 1.58	22.19± 2.12	18.10± 1.40	20.927^{d} ±1.87	166.66± 1.72	159.45± 1.64	161.57± 1.72	151.42± 1.61	159.775^{d} ±1.67	2.50±0 .11	2.44±0 .11	2.51±0 .11	2.31±0 .11	2.44^{d}±0 .11
ANOVA	**Park**				10.664					48.22					10.00
	Season				12.097					16.653					9.762
P-value	**Park**				0.001					0.00					0.00
	Season				0.000					0.00					0.002

S- Summer, M-Monsoon, PM- Post monsoon, W-Winter.

Significant differences were found at 5% level of significance. Results in a column under various indices followed by different letters indicate significant differences among different seasons at P<0.05. Results in a column followed by same letters indicate non-significant differences among different seasons at P>0.05 (two-way ANOVA and Tukey’s HSD post-hoc test.

Table 4. Bray-Curtis dissimilarity matrix of butterfly species between selected urban parks of the study area.

Urban Park	Nehru Park	Town Park	Bhagat Singh Park	Tikona Park
Jawahar Rose Garden	0.54	0.55	0.47	0.42
Tikona Park	0.56	0.52	0.45	
Bhagat Singh Park	0.58	0.57		
Town Park	0.35			

Table 5. Bray-Curtis dissimilarity matrix of butterfly species between seasons in the study area.

Season	Summer	Monsoon	Post monsoon
Winter	0.17	0.18	0.14
Post monsoon	0.10	0.14	
Monsoon	0.11		

Table 6. Butterfly Species with the Highest Contribution to Community Abundance

Common Name	**Average Abundance**	**Average Dissimilarity Contribution (%)**
Indian Cabbage White	3.8	9.7
Plain Tiger	4.5	10.8
Common Grass Yellow	4.9	12.0
Common Emigrant	5.4	14.9
Peacock Pansy	6.2	17.8
Total		65.5

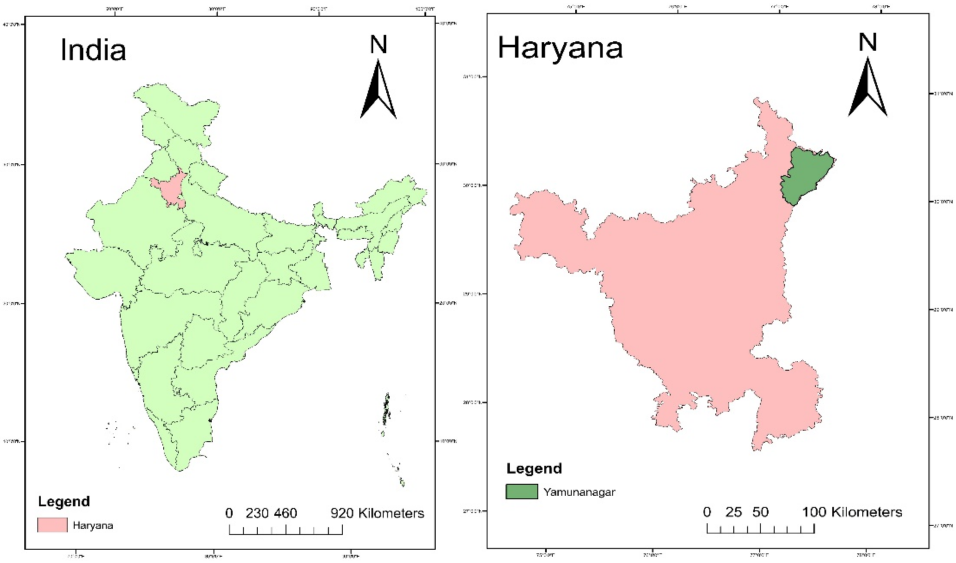

Figure 1. Map depicting the location of Yamunanagar city.

Figure 2. Pictures of selected urban parks of Yamunanagar city, (A) Town Park, (B) Nehru Park, (C) Shaheed Bhagat Singh Park, (D) Jawahar Rose Garden, (E) Tikona Park

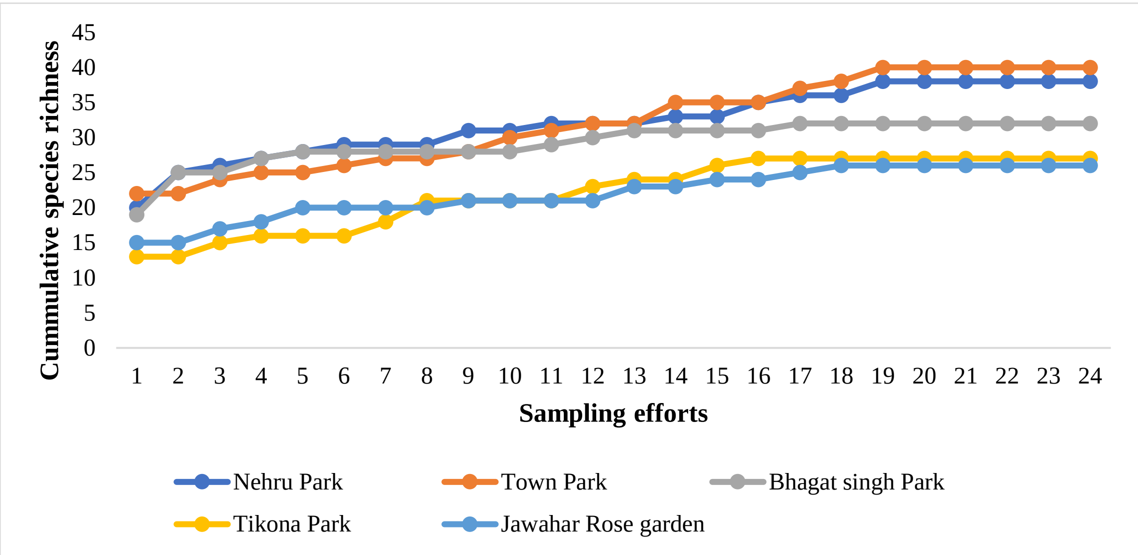

Figure 3. Species accumulation curve of the butterfly fauna recorded across different urban parks of Yamunanagar

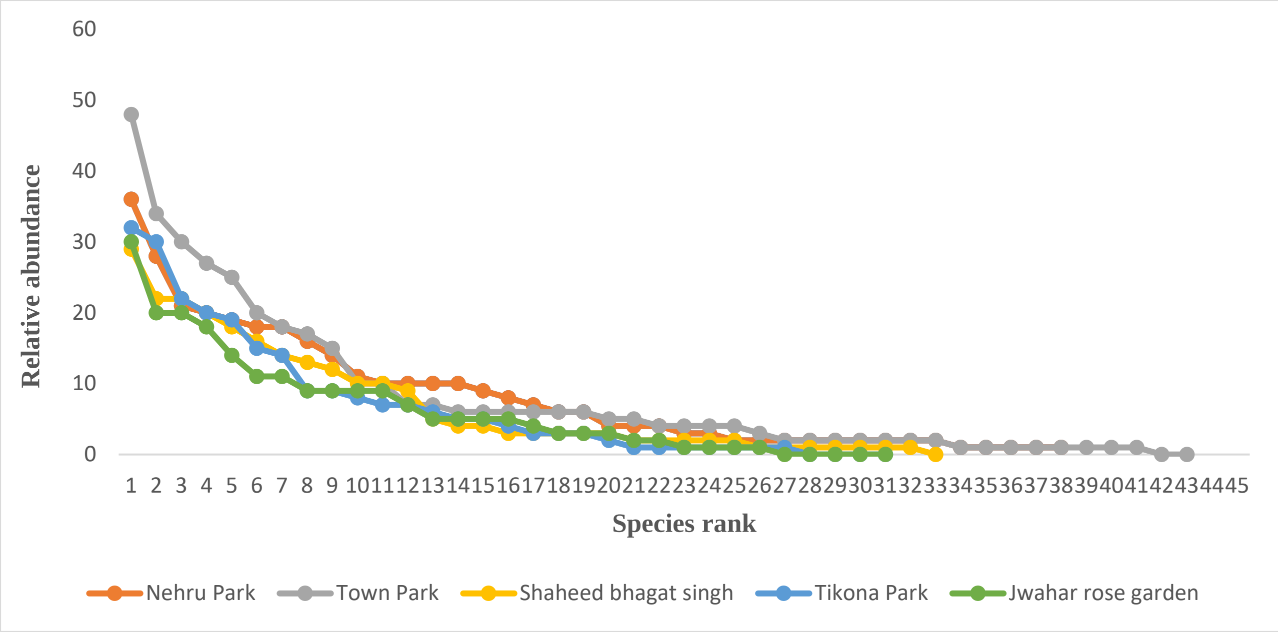

Figure 4. Rank abundance curve illustrating the relative abundance of species recorded across different urban parks in Yamunanagar.

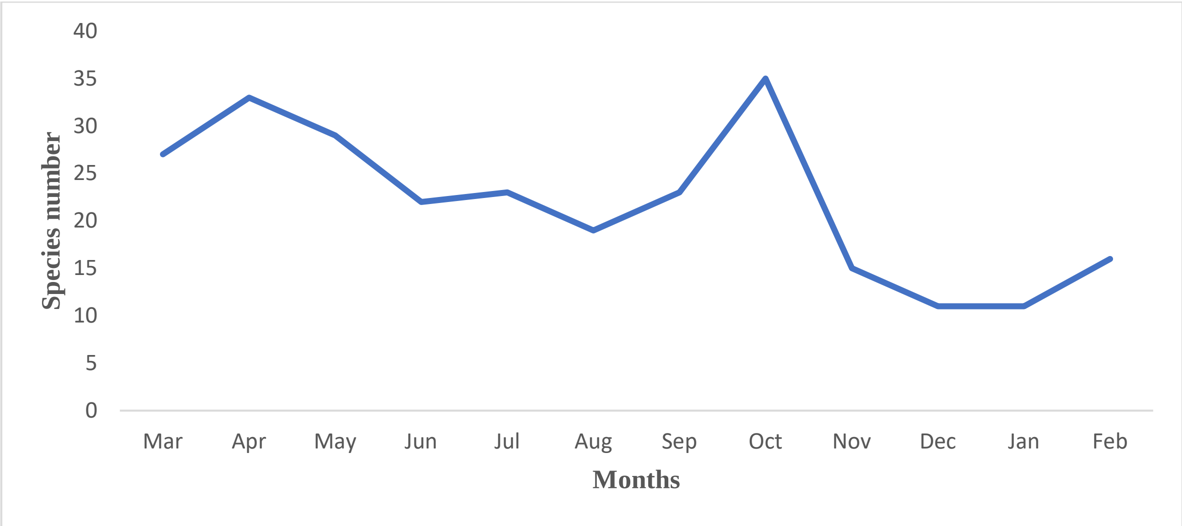

Figure 5. Monthly variations in species richness of butterfly fauna recorded from urban parks of Yamunanagar.

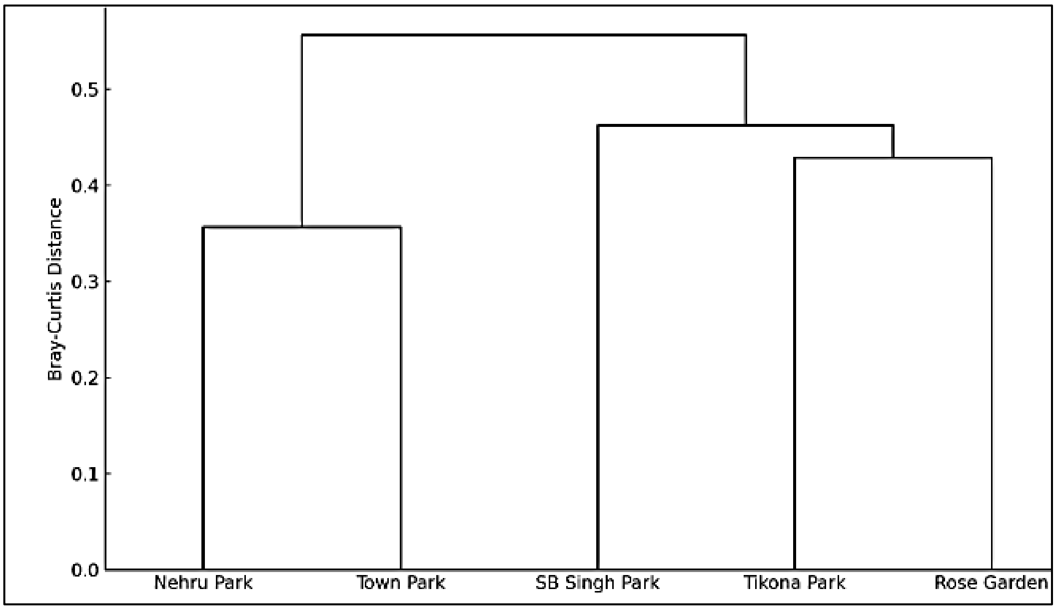

Figure 6. Dendrogram based on Bray-Curtis dissimilarity matrices illustrating the similarity in butterfly species composition in different urban parks

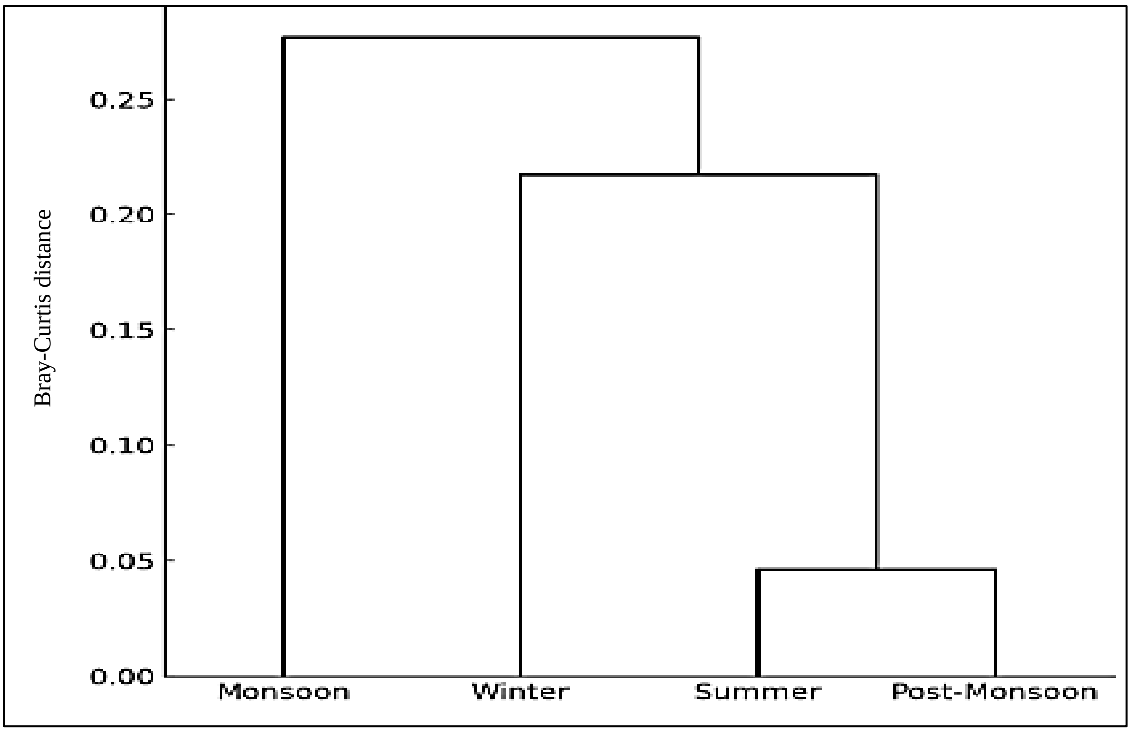

Figure 7. Dendrogram based on Bray-Curtis dissimilarity matrices illustrating the similarity in butterfly species composition among the seasons.

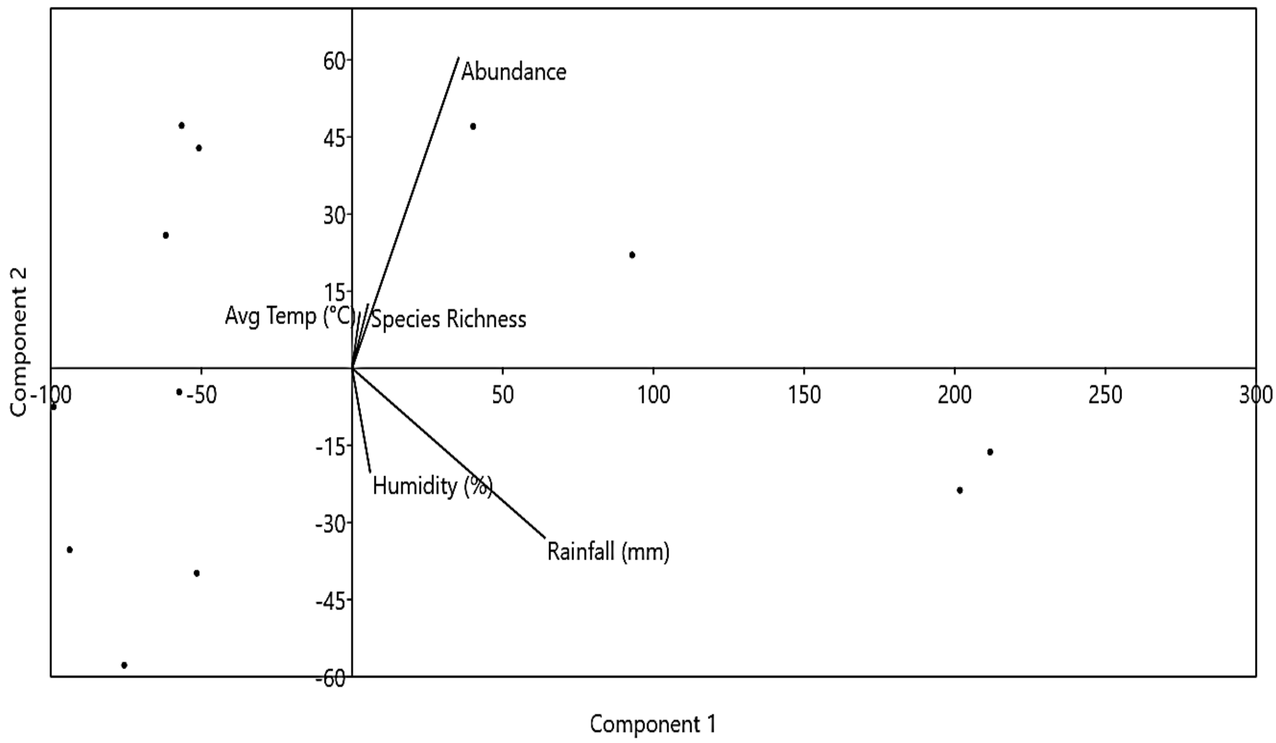

Figure 8. Principal Component Analysis (PCA) biplot showing the relationship between butterfly richness and abundance with climatic factors (temperature, humidity, and rainfall) across four seasonal observations in Yamunanagar district, Haryana. Each point represents a season. The vectors indicate the direction and strength of influence of each variable on butterfly diversity.