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Population dynamics of *Danaus chrysippus* and *Tirumala limniace* with respect to seasonality in an urban ecosystem

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Abstract
Urban ecosystems play a critical role in supporting biodiversity, particularly for species sensitive to environmental changes, such as butterflies. This study examines the population dynamics of two tropical butterfly species, *Danaus chrysippus* and *Tirumala limniace*, in the Presidency College campus and surrounding areas in Chennai, India, over three years (2021–2023). Monthly surveys were conducted across five distinct sampling locations to monitor butterfly populations and their correlations with climatic variables, including temperature and rainfall. Statistical analyses revealed significant seasonal variations, with *D. chrysippus* exhibiting population peaks during post-monsoon and summer seasons, while *T. limniace* thrived during the monsoon period. Spearman correlation showed strong positive associations between tempe rature and *D. chrysippus* ($r = 0.72$, $p < 0.05$), and between rainfall and *T. limniace* ($r = 0.81$, $p < 0.01$). Analysis of variance (ANOVA) confirmed significant seasonal differences in populations ($p < 0.01$ for both species). These findings highlight the critical role of climatic factors and host plant phenology in shaping butterfly populations in urban landscapes. Conservation strategies must prioritize native vegetation and adapt to seasonal climatic variability to sustain urban butterfly diversity.

Keywords: Butterfly population dynamics, *Danaus chrysippus*, *Tirumala limniace*, urban ecosystems, seasonality, climatic factors

Introduction

Butterflies are sensitive indicators of ecological health, reflecting the impacts of habitat degradation and climate change (Parikh *et al.*, 2021; Chowdhury *et al.*, 2023) [1, 2]. As essential pollinators and key components of food webs, their presence and population levels highlight habitat quality and biodiversity (Ollerton, 2017) [3]. Despite human pressures, urban environments can support diverse butterfly species if suitable habitats and host plants are available (Chowdhury *et al.*, 2017) [4]. This makes urban areas important for studying how butterflies adapt to human-altered landscapes and climate variability (Wepprich *et al.*, 2019) [5]. Global research shows butterflies rely heavily on climatic factors like monsoonal rainfall and host plant phenology (Hall, 2023) [6]. Tropical species, such as Danaus chrysippus, exhibit remarkable resilience to climate fluctuations, aiding their widespread distribution (James, 2024) [7]. Meanwhile, in temperate regions, urbanization affects butterfly communities differently—some species benefit from fragmented habitats, while others decline due to limited resources (Ruas *et al.*, 2022) [8]. European studies stress the importance of native vegetation and habitat connectivity in sustaining urban butterfly populations (Lampinen *et al.*, 2018; Warren *et al.*, 2021) [9, 10].

In India, butterfly studies have largely focused on natural and semi-natural habitats like the Western Ghats and Himalayas, both renowned biodiversity hotspots. Research by Kunte (2000) [11] in the Western Ghats revealed clear seasonal patterns in butterfly populations linked to rainfall and host plant availability. Similarly, studies in Karnataka and Maharashtra noted monsoon-driven population peaks in species such as *Tirumala limniace* (Padhye *et al.*, 2006) [12]. Urban ecosystems, despite their potential to support diverse butterfly species, have been less studied. However, research from Bangalore (Remadevi *et al.*, 2018) [13] and Kolkata (Mukherjee *et al.*, 2018) [14] shows urban green spaces can sustain butterfly populations, provided host plants and nectar sources are preserved.

In Chennai, a tropical coastal city, the Presidency College campus and nearby areas serve as vital green spaces for butterfly populations. This study examines two key species: the Plain Tiger (*Danaus chrysippus*), which thrives in drier environments using plants like *Calotropis spp*., and the Blue Tiger (*Tirumala limniace*), adapted to wetter habitats with host plants like *Heterostemma* and *Tylophora indica*. Understanding how these butterflies interact with climatic factors is crucial for conservation, especially in urban areas facing ecological pressures. Despite their significance, little is known about their responses to seasonal changes in urban ecosystems. The research integrates population monitoring with climatic data, exploring how seasonal patterns relate to temperature, rainfall, and host plant availability. Insights aim to guide urban conservation strategies by identifying critical drivers of butterfly population dynamics in Chennai. By studying populations across multiple urban sites, the research highlights climatic influences and offers actionable recommendations for habitat and biodiversity management, contributing to national and global urban butterfly ecology research.

Materials and Methods

Study Area

The study area includes the Presidency College campus and its surroundings, Chennai [13.0827° N, 80.2707° E]. This urban ecosystem is comprised of different habitat types such as gardens, scrublands, and coastal vegetation. In the study area, five sampling sites with different butterfly population and habitat types were selected. The first site is Presidency College, an urban garden area with mixed vegetation. The Presidency College (b) had coastal scrublands along the beach, whereas Presidency College (c) had some shaded areas with flowering plants. The fourth site was Marina Beach, which had open coastal vegetation. Lastly, Tiruvallikeni represented urban residential green pockets adding to the habitat diversity in the study region (Figure 1).

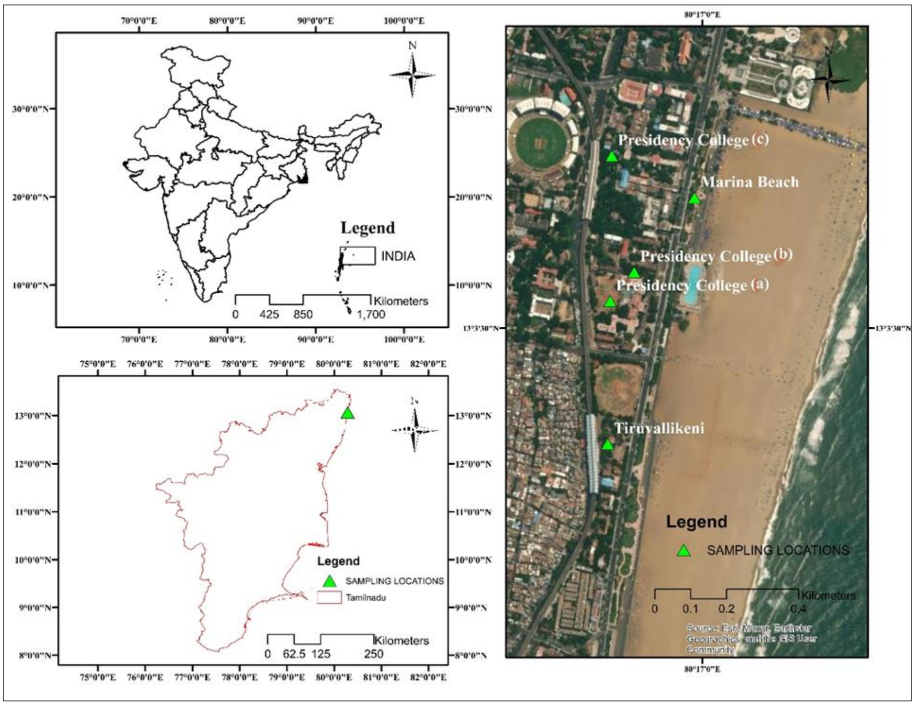

Fig 1: Map of the study area showing sampling locations.

Sampling Procedure

Monthly counts were carried out each month from January 2021 to December 2023 to monitor butterfly populations. A standardized transect-based method of data collection is the Pollard Walk method. Transects are 500 meters in length, with the survey time falling between 07:00-09:00 AM—the peak morning hours of butterfly activity. Data is only recorded under favorable weather conditions to ensure comparison of consistent and comparable data.

Climatic Data

The climatic data monthly temperature and rainfall were received from the Indian Meteorological Department, Chennai Camp, via (https://mausam.imd.gov.in/chennai/). Winter ushers in a temperature as low as 20°C and varies up to as high as 40°C in summer, reflecting the tropical climate of Chennai. Precipitation during one season dominates most of the months, June–September, thus being referred to as the monsoon season.

Data Analysis

Data analysis was carried out for a wide range of variables using various statistical and visualization methods. Temporal trends in monthly and seasonal means of both species were studied. Associations of climatic variables with the butterfly population count were studied using Spearman's rank correlation to assess nonlinear relationships. One-way ANOVA was used to see the significant differences among the seasons, namely winter, summer, monsoon, and post-monsoon seasons, in butterfly population. Line plots, scatterplots, and bar charts were finally used to visualize the results to provide clear and interpretable insights into the population dynamics and their relationship with environmental factors.

Results

Monthly Population Dynamics

The seasonal fluctuation of *Danaus chrysippus* (Figure 2a) and *Tirumala limniace* (Figure 2b) in the study area was well differentiated during the three-year study.

Fig 2a: *Danaus chrysippus*

Figure 2b: *Tirumala limniace*

Danaus chrysippus had two major peak seasons, namely April-May (summer) and October-November (post-monsoon) (Figure 3). In *D. chrysippus*, October was the peak month with a mean population count of 83.2 ± 15.6 individuals, followed by April with 76.4 ± 12.2 individuals. These coincided with the peak availability of its larval host plants (*Calotropis* spp.) that bloom heavily in these seasons. This was followed by the depression in its population during the monsoon season (June-August), which reached a trough in July (38.4 ± 9.2 individuals). *Tirumala limniace* showed a different trend. The species showed its maximum abundance during the monsoon period (June-August), with the maximum mean population count in July (72.6 ± 18.4 individuals). This peak coincided with higher rainfall and the growth of host plants such as *Tylophora indica* and *Heterostemma spp*. Another secondary peak was observed in September-October, which coincides with the late monsoon to post-monsoon transition period. The minimum population counts for *T. limniace* were noted during the dry winter months of December and January, when the mean population fell to 24.6 ± 6.4 individuals. These monthly population trends thus underline the divergent ecological strategies of the two species: whereas *D. chrysippus* is adapted to drier conditions and utilizes the post-monsoon flowering of its host plants, *T. limniace*, on the other hand, reaches a peak during wetter months of the monsoon period, where its preferred larval plants have proliferated.

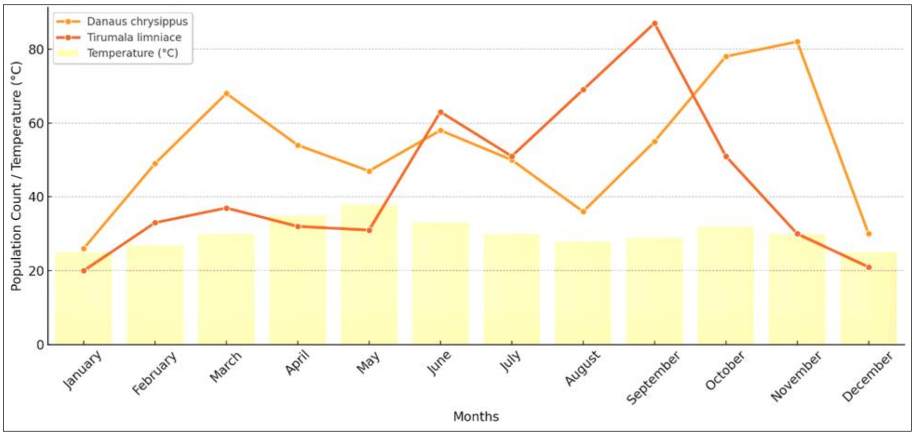

Fig 3: Monthly population dynamics of *Danaus chrysippus* and *Tirumala limniace* with climatic trends.

Correlation with Climatic Variables

By analyzing the correlation between butterfly populations and climatic factors, the seasonal trends were clearly explained. *Danaus chrysippus* indicated a strong positive correlation with temperature (Spearman's r = 0.72, p < 0.05). This correlation establishes the species' preference for high-temperature conditions, especially during the summer and post-monsoon seasons (Figure 4). However, its correlation with rainfall was weak and non-significant (r = 0.30, p > 0.05), indicating that rainfall had minimal direct impact on its population dynamics. In contrast, *Tirumala limniace* showed a strong positive correlation with rainfall (Spearman's r = 0.81, p < 0.01), highlighting its heavy reliance on wet conditions during the monsoon season. It also exhibited a moderate correlation with temperature (r = 0.54, p < 0.05), indicating that while temperature influences its lifecycle, rainfall remains the dominant climatic factor driving its population trends.

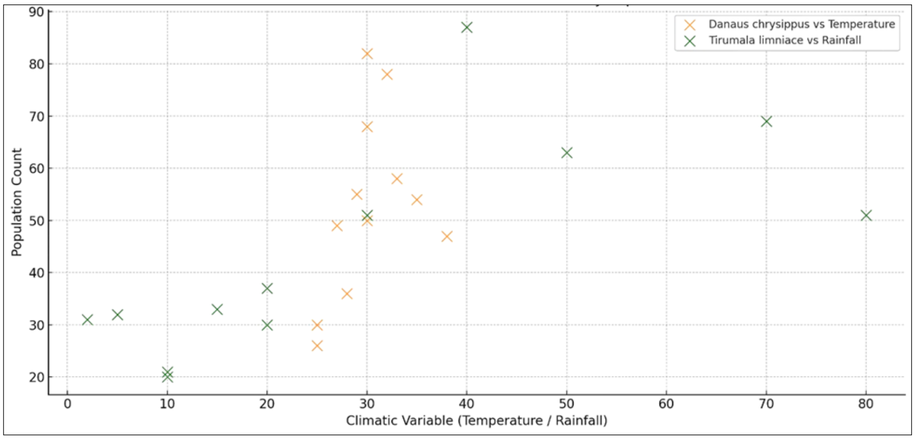

Fig 4: Correlation of climatic variables with butterfly populations.

Seasonal Variations

Further one-way ANOVA was conducted to examine the seasonal trends in the population of both species. This analysis showed significant differences in the population means of the two species across the four defined seasons: winter, summer, monsoon, and post-monsoon (Figure 5). For D*anaus chrysippus*, ANOVA results yielded F(3, 33) = 5.42, p = 0.0043, indicating that its population is significantly influenced by seasonal variations. Post-hoc analysis revealed that the post-monsoon and summer seasons supported significantly higher populations compared to the monsoon and winter seasons. In the case of *Tirumala limniace*, the ANOVA results were even more striking, with $F(3, 33) = 7.86$, $p = 0.0018$. Population counts during the monsoon season were significantly higher compared to other seasons, confirming the species' dependence on monsoonal rainfall and the resultant availability of its host plants. Although not as productive as the monsoon season, the post-monsoon period also supported elevated population counts, likely due to the carry-over effects of favorable conditions during the monsoon.

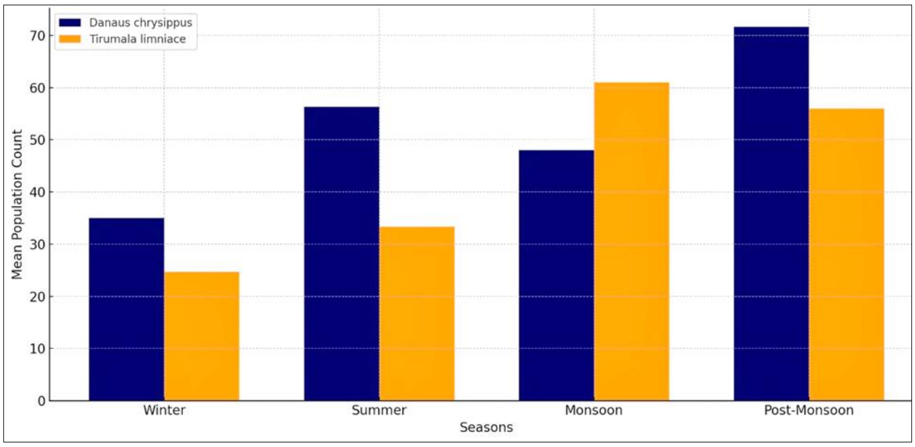

Fig 5: Seasonal population comparison of *Danaus chrysippus* and *Tirumala limniace.*

Host Plant Phenology

The abundance and phenology of larval host plants played a significant role in shaping butterfly population dynamics. For *Danaus chrysippus*, *Calotropis spp*. experienced peak flowering during the post-monsoon and summer seasons, providing ample food resources for larval growth. This synchrony between host plant phenology and the butterfly lifecycle facilitated the population peaks observed during these periods. For *Tirumala limniace*, the monsoon-induced growth of *Tylophora indica* and *Heterostemma* spp. supported larval development, leading to a population surge during June–August. The secondary peak observed in September–October may result from the continued availability of these host plants as the monsoon receded.

Discussion

The outcome of this study provides valuable insights into the seasonal population dynamics of *Danaus chrysippus* and *Tirumala limniace* within an urban ecosystem, emphasizing their differing responses to climatic variables such as temperature and rainfall. The findings illustrate that these species have developed distinct ecological strategies to adapt to variable urban conditions, highlighting the crucial role of climatic factors and host plant phenology in shaping butterfly populations. For *D. chrysippus*, the observed seasonal trends reveal a preference for warmer and drier conditions during summer (April–May) and the post-monsoon period (October–November). These periods coincide with the peak flowering of its primary larval host plants, *Calotropis spp*. The weak correlation between *D. chrysippus* populations and rainfall suggests that this species is highly adapted to drier conditions, consistent with its widespread presence in arid and semi-arid regions of India and other tropical areas. In contrast, *T. limniace* demonstrated a strong reliance on monsoonal rainfall, with peak populations observed during June–August. This dependence aligns with the proliferation of its larval host plants, such as *Tylophora indica* and *Heterostemma spp*., which thrive during the monsoon season. The secondary population peak observed during the post-monsoon period likely reflects the lingering favorable conditions following the monsoon. These findings are consistent with research conducted in other regions of India, such as Karnataka and Maharashtra, which also reported monsoon-driven population peaks for *T. limniace* (Kunte, 2000; Padhye *et al.*, 2006) [11, 12].

The seasonal trends observed in this study align with findings from other urban and semi-urban regions of India. For example, research in the Western Ghats by Krishnakumar *et al*. (2008) [15] revealed that *D. chrysippus* peaks during dry months, while *T. limniace* flourishes during monsoons, reflecting the patterns recorded in Chennai. Similarly, Mukherjee *et al*. (2018) [14] found that the availability of larval host plants drives butterfly abundance in Kolkata, emphasizing the importance of vegetation management in urban areas. Unlike the Western Ghats, where diverse vegetation supports a wider range of butterfly species, Chennai's fragmented green spaces limit species diversity.

Globally, studies on butterfly population dynamics highlight the influence of climatic factors and host plant availability. For instance, Ngowi (2019) [16] observed in tropical Africa that *D. chrysippus* is highly resilient to fluctuating rainfall, consistent with the findings in Chennai. This ecological adaptability has enabled the species to thrive across diverse tropical and subtropical habitats. Conversely, studies in Southeast Asia have shown that monsoonal rainfall significantly shapes butterfly communities, particularly species like *T. limniace* (Liao *et al.*, 2017; Al-Jahdhami *et al.*, 2020) [17, 18]. Unlike tropical rainforests, which support continuous populations due to abundant vegetation, urban ecosystems like Chennai experience more pronounced seasonal fluctuations due to limited resource availability.

Conclusion

The population dynamics of *Danaus chrysippus* and *Tirumala limniace* in Chennai reflect their contrasting ecological adaptations to seasonal climatic variability. While *D. chrysippus* thrives in warmer, drier conditions, *T. limniace* relies on monsoonal rainfall and the associated growth of larval host plants. These findings align with national and international studies, underscoring the importance of climatic factors and host plant phenology in shaping butterfly populations. Urban ecosystems can play a vital role in conserving butterfly biodiversity, but this requires proactive habitat management and climate-adaptive strategies. By preserving native vegetation and enhancing habitat connectivity, cities like Chennai can ensure the survival of these ecologically important species in the face of ongoing environmental change.

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