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Seasonal Ecology of Butterfly Communities and Its Implications for Conservation in Sariska National Park

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Abstract

Butterflies are considered important ecological indicators due to their close association with vegetation structure, host plant availability, climatic conditions and habitat quality. Seasonal fluctuations strongly influence butterfly emergence, abundance, reproductive activity and community composition. The present study investigates seasonal variations in butterfly diversity in Sariska National Park, Rajasthan, India, across four ecological seasons: summer, monsoon, post-monsoon and winter. Seasonal differences were evaluated using abundance, species richness, Shannon–Wiener diversity index, Simpson diversity index, Pielou evenness and statistical analyses including one-way ANOVA and Tukey pairwise comparisons. The results revealed significant seasonal variation in butterfly abundance and richness, with the highest abundance recorded during the post-monsoon season (892 individuals), followed by summer (338 individuals), monsoon (309 individuals) and winter (245 individuals). Diversity indices also showed maximum values during post-monsoon, indicating favourable ecological conditions due to increased vegetation growth, flowering intensity and availability of larval host plants after rainfall. The seasonal pattern demonstrates the strong influence of climatic factors and resource availability on butterfly community structure. The findings highlight the importance of long-term seasonal monitoring and habitat-based conservation approaches for maintaining butterfly diversity in semi-arid protected landscapes such as Sariska National Park.

Keywords

Butterfly diversity; Seasonal ecology; Sariska National Park; Species richness; Habitat association; Ecological indicators.

1. Introduction

Butterflies are important components of biodiversity and serve as effective ecological indicators due to their sensitivity to environmental changes, vegetation structure and resource availability (Bonebrake et al., 2010). Seasonal factors such as temperature, rainfall, humidity and flowering patterns strongly influence butterfly abundance, species richness and community composition (Thomas et al., 2010). Sariska National Park, located in the Aravalli landscape of Rajasthan, represents a semi-arid ecosystem with diverse habitats including dry deciduous forests, scrublands and grasslands that support varied butterfly communities (Joshi et al., 2011). Seasonal changes in vegetation and climatic conditions affect the availability of nectar plants and larval host plants, thereby influencing butterfly populations (Oostermeijer & Van Swaay, 1998).

Therefore, understanding seasonal variation in butterfly diversity is essential for evaluating habitat quality and developing effective conservation strategies. The present study examines seasonal changes in butterfly abundance, richness and diversity in Sariska National Park to understand their ecological significance and conservation implications.

Research Gap

Although butterfly diversity has been studied in several Indian ecosystems, limited information is available on the seasonal variation of butterfly communities in semi-arid protected landscapes like Sariska National Park. Previous studies have mainly focused on general biodiversity assessment, while the influence of seasonal factors such as rainfall, temperature, vegetation growth and resource availability on butterfly abundance and diversity remains less explored. Therefore, the present study aims to address this gap by analysing seasonal patterns of butterfly abundance, richness and diversity and their implications for conservation in Sariska National Park

Objectives of the Study

1. To assess the seasonal variation in butterfly abundance, species richness and diversity patterns in Sariska National Park.
2. To analyse the influence of seasonal climatic and ecological factors on butterfly community structure and distribution.
3. To evaluate the conservation implications of seasonal butterfly diversity patterns for protected area management.

2 Literature Review

Butterflies are considered important components of biodiversity and are widely used as ecological indicators because their distribution and abundance are closely associated with habitat quality, vegetation structure and environmental conditions. Their dependence on specific host plants, nectar resources and microhabitat conditions makes them highly sensitive to ecological changes and suitable for biodiversity monitoring studies (Bonebrake et al., 2016). Butterfly communities respond rapidly to habitat alteration and climatic variations, providing valuable information about ecosystem stability and conservation status (Thomas et al., 2015).

Seasonal variation is one of the major factors influencing butterfly community structure. Climatic variables such as temperature, rainfall, humidity and sunlight availability regulate butterfly emergence, flight activity, reproduction and survival. Rainfall-induced vegetation growth increases the availability of flowering plants and larval host plants, resulting in higher butterfly abundance during favourable seasons (Kharouba et al., 2018). However, extreme climatic conditions such as high summer temperatures and reduced winter activity may negatively affect butterfly populations by limiting movement and resource availability.

Vegetation characteristics and habitat heterogeneity play a crucial role in maintaining butterfly diversity. Different habitat types provide specific ecological resources required for butterfly survival, including larval host plants, nectar sources and suitable breeding environments. Habitat degradation, fragmentation and loss of native vegetation are considered major factors responsible for declining insect diversity worldwide (Heinrichs et al., 2016; Wagner et al., 2021).

Protected areas provide suitable habitats for butterfly conservation; however, biodiversity assessments have traditionally focused more on large mammals and charismatic species. Recent studies emphasize the importance of including insects in conservation planning because they contribute to pollination, food-web interactions and ecosystem functioning (Cardoso et al., 2020). Seasonal monitoring of butterfly communities can provide early indications of ecological changes and habitat disturbances.

In Indian ecosystems, butterfly diversity has been reported to vary according to habitat type, geographical location and seasonal conditions. Studies from semi-arid and forest landscapes indicate that butterfly communities are strongly influenced by vegetation availability and climatic factors (Prajapat et al., 2023). Sariska National Park, located in the Aravalli landscape of Rajasthan, represents an important semi-arid protected ecosystem with dry deciduous forests, scrublands and grasslands supporting diverse biological communities (Joshi et al., 2011). However, seasonal patterns of butterfly abundance, diversity and community structure in Sariska remain comparatively less explored.

Therefore, systematic seasonal assessment of butterfly diversity is essential to understand ecological responses to climatic variation and to develop effective conservation strategies for protected landscapes.

3 Research Methodology

Study Area

The present study was conducted in **Sariska National Park, Rajasthan, India**, which forms an important part of the Aravalli hill ecosystem. The landscape represents a semi-arid protected ecosystem characterized by tropical dry deciduous forests, scrublands, grasslands, rocky habitats and seasonal vegetation changes. The variation in habitat structure and climatic conditions provides diverse ecological niches supporting a variety of butterfly communities. The seasonal fluctuations in temperature, rainfall and vegetation productivity influence the availability of nectar plants and larval host plants, thereby affecting butterfly population dynamics (Joshi et al., 2011).

Study Design and Seasonal Assessment

A **season-based ecological assessment approach** was adopted to evaluate temporal variations in butterfly communities. Butterfly observations were categorized into four ecological seasons:

1. **Summer**
2. **Monsoon**

3. **Post-monsoon**
4. **Winter**

The seasonal assessment was designed to understand variations in butterfly abundance, species richness and community composition under changing environmental conditions. Seasonal observations were analysed to determine the influence of climatic factors, vegetation availability and habitat conditions on butterfly diversity patterns.

Butterfly Sampling and Data Collection

Butterfly diversity data were collected through systematic field observations conducted across different habitat types of Sariska National Park. Observations focused on recording butterfly individuals, species occurrence and seasonal distribution patterns. The sampling considered different ecological habitats, including forest areas, scrub vegetation, grasslands and open habitats.

Butterfly identification was carried out based on morphological characteristics and standard identification resources. Recorded observations were compiled season-wise to evaluate changes in abundance and diversity patterns.

Assessment of Butterfly Diversity

The seasonal butterfly community structure was evaluated using quantitative biodiversity parameters:

Species Richness

Species richness was determined by calculating the total number of butterfly species recorded during each season. It represents the diversity of butterfly species occurring under different seasonal conditions.

Shannon–Wiener Diversity Index (H′)

The Shannon–Wiener index was used to measure butterfly diversity by incorporating both species richness and relative abundance of species within each season.

Simpson Diversity Index (1-D)

Simpson's diversity index was calculated to evaluate dominance patterns and community diversity among different seasons.

Pielou's Evenness Index (J)

Pielou's evenness index was used to assess the distribution uniformity of butterfly individuals among different species.

These indices provided a comprehensive understanding of seasonal changes in butterfly community structure.

Statistical Analysis

The seasonal differences in butterfly abundance and species richness were statistically evaluated using **one-way Analysis of Variance (ANOVA)** to determine whether variations among seasons were significant. Tukey's post-hoc pairwise comparison test was subsequently performed to identify significant differences between specific seasonal groups.

The statistical analysis was performed to validate whether observed seasonal patterns represented significant ecological differences rather than random variation. In addition, year-wise seasonal comparisons were examined to assess the consistency and repeatability of seasonal trends.

Data Interpretation and Conservation Assessment

The observed seasonal patterns were interpreted in relation to ecological factors including rainfall, temperature variation, flowering intensity, vegetation growth and availability of larval host plants. The relationship between seasonal environmental conditions and butterfly community responses was evaluated to understand the ecological significance of butterflies as indicators of habitat quality.

The findings provide baseline information for seasonal biodiversity monitoring and support conservation planning for butterfly communities in semi-arid protected ecosystems such as Sariska National Park.

4. Results

This section investigates the variation in the butterfly abundance, richness, diversity, evenness in summer, monsoon, post-monsoon and winter. Seasonal analysis is significant as emergence, movement, feeding, oviposition and detectability of butterflies are dependent on temperature, rainfall, humidity, sunshine, flowering intensity and host plant availability. The abundance, mean session abundance, Simpson diversity, Pielou evenness, Shannon-Wiener diversity, species richness and dominance measures with confidence interval were used to compare seasonal differences. Analysis of variance and Tukey pairwise comparisons were performed to determine if the seasonal differences are statistically significant and year-specific comparisons to determine the repeatability of the seasonal pattern.

Table 1. Season-wise abundance, richness, diversity and evenness

season	Individuals	Species	Shannon H	Simpson 1 D	Pielou J	Mean per species
Summer	338	38	3.469	0.964	0.954	8.895
Monsoon	309	38	3.541	0.969	0.974	8.132
Post-monsoon	892	38	3.549	0.969	0.976	23.47

season	Individuals	Species	Shannon H	Simpson 1 D	Pielou J	Mean per species
Winter	245	37	3.432	0.964	0.950	6.622

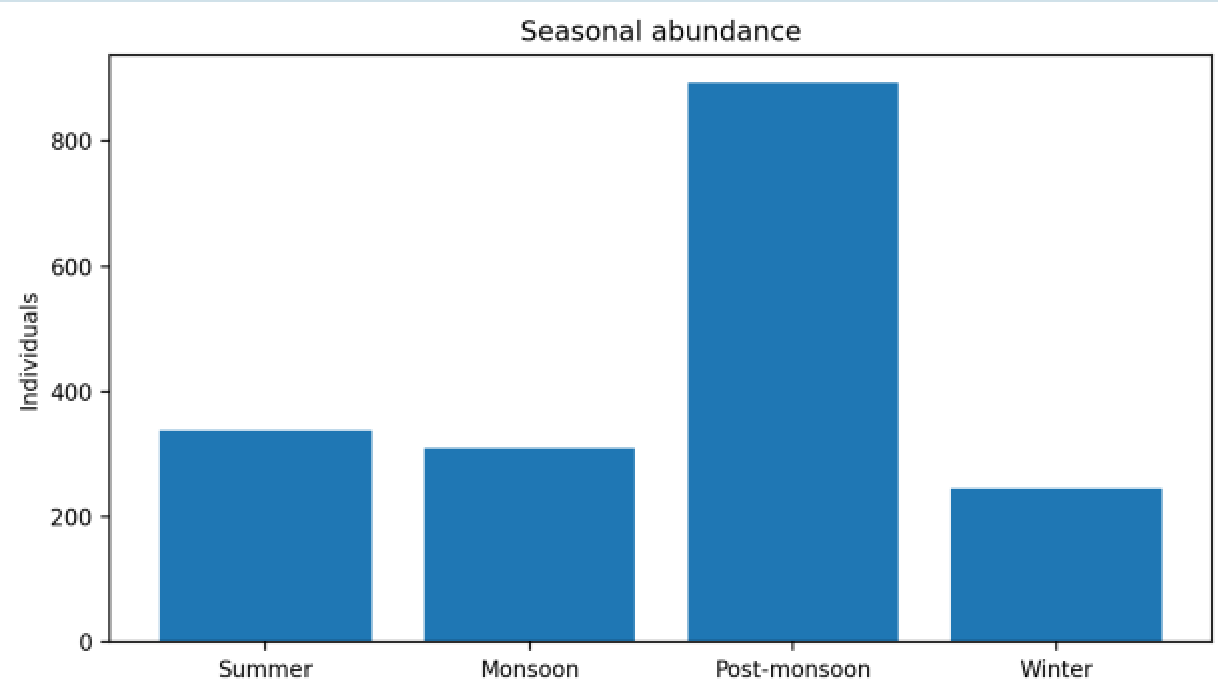

Figure 1. Total abundance across the four ecological seasons

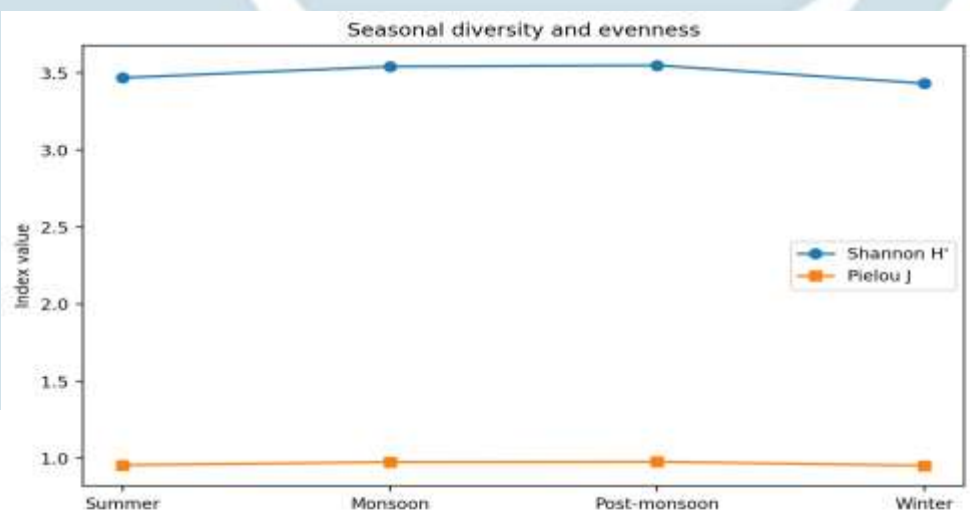

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Figure 2. Seasonal Shannon diversity and Pielou evenness

The total abundance and combined diversity values were the highest in post-monsoon. Monsoon was the second most productive season and the lowest abundance was in winter. The post-monsoon peak is in line with that of dry-deciduous systems as rainfall triggers vegetative growth and flowering and warm weather (needing less rain and fewer clouds to fly) coupled with nectar availability and host larval availability in turn. High temperatures and low rainfall did not seem to affect the meaningful butterfly assemblage abundant in Summer. Species that survive the summer are likely to take advantage of microhabitats that are associated with irrigation, riparian, or provide shade, or host plants. The temperature and time of suitable flight conditions were reduced during the winter, which lowered the level of reduction. Changes in total activity were reflected more strongly than changes in the relative proportions of species in evenness, which remained comparatively stable. The seasonality seems to support the overall finding that there is a relationship between climate change and butterfly diversity as concluded by Rani and Ahmed in their Sariska study. It also matches with recent Indian vegetation monitoring when there is an increase in vegetation and flowering following rains, in congruence with monsoon or post monsoon periods. This peak may vary across geographic regions due to differences in precipitation intensity, temperature, habitat type and sampling timing.

Table 2. Year-specific seasonal abundance and richness

year	season	Individuals	Mean individuals	SD individuals	Mean richness	SD richness
2,024	Monsoon	155	3.875	2.115	3.500	1.840
2,024	Post-monsoon	442	11.05	4.596	9.550	3.580
2,024	Summer	181	4.525	3.047	4.175	2.640
2,024	Winter	122	3.050	2.037	2.875	1.828
2,025	Monsoon	154	3.850	2.107	3.675	1.900
2,025	Post-monsoon	450	11.25	4.792	9.200	3.568
2,025	Summer	157	3.925	2.576	3.700	2.312
2,025	Winter	123	3.075	2.018	2.925	1.845

These two survey years had the same general seasonal ordering suggesting it was not an outlier year. Variation between years is expected and is due to the variability in the timing of rainfalls, the intensity of flower production and the extent to which disturbance occurs locally. It is therefore beneficial that the same area is re-sampled year on year, rather than a single annual inventory. The resemblance of the two years further indicates that the standardized design had good internal consistency. If variations in a real field data set were unusually large from one year to another, it should first be determined whether any rainfall anomalies occurred, whether there were changes in fire, grazing, road use, and observer or plant phenology before reaching the conclusion that there was a change in population.

Table 3. One-way analysis of variance for seasonal differences

Outcome	F	df between	df within	p value	Effect ratio
Abundance	117.75	3	316	<0.001	0.528
Richness	111.23	3	316	<0.001	0.514

A one-way analysis of variance was used to determine if the mean abundance and mean richness per session were the same for each of the four seasons. The probability values obtained were not significant enough in the conventional sense and this result reinforces the hypothesis that the season made a statistically significant contribution. The section effect ratio suggests that a significant amount of variation in session outcomes was accounted for by explaining between sessions using a grouping criterion. Ecological magnitude should be used to interpret statistical significance. When the number of sessions is large and there are repeated small differences, it can be a significant difference. The probability value alone is not enough to conclude the same ecological conclusion as the descriptive, the diversity indices and the graphical pattern here show the same result supporting the ecological conclusion.

Table 4. Tukey pairwise comparisons of seasonal session abundance

group1	group2	meandiff	p-adj	lower	upper	reject
Monsoon	Post-monsoon	7.287	<0.001	6.026	8.549	1
Monsoon	Summer	0.362	0.880	-0.899	1.624	0
Monsoon	Winter	-0.800	0.359	-2.062	0.462	0
Post-monsoon	Summer	-6.925	<0.001	-8.187	-5.663	1
Post-monsoon	Winter	-8.088	<0.001	-9.349	-6.826	1

group1	group2	meandiff	p-adj	lower	upper	reject
Summer	Winter	-1.163	0.083	-2.424	0.099	0

The post-hoc comparisons indicate which season pairs had a significant variance. The biggest mean contrasts were between post-monsoon and winter, and between ecologically adjacent productive seasons, were smaller. The coded rejection column indicates whether each pairwise difference was less than (or greater than) the adjusted significance criterion. The comparisons are useful for making planning decisions about monitoring. Avoid limiting surveys to the season with the highest productivity as this would overestimate perceived abundance, especially if resources are limited. This means that some of the visits during the winter and summer should be kept so that any decrease in visits and any seasonal turnover can be detected.

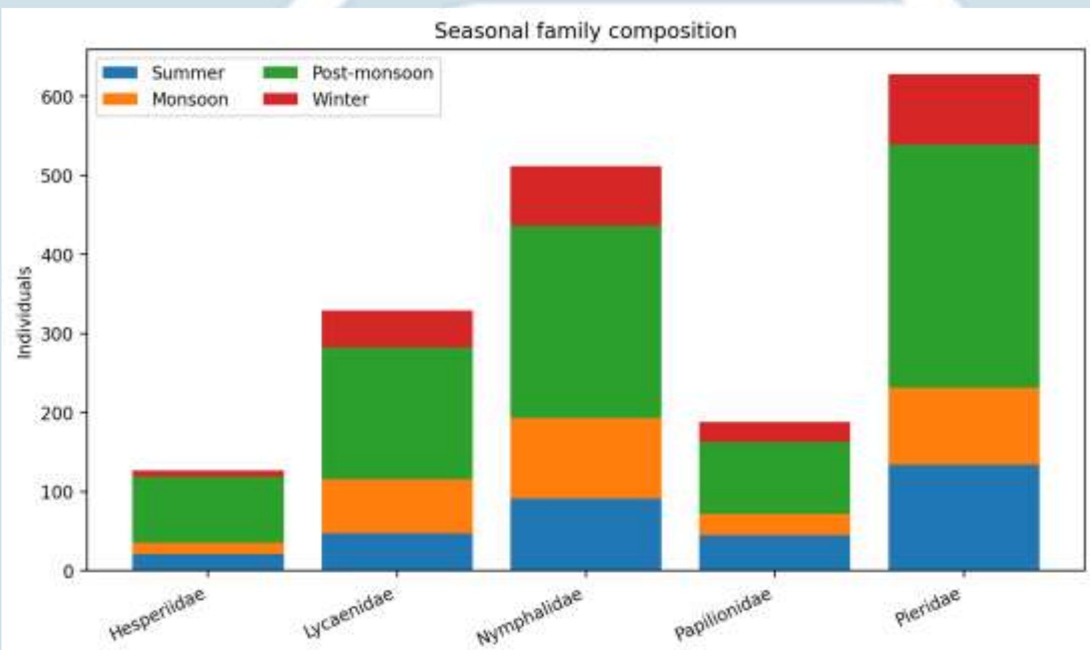

Figure 3. Seasonal abundance profile of the five butterfly families

5. Discussion

The present study demonstrates that seasonal variation significantly influences butterfly abundance, diversity and community structure in Sariska National Park. The highest butterfly abundance was recorded during the **post-monsoon season (892 individuals)**, while the lowest abundance was observed during winter (245 individuals), indicating the strong influence of climatic conditions and resource availability on butterfly populations. The higher abundance during post-monsoon may be attributed to increased vegetation growth, flowering intensity and availability of nectar resources and larval host plants after rainfall (Bonebrake et al., 2016; Kharouba et al., 2018).

The maximum Shannon diversity (H′ = 3.549) and Pielou evenness (J = 0.976) during post-monsoon indicate favourable habitat conditions supporting a balanced butterfly community. Seasonal changes in vegetation structure and habitat resources play an important role in determining butterfly distribution and diversity (Thomas et al., 2015). Lower abundance during winter may be related to reduced temperature, limited flowering resources and decreased flight activity.

Statistical analysis confirmed significant seasonal differences in butterfly abundance and richness, with ANOVA showing significant effects of season ($p < 0.001$). Tukey's comparison revealed major differences between post-monsoon and winter seasons, confirming that seasonal conditions strongly regulate butterfly community patterns.

The consistent seasonal pattern across study years suggests that butterfly responses are linked with ecological cycles rather than random variation. The findings highlight the importance of seasonal monitoring, conservation of native vegetation and protection of host plants for maintaining butterfly diversity in semi-arid protected ecosystems such as Sariska National Park. (Wagner et al., 2021).

6. Conclusion

The present study highlights the significant influence of seasonal variations on butterfly diversity and community structure in Sariska National Park. The results demonstrate that post-monsoon conditions provide the most favourable environment for butterfly populations due to improved vegetation growth, flowering resources and availability of host plants, resulting in maximum abundance and diversity. Seasonal differences were statistically significant, confirming the importance of climatic and ecological factors in shaping butterfly communities. The findings emphasize the need for long-term seasonal monitoring, conservation of native vegetation and protection of butterfly habitats to maintain biodiversity in semi-arid protected landscapes. Incorporating butterfly-based ecological assessments into conservation planning can provide valuable insights into ecosystem health and support effective biodiversity management in Sariska National Park.

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