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Ecological Assessment of Butterfly Communities Across Different Habitat Types in Sariska National Park, Rajasthan

[1]Sandhya Kumar, [2]Dr. Priyanka Sharma

[1]Ph.D in Zoology, Lord University Chikani Alwar, [2]Professor Lords University Chikani Alwar

Abstract

Butterflies are important ecological indicators because their distribution, abundance and community composition are strongly influenced by habitat characteristics, vegetation structure and resource availability. The present study evaluates habitat-specific patterns of butterfly communities in Sariska National Park, Rajasthan, India. Five major habitat types, including forest edge, scrub forest, grassland, riparian patch and open sunny habitat, were assessed using abundance, species richness, Shannon diversity, Simpson diversity, Pielou evenness, Bray–Curtis similarity analysis and statistical comparisons. The results revealed variations in butterfly community structure among different habitats, with riparian patches and forest edges supporting higher diversity due to greater moisture availability, vegetation complexity and resource availability. Species-level analysis indicated habitat preferences among butterfly taxa, with different groups associated with specific ecological conditions. Transect-wise assessment showed similar patterns, highlighting the importance of fixed-route monitoring for biodiversity assessment. The findings demonstrate that habitat heterogeneity plays a crucial role in maintaining butterfly diversity and emphasize the need for conserving multiple complementary habitats for effective butterfly conservation in semi-arid protected landscapes.

Keywords

Butterfly diversity; Habitat association; Community structure; Habitat heterogeneity; Sariska National Park.

1. Introduction

Butterflies are important components of biodiversity and serve as effective ecological indicators due to their sensitivity to habitat changes, vegetation structure and resource availability. Their dependence on specific host plants, nectar sources and microhabitat conditions makes them valuable for assessing ecosystem health and biodiversity patterns (Bonebrake et al., 2016). Habitat characteristics such as vegetation complexity, canopy cover, moisture conditions, sunlight availability and flowering resources strongly influence butterfly abundance, species richness and community composition (Thomas et al., 2015). Different habitat types provide distinct ecological conditions; forest edges offer transitional zones, grasslands provide feeding resources, riparian habitats maintain moisture and floral availability, while scrub and open habitats support species with specific ecological requirements (Habel et al., 2016). Recent studies emphasize that conservation of multiple habitat types is essential because protecting only a single habitat may not support the complete butterfly community (Cardoso et al., 2020). Sariska National Park, located in the semi-arid Aravalli landscape of Rajasthan, contains diverse habitats including forest edges, scrub forests, grasslands, riparian patches and open sunny areas that contribute to butterfly diversity. However, habitat-specific patterns of butterfly abundance, diversity and species distribution in Sariska remain insufficiently explored. Therefore, the present study evaluates habitat-wise and transect-wise patterns of butterfly communities to understand the influence of habitat variation on butterfly diversity and its implications for conservation management.

Research Gap

Although butterfly diversity studies have been conducted in several Indian ecosystems, limited information is available regarding the influence of specific habitat types on butterfly community structure in semi-arid protected landscapes such as Sariska National Park. Most studies focus on overall species inventories, while habitat-level variation in abundance, diversity, species composition and habitat preference remains comparatively less explored. Therefore, the present study addresses this gap by assessing habitat-specific butterfly diversity patterns and identifying important habitats for conservation planning in Sariska National Park.

Objectives of the Study

1. To assess habitat-wise variation in butterfly abundance, richness and diversity across different habitats of Sariska National Park.
2. To analyse the influence of habitat characteristics on butterfly community composition and species distribution patterns.
3. To identify important habitats and conservation priorities for maintaining butterfly diversity in Sariska National Park.

2. **Literature Review**

Butterflies have been widely recognized as important ecological indicators because their diversity, abundance and distribution patterns reflect changes in habitat quality, vegetation structure and environmental conditions. Their dependence on specific host plants, nectar resources and microclimatic conditions makes them highly sensitive to habitat modification and suitable for biodiversity monitoring (Bonebrake et al., 2016). Studies have demonstrated that butterfly communities respond strongly to variations in habitat characteristics, including vegetation composition, resource availability

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and landscape structure (Thomas et al., 2015).

Habitat heterogeneity plays a crucial role in maintaining butterfly diversity by providing multiple ecological resources required for different life stages. Forest edges often support higher butterfly activity because they combine shaded areas with open spaces, increased sunlight exposure and diverse plant resources. Similarly, grasslands and open habitats provide suitable conditions for nectar feeding and basking, whereas riparian habitats contribute through higher moisture availability, vegetation complexity and stable microclimatic conditions (Habel et al., 2016). The presence of diverse habitat patches within a landscape can therefore enhance species richness and maintain community stability.

Research has also shown that habitat degradation, fragmentation and loss of native vegetation are major factors affecting insect biodiversity worldwide. Changes in land use can reduce host plant availability, disturb breeding habitats and alter butterfly community composition (Heinrichs et al., 2016). Maintaining habitat connectivity and conserving multiple habitat types are considered important strategies for sustaining insect diversity because different species exhibit specific habitat preferences and ecological requirements (Cardoso et al., 2020).

In Indian ecosystems, butterfly diversity varies considerably according to habitat type, vegetation characteristics and climatic conditions. Studies from protected landscapes have highlighted the importance of forest edges, grasslands, scrub habitats and riparian zones in supporting diverse butterfly assemblages. Semi-arid ecosystems such as the Aravalli landscape contain heterogeneous habitats that provide important resources for butterfly communities (Prajapat et al., 2023). However, detailed assessments of habitat-specific butterfly distribution patterns, species composition and habitat associations remain limited in many protected areas, including Sariska National Park.

Therefore, habitat-wise and transect-based assessment of butterfly communities is essential for understanding spatial patterns of diversity, identifying important habitats and developing effective conservation strategies. The present study addresses this knowledge gap by evaluating butterfly abundance, richness, diversity and species distribution across different habitat types of Sariska National Park.

3. Research Methodology

The present study was conducted in **Sariska National Park, Rajasthan, India**, to assess the influence of habitat variation on butterfly community structure and diversity patterns. The study area represents a semi-arid Aravalli ecosystem consisting of diverse habitat types, including **forest edge, scrub forest, grassland, riparian patch and open sunny habitat**, which differ in vegetation structure, moisture availability, sunlight exposure, flowering resources and host plant availability. These habitat variations provide different ecological conditions that influence butterfly distribution and abundance.

A **habitat-based ecological assessment approach** was adopted to evaluate butterfly diversity across different habitat types. Systematic field observations were carried out along fixed transects representing different habitats. Butterfly individuals and species occurrence were recorded to compare habitat-wise and transect-wise patterns of abundance, richness and community composition. Species identification was performed using morphological characteristics and standard identification resources.

Butterfly community structure was evaluated using quantitative biodiversity parameters, including **species richness, Shannon–Wiener diversity index, Simpson diversity index and Pielou's evenness index**. These indices were used to assess differences in diversity, dominance and species distribution patterns among different habitats. Species-level habitat preferences were also analysed to understand the association of individual butterfly taxa with specific ecological conditions.

To examine similarity among habitat assemblages, **Bray–Curtis similarity analysis** and hierarchical clustering approaches were applied. Statistical differences in butterfly abundance and species richness among habitats were evaluated using **one-way Analysis of Variance (ANOVA)** followed by **Tukey's post-hoc comparison test** to identify significant differences between habitat groups.

The transect-wise assessment was conducted to evaluate the consistency of habitat patterns and establish a repeatable monitoring framework for future biodiversity studies. The observed patterns were interpreted in relation to habitat characteristics such as vegetation complexity, moisture conditions, flowering resources and disturbance levels to understand their ecological influence on butterfly communities and their implications for conservation planning in Sariska National Park.

4. Results

This section measures butterfly diversity at the forest edge, scrub forest, grassland, riparian patch and open sunny habitat. The habitat types varied in the amount of canopy, shrub, and herb cover, in moisture, in sunlight, in host plant presence, in flowering information and disturbance, and hence differed in other ecological properties that influence the activity and persistence of butterflies. Abundance and species richness, species distribution, evenness, species diversity index, Bray Curtis similarity index, analysis of variance and post hoc comparisons, and hierarchical clustering were used to analyze habitat and transect comparisons. The analysis is combined to show both habitat with a high number of local species and habitat with distinctive species-composition patterns to the wider landscape.

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

habitat	Individuals	Species	Shannon H	Simpson 1 D	Pielou J	Mean per species
Forest edge	394	38	3.462	0.965	0.952	10.37
Scrub forest	251	38	3.473	0.965	0.955	6.605
Grassland	399	38	3.504	0.967	0.963	10.50
Riparian patch	407	38	3.511	0.966	0.965	10.71
Open sunny patch	333	38	3.481	0.965	0.957	8.763

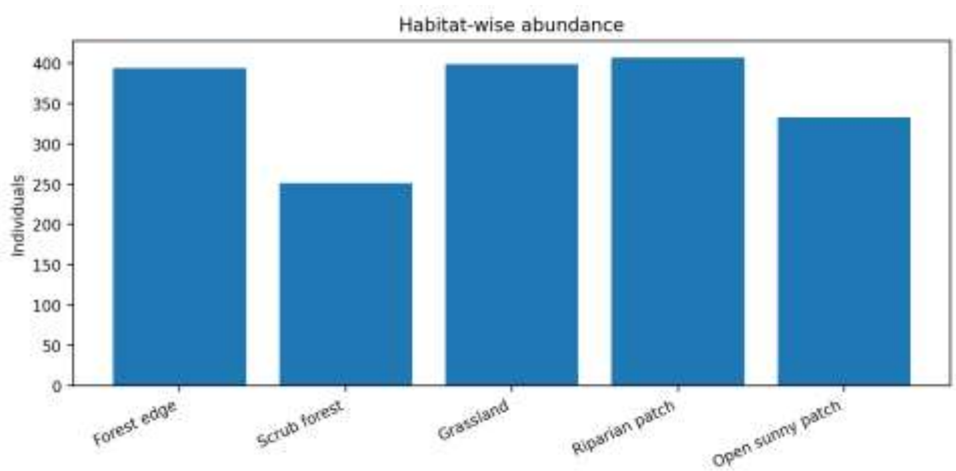

Figure 1. Total butterfly abundance by habitat type

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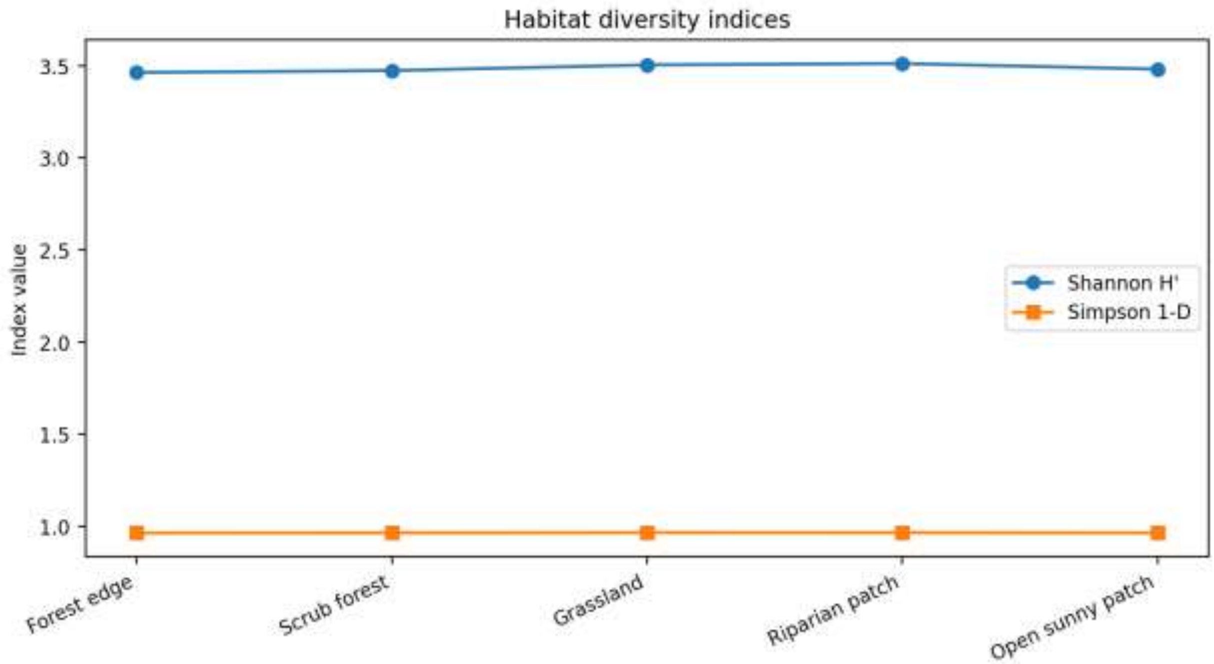

Figure 2. Shannon and Simpson diversity across habitat types

Overall assemblage values were best for the riparian patch and the forest edge, and then grassland. Forest and the open sunny patch were important, but with lower proportion of diversity or evenness for some indicators. Access to both shaded forest and open flight space was offered by forest edges, riparian habitat combined moisture, structural vegetation, flowering resources and sheltered microclimates.

Herbaceous flowering and sighting increased grassland abundance. Sunny interstices were generally conducive for basking and for growing heat-tolerant species, but had low suitability owing to high disturbance and low moisture. Solid scrub forest provided host and shelter resources, but may be difficult to detect and provide nectar due to dense thorny vegetation and lower flowering. The habitat pattern is an example of why a reserve is not a homogeneous forest unit. Suitable habitats for butterflies are edges, gaps, water associated vegetation, grassland and scrub. Closed woody cover conservation may be inadequate for open habitats that are needed for basking, nectaring and movement.

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Table 2. One-way analysis of variance for habitat differences

Outcome	F	df between	df within	p value	Effect ratio
Abundance	3.510	4	315	0.008	0.043
Richness	3.084	4	315	0.016	0.038

Table 3. Tukey pairwise comparisons of habitat session abundance

group1	group2	meandiff	p-adj	lower	upper	reject
Forest edge	Grassland	0.078	1.000	-2.059	2.215	0
Forest edge	Open sunny patch	-0.953	0.738	-3.090	1.184	0
Forest edge	Riparian patch	0.203	0.999	-1.934	2.340	0
Forest edge	Scrub forest	-2.234	0.035	-4.371	-0.097	1
Grassland	Open sunny patch	-1.031	0.676	-3.168	1.106	0
Grassland	Riparian patch	0.125	1.000	-2.012	2.262	0
Grassland	Scrub forest	-2.312	0.026	-4.450	-0.175	1
Open sunny patch	Riparian patch	1.156	0.573	-0.981	3.293	0
Open sunny patch	Scrub forest	-1.281	0.470	-3.418	0.856	0
Riparian patch	Scrub forest	-2.438	0.016	-4.575	-0.300	1

There was a statistically significant difference in abundance and richness between the sessions (habitat analysis of variance). Highest differences were found

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among resource-rich riparian or forest-edge species and more disturbed or resource-lacking habitat for each species. Not all habitat pairs were significantly different, as should be the case in a species that migrates between neighbouring habitat types, and many species are generalists. Migration between habitats, which diminishes ecological independence, is ecologically significant. Forest edges may act as transitional areas, grass land as feeding areas, riparian strips as refuges and open patches as basking or dispersal areas. Thus, preservation of connectivity should be preserved between complementary resource zones.

Table 4. Habitat distribution of the 15 most abundant butterfly species

species	Forest edge	Scrub forest	Grassland	Riparian patch	Open sunny patch	Total
Eurema hecabe	22	14	25	27	14	102
Target Papilio taxon (study code PD)	22	10	21	24	15	92
Catopsilia pomona	18	12	17	22	15	84
Catopsilia pyranthe	21	12	21	11	13	78
Danaus chrysippus	18	9	16	16	17	76
Belenois aurota	14	7	11	17	22	71
Delias eucharis	11	2	17	11	17	58
Euploea core	20	6	6	20	6	58
Leptotes plinius	22	6	9	8	13	58

species	Forest edge	Scrub forest	Grassland	Riparian patch	Open sunny patch	Total
Junonia lemonias	9	11	12	13	10	55
Ixias marianne	8	4	15	17	10	54
Zizina otis	11	13	3	15	10	52
Tirumala limniace	17	6	12	12	4	51
Ixias pyrene	12	7	12	2	15	48
Chilades pandava	13	11	6	10	7	47

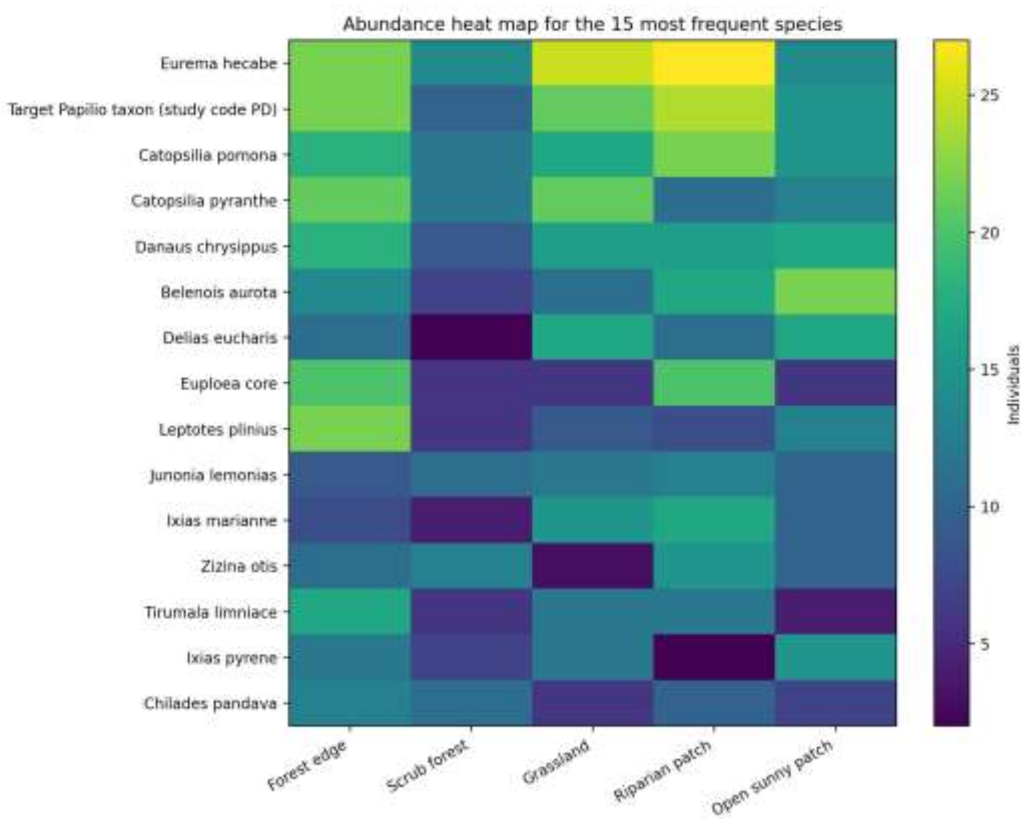

Figure 3. Species-by-habitat abundance heat map for the 15 most abundant species

The heat map shows a deviation in the distribution of common species. The Pierids were well represented in grassland and open sunny habitat while a number of Nymphalids were more common at forest edge and riparian locations. Target Papilio taxon was found in all habitats but preferred more open sunny and forest-edge habitats. Such a differentiation facilitates the use of a species-level analysis. Habitat responses can be found at the family level but can mask contrasting species-level responses. Taxonomic groups associated with forests may not be able to benefit from a conservation action designed to help open-country pierids without also providing the necessary shade, moisture or host plant.

Table 5. Bray-Curtis similarity among habitat assemblages

Habitat	Forest edge	Scrub forest	Grassland	Riparian patch	Open sunny patch
Forest edge	1.000	0.701	0.764	0.806	0.779
Scrub forest	0.701	1.000	0.658	0.708	0.712
Grassland	0.764	0.658	1.000	0.806	0.757
Riparian patch	0.806	0.708	0.806	1.000	0.730
Open sunny patch	0.779	0.712	0.757	0.730	1.000

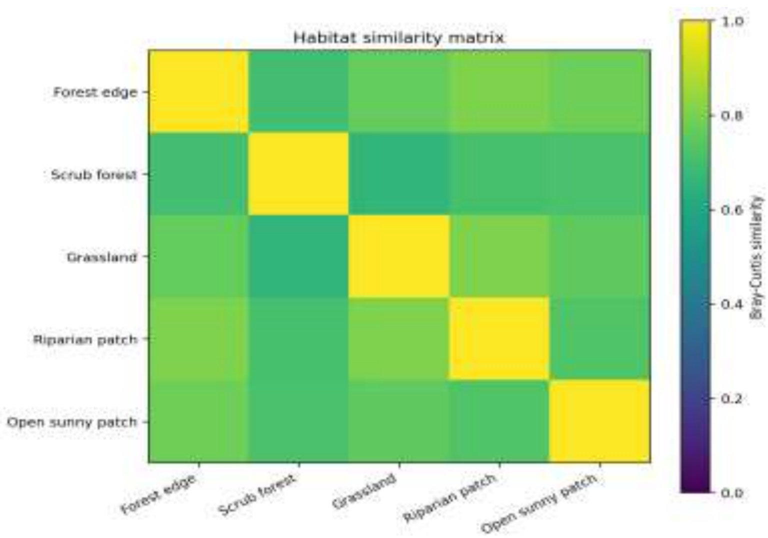

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Figure 4. Bray-Curtis similarity matrix for the five habitat assemblages

Habitats with similar vegetation structure or ecological resources were most similar with Bray-Curtis similarity. However, the forest edge and riparian habitat tended to be similar, while the open sunny patch was more distinct. Variability in similarity values below complete identity is acceptable as the various habitats had varying amounts of shade, moisture, flowering plants, and disturbance. Practical application of assemblage similarity in reserve zoning. Local diversity may not be the highest in highly distinctive habitats but yet this habitat in the local community can add an unrealized contribution to the landscape level diversity. A measure of conservation security is provided by maintaining representative and complementary habitats than by protecting only the richest habitat.

Table 6. Transect-wise abundance, richness, diversity and evenness

transect	Individuals	Species	Shannon H	Simpson 1 D	Pielou J	Mean per species
T1	394	38	3.462	0.965	0.952	10.37
T2	251	38	3.473	0.965	0.955	6.605
T3	399	38	3.504	0.967	0.963	10.50
T4	407	38	3.511	0.966	0.965	10.71
T5	333	38	3.481	0.965	0.957	8.763

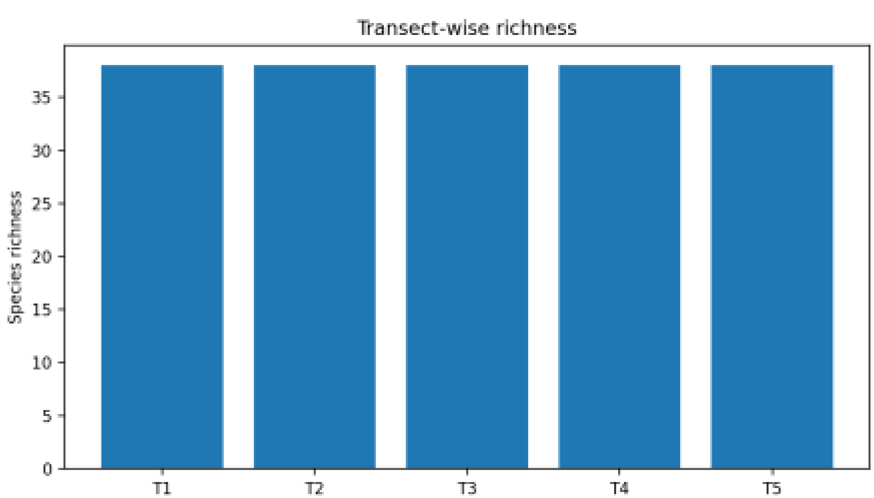

Figure 5. Species richness recorded on each fixed transect

Each transect was a principal habitat type so the results of each transect paralleled the habitat pattern. The concept of 'habitat' and 'transect' is useful; an ecological category, a ‘habitat' is a repeatable field route, ‘transect'. Monitoring can be continued on the same routes and allow for comparison of changes without changing the sampling unit. Conservatorship is a use for which a fixed transect monitoring system is well suited to detecting more subtle changes in abundance, richness and target species utilization. This design scheme may be repeated each year, as long as the timing, walking speed, route length and weather conditions are the same.

5. Discussion

The present study highlights the significant influence of habitat heterogeneity on butterfly community structure in Sariska National Park. Among the studied habitats, riparian patches and forest-edge habitats showed comparatively higher diversity values due to greater moisture availability, vegetation complexity, flowering resources and suitable microclimatic conditions. These habitats provide multiple ecological resources required for butterfly feeding, breeding and shelter, supporting diverse butterfly assemblages (Bonebrake et al., 2016; Thomas et al., 2015).

Grassland habitats also supported considerable butterfly abundance because of the availability of herbaceous flowering plants and open spaces suitable for nectar feeding and basking activities. In contrast, scrub forest showed comparatively lower abundance, which may be associated with dense vegetation structure, reduced accessibility and lower detectability of butterflies. The significant differences observed among habitat types for abundance and richness indicate that habitat characteristics play an important role in determining butterfly distribution patterns.

Species-level analysis revealed that butterfly taxa exhibited specific habitat associations. Pierid butterflies were more frequently observed in grassland and open sunny habitats, whereas several Nymphalid species showed stronger associations with forest edges and riparian habitats. The target Papilio taxon occurred across different habitats but showed greater preference for open sunny and forest-edge areas, indicating the importance of maintaining diverse habitat conditions for species conservation.

The Bray–Curtis similarity analysis demonstrated that habitats with similar ecological characteristics showed greater similarity in butterfly composition, particularly forest-edge and riparian habitats. Transect-wise patterns followed similar trends to habitat-level observations, indicating that fixed transect monitoring can provide a reliable approach for detecting spatial changes in butterfly communities. Overall, the findings emphasize that conservation of multiple complementary habitats rather than a single habitat type is essential for maintaining butterfly diversity in semi-arid protected landscapes.

6. Conclusion

The present study demonstrates that habitat variation strongly influences butterfly abundance, diversity and community composition in Sariska National Park. Riparian patches and forest-edge habitats were identified as important habitats supporting higher butterfly diversity due to favourable ecological conditions, while grasslands and open habitats contributed valuable resources for specific butterfly groups. The significant habitat-level differences and species-specific habitat preferences highlight the importance of conserving a mosaic of habitats for effective butterfly management. Maintaining habitat connectivity, protecting vegetation resources and implementing long-term transect-based monitoring can strengthen biodiversity conservation strategies in semi-arid protected ecosystems.

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