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Butterfly diversity and species composition of Kambalakonda Eco Park, Visakhapatnam district, Andhra Pradesh

Dr. Mousumi Das[1*], Rupsa Sarkar[2], Tanisha Chakraborty[2], Soulima Dutta[2], Anubhab Kanrar[2], Suptika Ghosh[2]
[1] Assistant Professor, In-Charge of Resource Ecology, Department of Zoology, Vidyasagar College, Salt Lake Campus, West Bengal, India
[2] Department of Zoology, Vidyasagar College, Salt Lake Campus, West Bengal, India
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Abstract
Preliminary survey-based field investigations were conducted in March, 2026 to record the diversity, abundance, and distribution patterns of butterflies at the Kambalakonda Eco Park in Visakhapatnam, Andhra Pradesh, India. A total number of 69 butterfly species were recorded from 48 genera, which belong to five families such as Nymphalidae, Papilionidae, Pieridae, Lycaenidae, and Hesperiidae. Family Pieridae was the most dominant, accounting for 38.31% of total butterflies, whereas Nymphalidae exhibited the highest species and genus composition (36.23% and 37.50% respectively). The Lemon Emigrant (*Catopsilia pomona*) was the most abundant species with highest relative abundance value of 4.83, followed by Common Wanderer (*Pareronia valeria*), Common Gull (*Cepora nerissa*), Common Crow (*Euploea core*), and Lemon Pansy (*Junonia lemonias*). The genus *Junonia* was represented by six species, followed by *Papilio* with five species each. The Shannon-Wiener, Simpson, Pielou's evenness, and Margalef's richness indices were 3.99, 0.98, 0.94, and 8.50, respectively, indicating that the area possesses high butterfly diversity with evenly distributed populations. This investigation offers insights into butterfly diversity in the study area, underscoring the need for habitat restoration to ensure ecological resilience and support future conservation efforts.

Keywords: Butterfly diversity, conservation efforts, ecological resilience, Kambalakonda Eco Park, Pieridae

Introduction
Biological diversity is the foundation of ecosystem resilience and sustains the functional roles of species in providing ecosystem services. Survey-based species diversity estimation of a region portrait the prospective functional roles of the species. In urban ecosystems, the survey-based diversity studies can be used as a conservation tool to manage the pollution, deforestation, constructions and agriculture expansion in urbanized, industrial and rural areas (Wilson, 1997) [49]. Therefore, comprehensive studies on urban species diversity are essential for understanding how anthropogenic development impacts ecosystem integrity and sustenance.

Research on insect diversity is primarily prioritized because insects dominate various ecosystems, provide vital services such as pollination, pest control, and nutrient decomposition, and sustain broader species diversity (Losey and Vaughan, 2006) [25]. Among them, butterflies (order Lepidoptera) are widely considered effective invertebrate flagships due to their remarkable diversity, wide distribution, and charismatic appearance (Barua et al., 2012; Kurve et al., 2013) [1, 23]. These winged jewels act as natural pollinators, ensuring the sustainability of habitats; they serve as herbivores and prey, contributing to the stability of the food chain, and they coevolve with plants (Gupta and Mondal, 2005; Patil et al., 2017; Ehrlich and Raven, 1964) [14, 33, 13]. Owing to their sensitivity to subtle environmental shifts, habitat alterations, phenological variations, and resource availability, they are widely recognized as effective bioindicators for assessing terrestrial ecosystem health, biodiversity status, and the impacts of anthropogenic disturbances (Kunte, 2000; Koh, 2007; Bonebrake et al., 2010) [21, 20, 3]. Therefore, they serve as a valuable model group for ecological and conservation research (Ehrlich and Hanski, 2004) [12]. In the present context, butterfly conservation is needed to maintain ecosystem health and sustain the vital services nature provides to humanity.

Home to about 1,500 butterfly species, diverse climatic zones, and rich flora, India is an important region for studying butterfly biodiversity (Varshney and Smetacek, 2015; Kunte, 2000) [45, 21]. Although there are several checklists for many of India's protected and semi-natural landscapes, such as those in Madhya Pradesh, Delhi, Assam, Odisha, Kerala, Telangana, Tamil Nadu, comprehensive studies on butterfly diversity and abundance in urban biodiversity parks and planned green spaces remain limited (Das et al., 2026a; Paul and Sultana, 2020; Dutta et al., 2022; Samal et al., 2021, Vijithra and Zeena, 2025; Ravivarma et al., 2023; Hussain et al., 2011) [7, 34, 11, 37, 46, 35, 16].

In view of the important ecological functions performed by these lepidopteran taxa and to promote conservation efforts, an attempt was made to estimate butterfly diversity and abundance in the Kambalakonda Eco-tourism Park of Visakhapatnam District, Andhra Pradesh, India. The findings of this study are expected to provide essential information for the conservation management of the butterfly species and its habitats.

Materials and Methods
Study Area
The study was conducted in Kambalakonda Eco Park (17.34°N to 17.47°N and 83.04°E to 83.20°E), spanning over an area of 70.7 sq km, was carved out of the Kambalakonda Wildlife Sanctuary, nestled on the Eastern Ghats on the outskirts of Visakhapatnam city, Andhra

Pradesh. The sanctuary is located about 20 km northeast of Visakhapatnam city, along NH5. Its topography is characterized by an undulating terrain of rolling hills with steep slopes, plateaus, and valleys, intersected by intermittent streams and thickly vegetated gorges, all at an average altitude of 200 m to 300 m (Raja Sekhar et al., 2008) [36]. The sanctuary hosts three broad categories of vegetation: tropical semi-evergreen, tropical moist-deciduous and tropical dry deciduous (Raja Sekhar et al., 2008) [36].

The sanctuary is rich in diverse flora, herb species (*Eyolvulus alsinoides*, *E. nummularis*, *Datura metal*, *Aristida* species, *Carissa carandus*, *Cassytha filiformis*, *Baridelia montana*, *Barleria prionitis*, *Tylophora indica*, etc.), shrub species (*Calotropis gigantea*, *Lantana camara*, *Gymnema sylvestre*, *Zizyphus oenoplia*, *Dodonaea viscosa*, *Manilkara hexandra*, *Syzygium cumini* and *Chomelia asiatica*) and tree species (*Leucaena leucocephala*, *Diospyros chloroxylon*, *Securinega virosa*, *Acacia nilotica*, *A. auriculiformis*, *A. chundra*, *A. leucophloea*, *Gardenia gummifera*, *Grewia rothii*, *Polyalthia cerasoides*, *Maba neligerrensis*, *Pongamia pinnata*, *Memecylon edule*, *Azadirachta indica*, *Ixora arborea*, *Morinda pubescens*, *Chloroxylon swietenia*, *Grewia tiliaefolia* and *Erythroxylum monogynum*) (Deepika and Laxmi, 2014) [9].

The sanctuary is located in a belt of tropical monsoon climate with distinct rainy seasons that start in late June and end in mid-October. The region features a humid climate, with average annual rainfall ranging from 900 mm to 1,600 mm. Temperatures generally range from 12°C to 40°C.

About Twenty villages are located less than 500 meters from the sanctuary. Several seasonal streams and small nullahs flow within the sanctuary and eventually merge into the Degala Gedda reservoir, which is the major source of water for all the wildlife.

Survey Technique

For sampling, field surveys were carried out by walking fixed transects of about 0.5 km, consisting of smaller sections from 07:00 h to 17:00 h on clear, dry days in March, 2026. The surveys recorded all butterflies in an imaginary box of 2.5 m to their left, 2.5 m to their right, 5 m above them and 5 m ahead of them (Suryanarayana et al., 2016) [41].

Butterflies were primarily identified in the site by observation or in any unfamiliar species, they were photographed and identified using standard field guide (Kunte et al., 2014; Kehimkar, 2016; Dey et al., 2017) [22, 18, 10]. Specimen collection was strictly avoided during the present study. All common English names and scientific names followed Varshney and Smetacek (2015) [45] guidelines.

Statistical data Analysis

Species occurrence analysis was carried out by Microsoft Excel Program with using the following formulas. Statistical analyses of alpha diversity indices were carried out by Microsoft Excel 2019 software. Shannon-Weiner diversity index (Shannon and Weaver, 1963) [38], Simpson index of Dominance (Simpson, 1964) [39] and Pielou's Evenness index (Mulder et al., 2004) [28], Margalef's Index for Richness (Margalef, 1958) [26] were calculated. To represent species richness and evenness a rank abundance curve was prepared (Whitaker, 1965) [48].

Shannon-Weiner diversity index (H′) = - Σ pi ln pi

Shannon H_{max}= Log_1 (N)

Dominance index (D_{BP})= N_{max}/N (Berger and Parker, 1970) [2]

Simpson's diversity index (Ds)= Σ^{S}_{i-1}[ni (ni-1)/N(N-1)]

Simpson's index of diversity (D)= 1-Σ^{S}_{i-1}[ni (ni-1)/N(N-1)]

Simpson's reciprocal index (Dr)= 1/ Σ^{S}_{i} pi^2

Pielou's evenness index (J′)= H′/ln N

Relative abundance (RA) = ni/N (Bisht et al., 2004) [6]

Margalef's Richness Index (d) = [(N_t-1) / ln(N)]

Here, pi is the proportion of the i^{th} species in the butterfly community. N is the number of species present in a butterfly fauna. Ni is the number of individuals of i^{th} species. N_{max} is the number of individuals in most abundant species. N_t is total number of all species.

The frequency of occurrence of each species was calculated based on the number of occasions the species was recorded during the surveys. The butterflies, recorded from the survey site, were categorized into four different classes on the basis of their prevalence, namely VC (very common; (>100 sightings), C (common; 51 to 100 sightings), NR (not rare; 16 to 50 sightings), R (rare; 3 to 15 sightings) and VR (very rare; 1 to 2 sightings) to indicate the most common to the rarest butterfly species (Tiple et al., 2006) [43] and denoted in Table 1 as status.

Results

During this study, altogether 69 butterfly species distributed across 48 genera and 5 families were observed in Kambalakonda Eco Park (Table 1). The most dominant family was Nymphalidae represented by 26 species, followed by Pieridae (16 species), Lycaenidae (13 species), Papilionidae (10 species), and Hesperiidae (5 species). In this study, Lemon Emigrant (*Catopsilia Pomona*) emerged as the most abundant species, exhibiting the highest relative abundance value of 4.83, followed by Common Wanderer (*Pareronia valeria*), Common Gull (*Cepora nerissa*), Common Crow (*Euploea core*), and Lemon Pansy (*Junonia lemonias*) with a relative abundance value of 4.33, 4.29, 3.52, 3.49 respectively reflecting their widespread occurrence in the study area. Conversely, the Black Prince (*Rohana parisatis*) exhibited much lower abundance, with a relative abundance value of 0.03, indicating its more sporadic occurrence across the sampling visits. This species was recorded as a 'singleton', a species represented by only a single individual. The relative abundance for 14 butterfly species ranged between 2 and 4, while for another 29 species, it fell between 1 and 2. The remaining butterfly species exhibited a relative abundance of less than 1. The highest occurrence frequency (100%) during the study period was observed for *Euploea core*, *Junonia lemonias*, *Pantoporia hordonia*, *Hypolimnas bolina*, *Phalanta phalantha*, *Neptis hylas*, *Acraea violae*, *Ypthima huebneri*, *Azanus ubaldus*, *Zizeeria karsandra*, *Catopsilia Pomona*, *Catopsilia pyranthe*, *Belenois aurota*, *Pieris rapae*, *Eurema hecabe*, *Leptosia nina*, *Cepora Nerissa* and *Pareronia valeria* (Table 1). Within the family Nymphalidae, the Common Crow (*Euploea core*) was the most abundant butterfly species followed by Lemon Pansy (*Junonia lemonias*), whereas, Black Prince (*Rohana parisatis*) was counted in least number. Lemon Emigrant (*Catopsilia Pomona*) was found to be the most abundant butterfly species for the family Pieridae, whereas Yellow Orange-Tip

(*Ixias pyrene*) was observed in least numbers. For the family Papilionidae, the Common Mormon (*Papilio polytes*) had the highest count, while the Red Helen (*Papilio helenus*) had the lowest count. Within the family Lycaenidae, the Dark grass blue (*Zizeeria karsandra*) was recorded in the highest numbers, while the Forget-Me-Not (*Catochrysops strabo*) was recorded in the lowest numbers. Finally, for the family Hesperiidae, Rice Swift (*Borbo cinnara*) was the most abundant species, while Common Redeye (*Matapa aria*) was recorded in the lowest numbers. Among the butterfly species recorded at the study site, twenty-four were found to be

Protected under the Wild Life (Protection) Act, 1972. Sixteen of these species are protected under Schedule II (*Graphium nomius, Papilio crino, Rohana parisatis, Junonia almana, Junonia hierta, Junonia orithya, Hypolimnas misippus, Hypolimnas bolina, Phalanta phalantha, Rathinda amor, Castalius rosimon, Appias albina, Appias lyncida, Cepora Nerissa, Pareronia valeria,* and *Ixias pyrene*), whereas five under Schedule I (*Pachliopta hector, Tirumala limniace, Cigaritis vulcanus, Belenois aurota,* and *Delias eucharis*), and three under Schedule IV (*Appias libythea, Suastus gremius,* and *Pelopidas mathias*) (Table 1).

Table 1: Checklist of butterfly species along with their family, relative abundance, occurrence frequency percentage, status and WPA Schedule recorded in the study site.

Sl. No.	Family	Common Name	Scientific name	Relative Abundance (RA)	Occurrence frequency (%)	Status	WPA Schedule
1	Papilionidae	Common Mormon	*Papilio polytes*	2.15	75	C	
2		Tailed Jay	*Graphium agamemnon*	2.08	62.5	C	
3		Common jay	*Graphium doson*	1.95	62.5	C	
4		Common Rose	*Pachliopta aristolochiae*	1.14	50	NR	
5		Crimson Rose	*Pachliopta hector*	0.50	37.5	R	Schedule I
6		Red Helen	*Papilio helenus*	0.30	37.5	R	
7		Lime swallowtail	*Papilio demoleus*	0.74	62.5	NR	
8		Blue Mormon	*Papilio agenor polymnestor*	0.34	37.5	R	
9		Spot Swordtail	*Graphium nomius*	0.77	50	NR	Schedule II
10		Common banded peacock	*Papilio crino*	0.70	50	NR	Schedule II
11	Nymphalidae	Black Prince	*Rohana parisatis*	0.03	12.5	VR	Schedule II
12		Common Castor	*Ariadne merione*	1.04	62.5	NR	
13		Common Crow	*Euploea core*	3.52	100	VC	
14		Painted Lady	*Vanessa cardui*	0.20	37.5	R	
15		Plain Tiger	*Danaus chrysippus*	1.48	62.5	NR	
16		Striped Tiger	*Danaus genutia*	0.13	50	R	
17		Blue Tiger	*Tirumala limniace*	0.84	50	NR	Schedule I
18		Grey Pansy	*Junonia atlites*	1.11	62.5	NR	
19		Lemon Pansy	*Junonia lemonias*	3.49	100	VC	
20		Peacock Pansy	*Junonia almana*	0.40	37.5	R	Schedule II
21		Chocolate Pansy	*Junonia iphita*	1.85	87.5	C	
22		Yellow Pansy	*Junonia hierta*	0.47	37.5	R	Schedule II
23		Blue Pansy	*Junonia orithya*	0.37	37.5	R	Schedule II
24		Common Lascar	*Pantoporia hordonia*	1.81	100	C	
25		Danaid Eggfly	*Hypolimnas misippus*	1.38	75	NR	Schedule II
26		Great Eggfly	*Hypolimnas bolina*	1.78	100	C	Schedule II
27		Common Leopard	*Phalanta phalantha*	2.21	100	C	Schedule II
28		Common Sailer	*Neptis hylas*	1.91	100	C	
29		Baronet	*Symphaedra nais*	1.41	75	NR	
30		Anomalous Nawab	*Charaxes agrarius*	0.13	25	R	
31		Common Palmfly	*Elymnias hypermnestra*	0.50	37.5	R	
32		Tawny Coster	*Acraea violae*	1.88	100	C	
33		Common Four-ring	*Ypthima huebneri*	1.85	100	C	
34		Common Bushbrown	*Mycalesis perseus*	1.11	87.5	NR	
35		Common Evening Brown	*Melanitis leda*	1.27	75	NR	
36	Lycaenidae	Indian Sunbeam	*Curetis thetis*	1.48	62.5	NR	
37		Tiny Grass Blue	*Zizula hylax*	1.04	62.5	NR	
38		Forget - Me-Not	*Catochrysops strabo*	0.60	62.5	NR	
39		Bright Babul blue	*Azanus ubaldus*	1.85	100	C	
40		Dark grass blue	*Zizeeria karsandra*	1.98	100	C	
41		Monkey puzzle	*Rathinda amor*	0.64	50	NR	Schedule II
42		Common Pierrot	*Castalius rosimon*	1.11	62.5	NR	Schedule II
43		Pea Blue	*Lampides boeticus*	1.21	75	NR	
44		Common Silverline	*Cigaritis vulcanus*	1.58	75	NR	Schedule I
45		Lime Blue	*Chilades lajus*	0.97	75	NR	
46		Plains Cupid	*Chilades pandava*	1.07	75	NR	
47		Common Cerulean	*Jamides celeno*	1.07	62.5	NR	
48		Dark Cerulean	*Jamides bochus*	0.91	62.5	NR	
49	Pieridae	Lemon Emigrant	*Catopsilia pomona*	4.83	100	VC	
50		Mottled Emigrant	*Catopsilia pyranthe*	3.29	100	C	

51		Indian Pioneer	*Belenois aurota*	2.92	100	C	Schedule I
52		Cabbage White	*Pieris rapae*	2.95	100	C	
53		Common Grass Yellow	*Eurema hecabe*	2.75	100	C	
54		Psyche	*Leptosia nina*	2.31	100	C	
55		Common Albatross	*Appias albina*	1.38	87.5	NR	Schedule II
56		Striped Albatross	*Appias libythea*	2.78	87.5	C	Schedule IV
57		Chocolate albatross	*Appias lyncida*	1.41	75	NR	Schedule II
58		Common Gull	*Cepora nerissa*	4.29	100	C	Schedule II
59		Common Wanderer	*Pareronia valeria*	4.33	100	C	Schedule II
60		Common Jezebel	*Delias eucharis*	0.81	62.5	NR	Schedule I
61		Large Salmon Arab	*Colotis fausta*	1.14	50	NR	
62		Small Salmon Arab	*Colotis amata*	1.41	62.5	NR	
63		White Orange Tip	*Ixias marianne*	0.97	62.5	NR	
64		Yellow Orange-Tip	*Ixias pyrene*	0.74	50	NR	Schedule II
65	Hesperiidae	Indian Palm Bob	*Suastus gremius*	0.67	62.5	NR	Schedule IV
66		Common Redeye	*Matapa aria*	0.40	50	R	
67		Rice Swift	*Borbo cinnara*	1.14	75	NR	
68		Small-Branded Swift	*Pelopidas mathias*	0.60	62.5	NR	Schedule IV
69		Common Banded Awl	*Hasora chromus*	0.54	62.5	NR	

VC - very common (>100 sightings), C – common (51 to 100 sightings), NR – nor rare (16 to 50 sightings), R – rare (3 to 15 sightings), VR – very rare (1 to 2) to indicate the rarest to the most common butterfly species (Tiple et al., 2006) [30].
WPA- Species enlisted in Indian Wildlife Protection Act, 1972.

In terms of individual counts, Pieridae was the most abundant family (38.31%), followed by Nymphalidae (32.17%), Lycaenidae (15.50%), Papilionidae (10.67%), and Hesperiidae (3.35%) (Figure 3). The maximum number of butterfly genera were found under family Nymphalidae (37.50%), followed by Lycaenidae and Pieridae (22.92% each), Hesperiidae (10.41%), and Papilionidae (6.25%) (Figure 4).

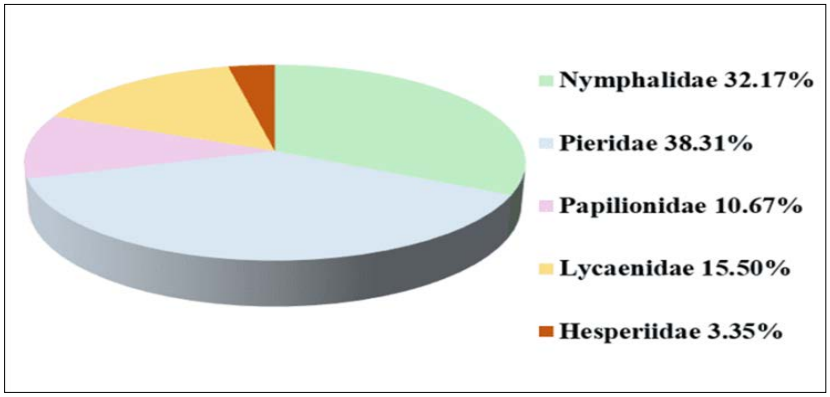

Fig 3: Percentage composition of five families of butterflies in the study area.

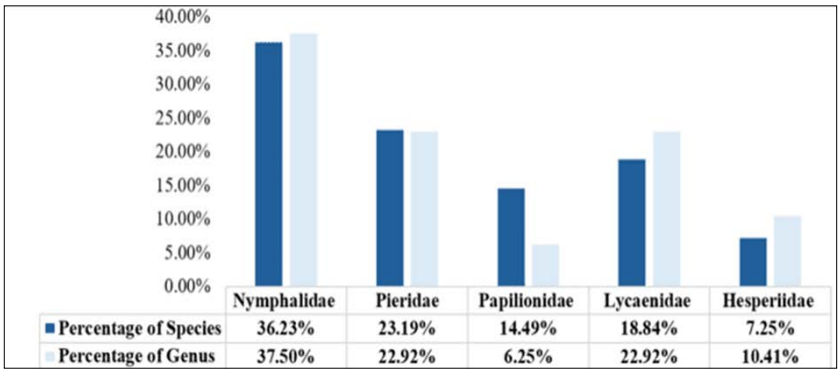

Fig 4: Genus to species proportion of butterflies of five families.

The genus *Junonia* was the most diverse, represented by six species (*J. atlites*, *J. almana*, *J. lemonias*, *J. orithya*, *J. hierta*, and *J. iphita*). This was followed by *Papilio* with five species (*P. polytes*, *P. polymnestor*, *P. demoleus*, *P. helenus*, and *P. crino*), and *Graphium* and *Appias* with three species each (*G. Agamemnon*, *G. doson*, and *G. nomius*, and *A. albina*, *A. libythea*, and *A. lyncida*, respectively). Eight genera, namely *Pachliopta*, *Danaus*, *Hypolimnas*, *Chilades*, *Jamides*, *Catopsilia*, *Colotis* and *Ixias* were represented by two species each, while the remaining 36 genera were represented by a single species each (figure 5). The species-to-genus ratio of the recorded butterfly fauna was calculated to be 1.44. Of the total counted butterflies, 48.91% belonged to the C category, 35.46% to the NR category, 11.84% to the VC category, 3.76% to the R category, and 0.03% to the VR category (figure 6).

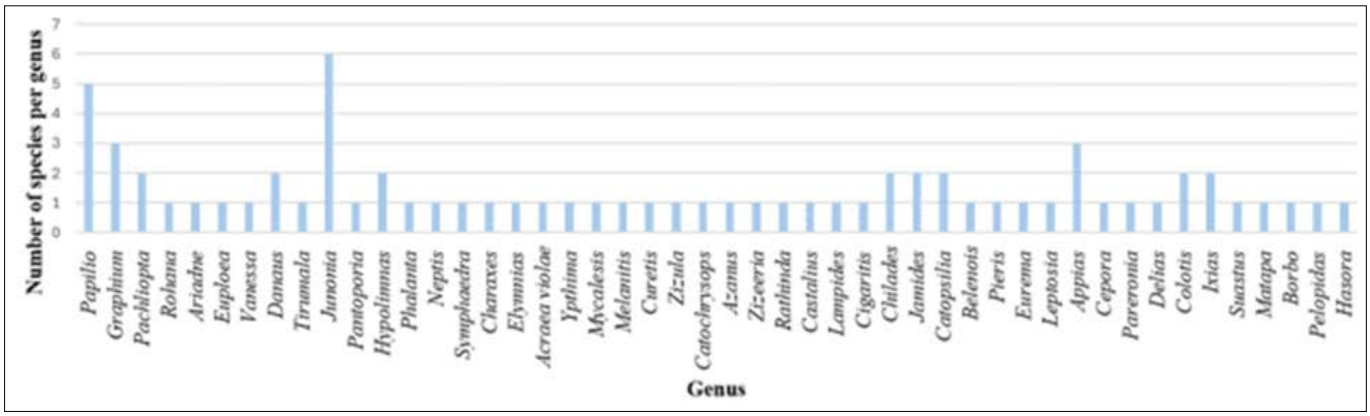

Fig 5: Species richness of the recorded butterfly genera of the study site.

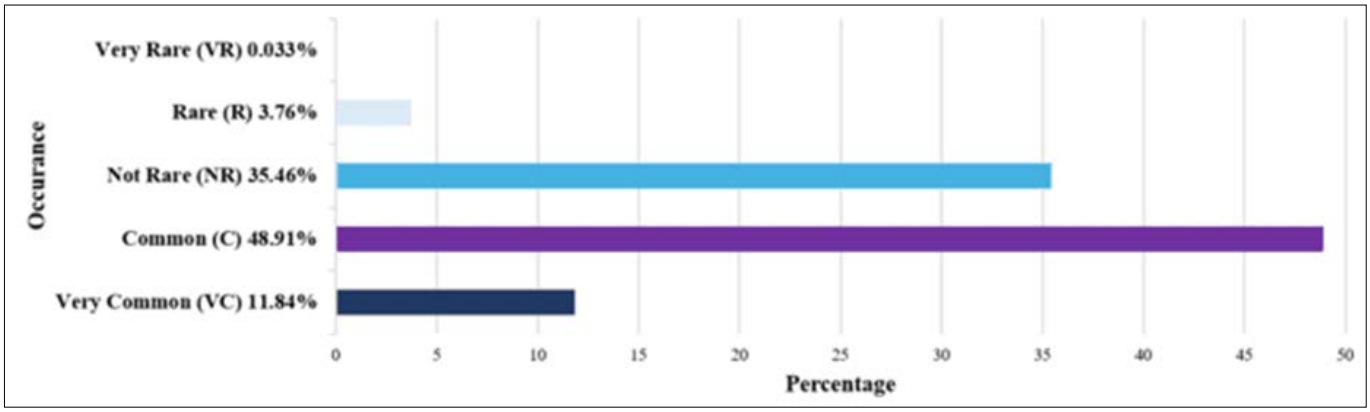

Fig 6: Occurrence status of different butterfly species in the study area.

The species diversity, abundance and evenness were expressed by Shannon (H'), Shannon H_{max}, and Simpson (Ds) and Pielou (J') indices (Table 2). The sampled site exhibited high butterfly species richness and diversity, as reflected by the high Shannon diversity index (H' = 4.28). The value of Simpson's dominance index (Ds = 0.02) was found to be close to 0, indicating low species dominance and high diversity within the community. The calculated Simpson's index of diversity (D=0.98) depicts high species diversity and high evenness with low dominance within the butterfly fauna. Pielou's evenness index (J'=0.94) is close to 1, indicating that the butterfly species in the studied community are highly balanced and uniformly distributed. A Margalef's Richness Index value of 8.50 indicates a highly diverse ecosystem in terms of species richness. While Simpson's reciprocal index (Dr = 46.04) indicates good species diversity in the surveyed butterfly community, it also confirms low dominance by any single species. Thus, the values of the studied diversity indices reveal that the butterfly community is highly diverse, reflecting both high evenness and high abundance. In this study, the Shannon diversity index (H') of the butterfly families ranged from 1.55 to 2.95. The Nymphalidae family showed the highest diversity, followed by the Pieridae (2.62), Lycaenidae (2.51). Papilionidae (2.10), and Hesperiidae (1.55). Similarly, the Nymphalidae recorded the highest H_{max} (3.22), with decreasing values in Pieridae (2.77), Lycaenidae (2.57), Papilionidae (2.30), and Hesperiidae (1.61). Pielou's evenness index (J′) was highest for Hesperiidae (0.96), indicating a highly even species distribution, followed closely by Pieridae (0.95). The values of Simpson's index of diversity (D) and Simpson's reciprocal index (Dr) were found to be highest for the family Nymphalidae (D=0.94 and Dr =16.78, respectively), revealing that this family is the most diverse one in the studied butterfly community (Table 3). Rank abundance curves for 69 species and five families were plotted to estimate evenness within the butterfly community and within each family, respectively, based on species proportions (figure 7 and figure 8 respectively). The Whittaker plot showed that the curve began steeply for the first ten butterfly species and then leveled off, indicating that these ten species occurred in much higher abundance and with lower evenness compared to the remaining species. Beyond species rank ten, butterfly abundance decreased, which correlated with higher species evenness across the study area. As shown in Figure 8, Hesperiidae recorded the highest species evenness, followed sequentially by Pieridae, Nymphalidae, Papilionidae, and Lycaenidae.

Table 2: Values of different biodiversity indices of butterfly population of the study area

Shannon diversity index (H')	Pielou's evenness index (J′)	Simpson's index (Ds)	Simpson's index of diversity (D)	Margalef's Richness index (d)	Simpson's reciprocal index (Dr)	Dominance index (D_{BP})
3.99	0.94	0.02	0.98	8.50	46.04	0.04

Table 3: Values of different biodiversity indices of butterfly population of the study area

Family	Shannon diversity index (H')	Shannon H_{max}	Pielou's evenness index (J′)	Simpson's index (Ds)	Simpson's index of diversity (D)	Simpson's reciprocal index (Dr)	Dominance index (D_{BP})
Nymphalidae	2.95	3.22	0.92	0.06	0.94	16.78	0.11
Pieridae	2.62	2.77	0.95	0.08	0.92	12.51	0.13
Papilionidae	2.10	2.30	0.91	0.14	0.86	7.20	0.20
Lycaenidae	2.51	2.57	0.80	0.08	0.92	11.94	0.13
Hesperiidae	1.55	1.61	0.96	0.22	0.78	4.54	0.34

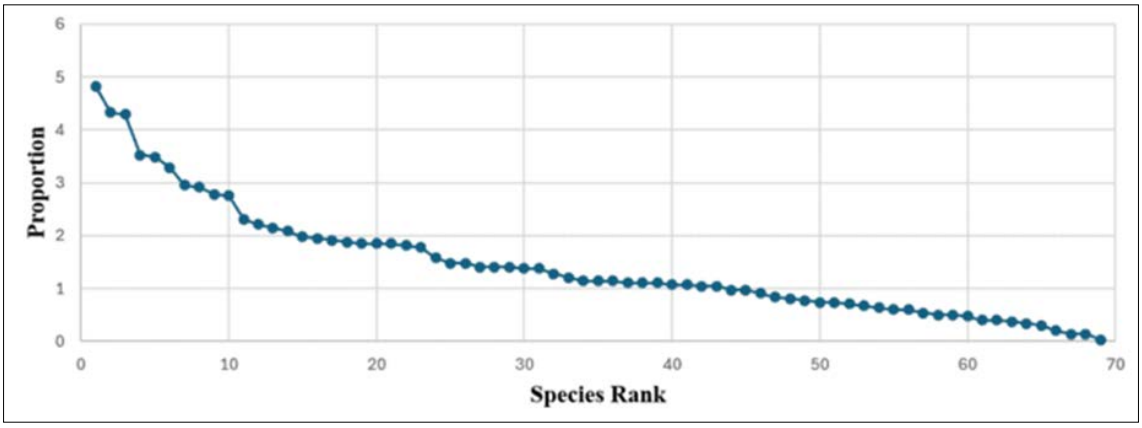

Fig 7: Rank abundance curve of 69 species of butterfly in the study area.

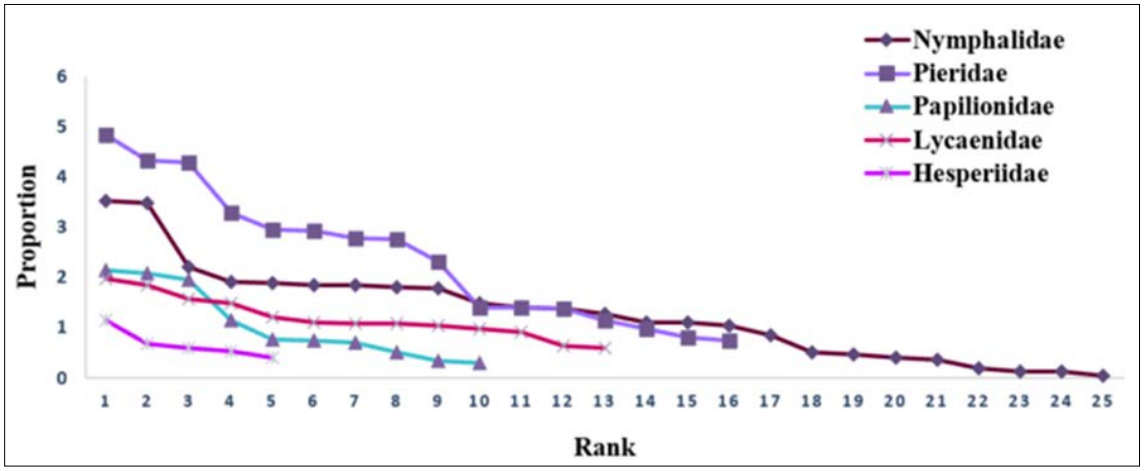

Fig 8: Rank abundance curve of five families of butterfly in the study area.

Discussion

The present documentation of 69 butterfly species belonging to 48 genera and five families at Kambalakonda Eco Park highlights the rich butterfly fauna within this managed subtropical urban ecosystem. This diversity is likely sustained by high habitat heterogeneity. Similar species richness has been reported in previous studies from other protected parks and green urban spaces, such as Indira Gandhi Zoological Park and Kailasagiri Park (62 species; Padmaja et al., 2021) [32], Padmapuram Botanical Garden, Araku Valley, Visakhapatnam (92 species; Das et al., 2026b) [8], Seshachalam Bio-reserve forest, Visakhapatnam (106 species; Suryanarayana et al., 2018) [42], and Eastern Ghats of Visakhapatnam District (190 species; Bhusala et al., 2024) [5]. This is likely due to healthy habitat conditions and conservation efforts across urban green patches in India. In this study, Pieridae emerged as the dominant family, closely followed by Nymphalidae, whereas earlier studies from this region reported the latter as dominant (Padmaja et al., 2021; Das et al., 2026b; Suryanarayana et al., 2018; Bhusala et al., 2024; Mounica and Mathew, 2020) [32, 8, 42, 5, 27]. This variation in the species richness of a family might be shaped by the vegetation composition throughout the region (Ockinger and Smith, 2006; Ockinger et al., 2006, 2009) [29, 31, 30]. Here, Pieridae was the most abundant family in terms of individuals, a result that might be due to their preference for open spaces observed at the study site (Gupta and Kumar, 2024) [15]. The second most abundant family was Nymphalidae, which is possibly due to their broad habitat adaptability, polyphagous nature, and strong dispersal abilities (Jaiswal et al., 2021; Tiple, 2020) [17, 44]. Conversely, host plant specificity and limited dispersal ability likely contributed to the lower species richness observed in the Hesperiidae and Papilionidae families (Kehimkar, 2008; Lodh and Agarwala, 2016) [19, 24]. Vu et al. (2010) [47] reported that grass and shrub habitats are the most common distribution areas for a high proportion of butterflies. Supporting this view, observed butterflies ranged from the smallest Tiny Grass Blue with a 13 mm wingspan to the largest Blue Tiger with a 115 mm wingspan. Furthermore, the species abundance categorization classifies

48.91% of the species as common, 35.46% as not rare, and 3.76% as rare, indicating that grassland and shrub-dominated habitats are highly suitable for butterfly populations

The presence of rare species, such as *Junonia iphita* and *Vanessa cardui*, reflects the area's excellent habitat quality and ecosystem resilience, highlighting its conservation value. The presence of species protected under Schedule I, II and IV of the Wild Life (Protection) Amendment Act, 1972, demonstrates the need for management and conservation policies. Grouping species by their abundance provides baseline information for monitoring urban butterfly populations. Future systematic surveys are essential for assessing habitat health and implementing effective biodiversity conservation measures.The utility of butterflies as bioindicators

Drives the study of butterfly diversity (Stefanescu et al., 2004) [41]. Their distribution and diversity PATTERN reflect environmental conditions, overall habitat health, and ecosystem resilience. The study area hosted a greater variety of butterfly species, possibly as a consequence of its larger size with diverse vegetation pattern. The findings accentuate the critical role of urban green spaces in sustaining butterfly populations. Most urban areas have limited green space to support diverse plant life and the resulting reduced vegetation exacerbates the urban heat island effect. This study will help in adopting targeted conservation strategies for habitat management and native plant species restoration, which will support urban biodiversity, sustain butterfly-derived ecosystem services, and ultimately aid in the long-term conservation of butterfly fauna in urban green spaces.

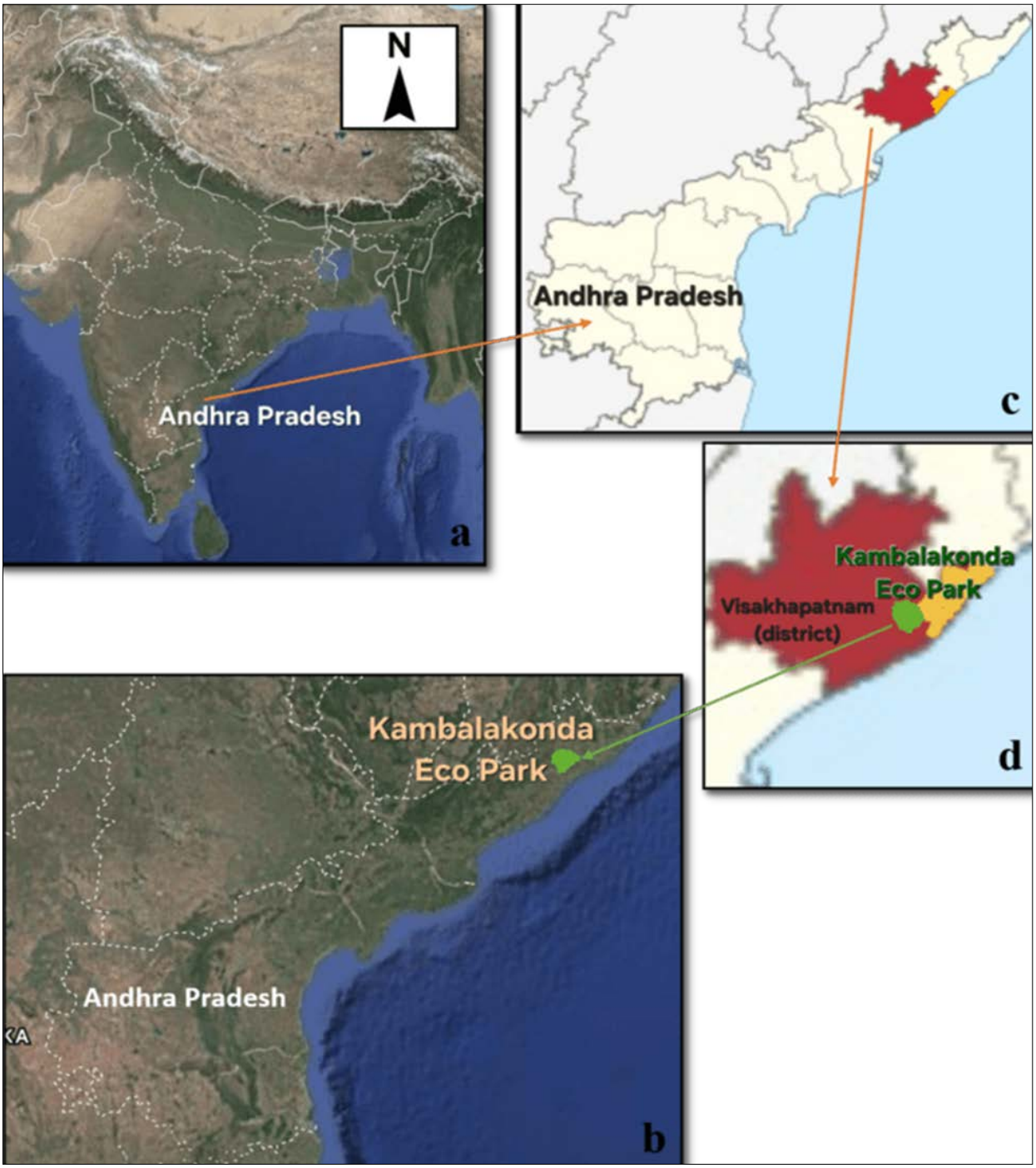

Fig 1: Satellite image of India (a), Andhra Pradesh (b) and map of Visakhapatnam district (c), and Kambalakonda Eco Park (d).

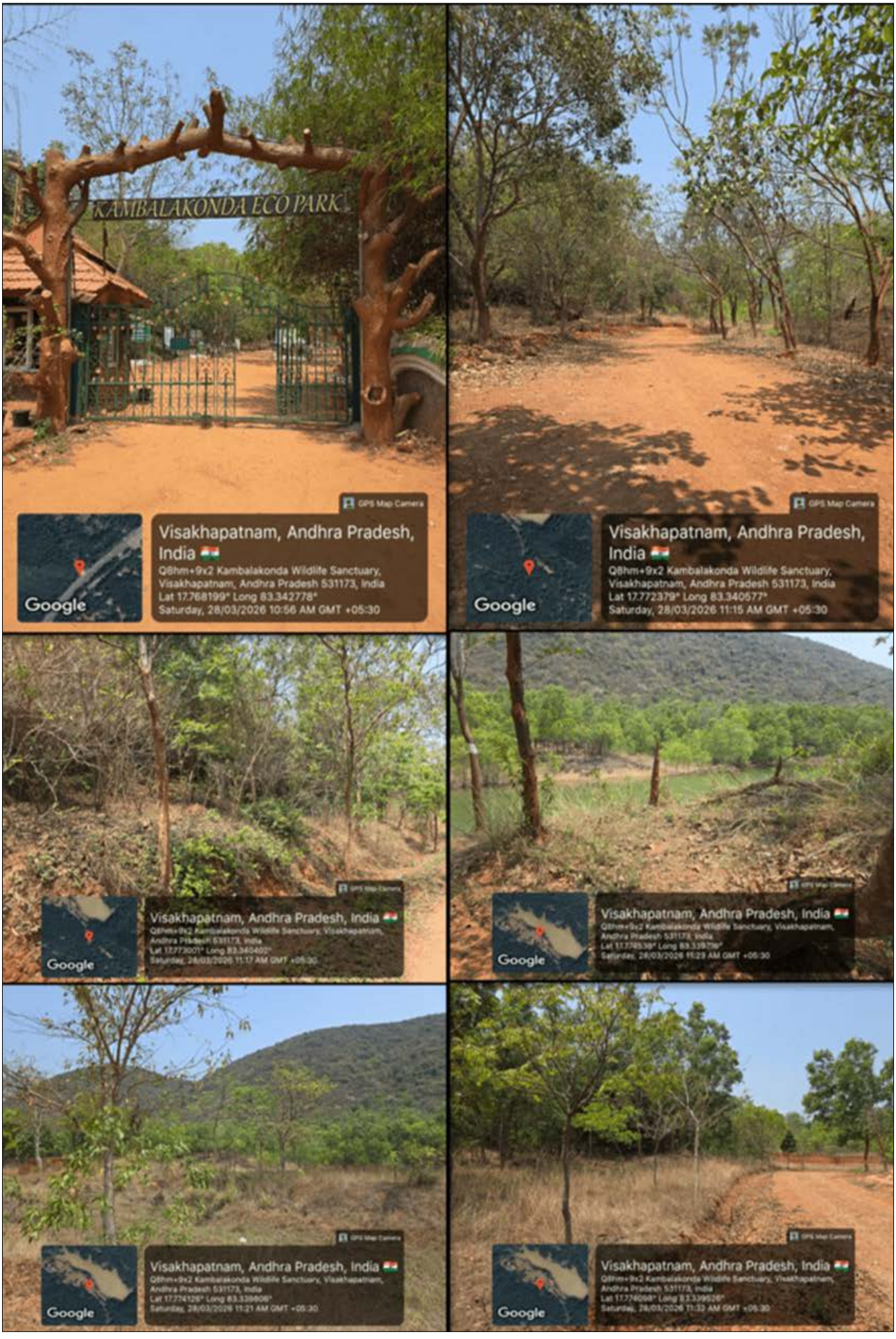

Fig 2: Photographs showing the vegetation of the study area.

Fig 9a: Photographs of different butterfly species recorded in the study area.

Fig 9b: Photographs of different butterfly species recorded in the study area.

Conclusion

The present study reveals that Kambalakonda Eco Park provides ideal ecological conditions and habitats that support a diverse array of butterfly species, though the area leaves much still to be explored. Hence, long-term, seasonal comprehensive systematic surveys are needed for adopting conservation policies. Additionally, it is essential to compile a checklist of rare butterfly species and ensure their conservation by establishing dedicated conservatories and butterfly parks. Further research is required to determine the species-specific roles of butterflies in monitoring environmental changes and sustaining ecosystem integrity.

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