International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 11-04-2026, Accepted: 12-05-2026, Published: 27-05-2026
Volume 11, Issue 2, 2026, Page No. 309-320

A study on butterfly diversity of Padmapuram Botanical Garden, Araku Valley, Visakhapatnam district, Andhra Pradesh: An appraisal for their conservation

Dr. Mousumi Das[1*], Suptika Ghosh[1], Anubhab Kanrar[1], Soulima Dutta[1], Dr. Animesh Bose[2]
[1] Assistant Professor, Department of Zoology, In-Charge of Resource Ecology, Vidyasagar College, Salt Lake Campus, Kolkata, India
[2] Department of Botany, Vidyasagar College, Salt Lake Campus, Kolkata, India

Abstract
Butterflies are crucial for monitoring biodiversity and environmental changes in ecological studies. A preliminary survey-based study on the diversity and distribution pattern of butterflies was carried out in Padmapuram Botanical Garden, Araku Valley, Visakhapatnam district, Andhra Pradesh, India, during March, 2026. Ninety-two butterfly species from 64 genera were recorded in five families during this study, of which ten species are protected under the Wildlife (Protection) Act of India, 1972. Nymphalidae family was the most dominant, accounting for 44.50% of total butterflies, 36.96% of recorded species, and 35.94% of recorded genera, followed by Pieridae, Lycaenidae, Hesperiidae, and Papilionidae. Common Sailer (*Neptis hylas*) and Chocolate Pansy (*Junonia iphita*) were the most observed butterfly followed by Common Emigrant (*Catopsilia pomona*), Tiny Grass Blue (*Zizula hylax*). Black Rajah (*Charaxes solon*), Red Helen (*Papilio helenus*) and Monkey Puzzle (*Rathinda amor*) were observed with a minimum count. The Shannon-Wiener index, Simpson's index, Pielou's evenness index, and Margalef's richness index were 4.28, 0.98, 0.95, and 11.54, respectively, indicating the area is rich in butterfly diversity with high abundance and evenness. The highest occurrence frequency (100%) was recorded for the *Junonia iphita*, *Junonia lemonias*, *Neptis hylas*, *Ypthima baldus*, *Melanitis leda*, *Catopsilia pomona*, *Graphium agamemnon* and *Zizula hylax.* The findings from this study will contribute to a better understanding of the butterfly diversity within the study area, highlighting the importance of habitat protection for ecological balance and future conservation efforts.

Keywords: Butterfly diversity, conservation efforts, nymphalidae, padmapuram botanical garden

Introduction

Insects are the most taxonomically diverse organisms on Earth. Among them, butterflies (order Lepidoptera), considered to be the most charismatic taxa of terrestrial ecosystems, are key components of biodiversity and serve as effective invertebrate flagships, aiding in the conservation of overall biodiversity (Barua *et al*., 2012; Kurve *et al*., 2013) [5, 28]. Diversity and abundance of species of an area depend on high biodiversity of flora and fauna; this link between biodiversity and ecosystems exists as higher species diversity enhances productivity and ecosystem stability (Naeem *et al*., 1994; Tilman *et al*., 1996; Majumder *et al*., 2012) [33, 44, 29]. Moreover, the climate and topography of a region determine its vegetation type, along with its species richness (Harinath *et al*., 2015) [20]. Diverse vegetation is home to many insects and butterflies (Kunte, 1997; Alfred *et al*., 2002; Agarwala *et al*., 2010) [25, 3, 2]. Butterflies, being highly sensitive to subtle environmental changes, serve as effective bioindicators for assessing terrestrial habitat quality (Kunte, 2000) [26]. These winged jewels are crucial to ecological, economic, and social well-being. Beyond their immense aesthetic value, they act as natural pollinators, ensuring the sustainability of habitats, and serve as herbivores and prey to predators, contributing to the stability of the food chain (Gupta and Mondal, 2005; Patil *et al*., 2017) [16, 35].

India is rich in butterfly diversity, hosting over 1,300 species; however, they are not uniformly distributed, with most occurring in the northeastern region (Varshney and Smetacek, 2015) [46]. Interest in biodiversity documentation in India has risen over the past decade, largely due to the ubiquitous nature of studied organisms and advancements in digital and mobile photography (Chandler *et al*., 2017) [10]. Survey coverage is not uniform across the country, even for well-surveyed taxa like butterflies. Even today, there are many regions where few or no studies have been conducted on butterfly diversity. The northern part of the Eastern Ghats is one such region. The Eastern Ghats is a discontinuous chain of low hills running parallel to India's east coast, extending from Odisha southwards through Andhra Pradesh to central Tamil Nadu (Kehimkar, 2008) [21].

The Madugula Konda is a group of hill ranges in the northern portion of Eastern Ghats, generally ranging in elevation between 900-1400 m, with multiple peaks exceeding 1,600 m. It spreads across Visakhapatnam district of Andhra Pradesh, including the Araku Valley. Araku Valley spans 36 square kilometers, nestled within the Ananthagiri and Sunkarimetta reserved forests; its Padmapuram Botanical Garden is one of the region's oldest, boasting rich floral diversity (Arumalla, 2024) [4]. Despite the region's ecological richness, growing tourism pressure necessitates an assessment to highlight the impact of anthropogenic activities on its natural habitat. Butterflies are ideal bioindicators of ecosystem change and are often used to predict habitat health (Chettri, 2010; Rakosy and Schmit, 2011) [11, 36]. No information was available on butterflies of Padmapuram Botanical Garden. Therefore, an attempt was

made here to record the list of butterfly fauna, along with their diversity and abundance in Padmapuram Botanical Garden, Araku Valley, Visakhapatnam district, Andhra Pradesh.

Materials and Methods

Study Area

The study was conducted in Padmapuram Botanical Garden (18.3373°N 82.8781°E), Araku Valley, Alluri Sitharama Raju district, Andhra Pradesh, India (figure 1). It is situated at a distance of about 2.5 km from the Araku Railway Station. It was built in 1942 by British officials in 26-acre plot.

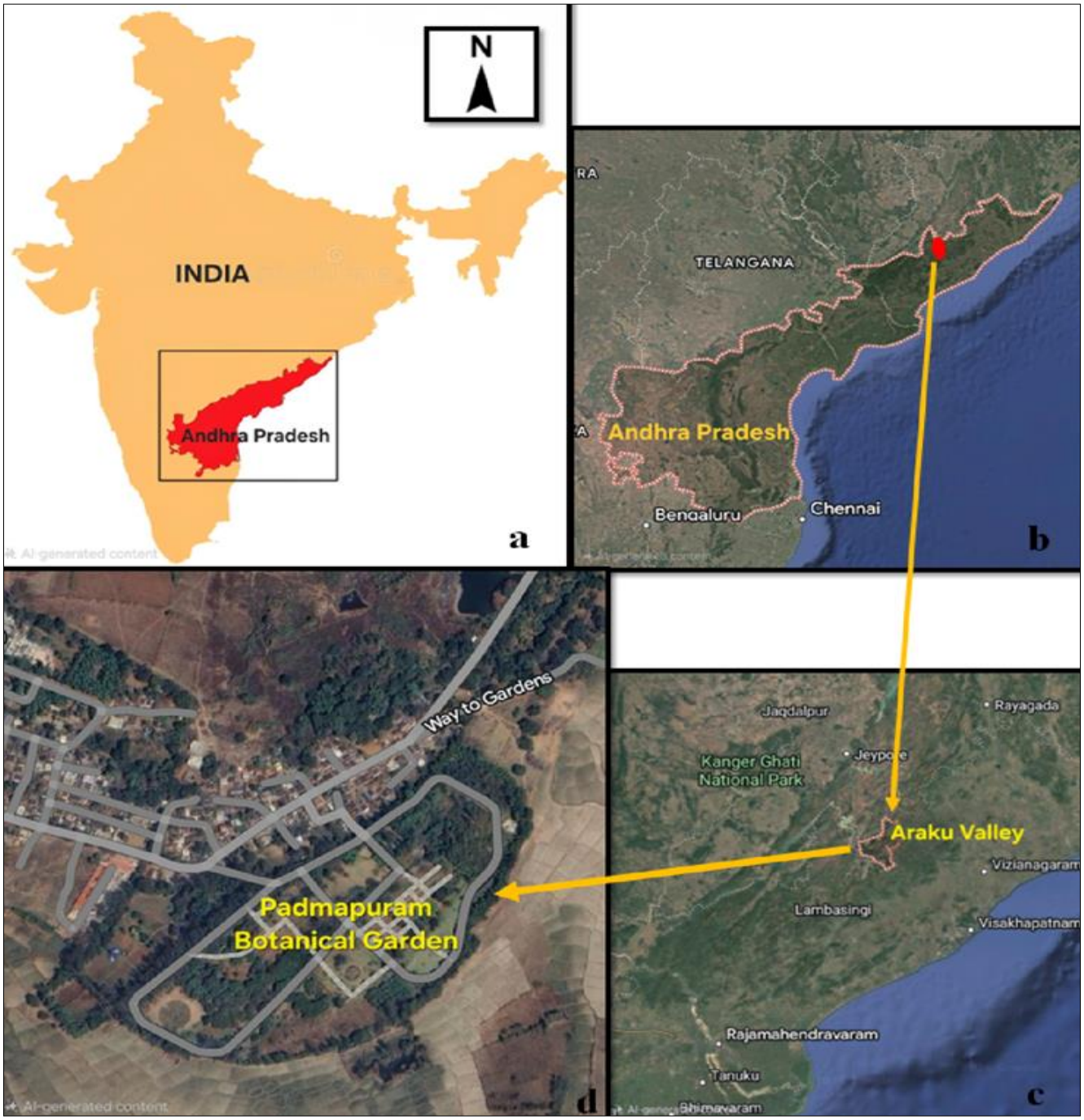


Fig 1: Map of India (a), and satellite image of Andhra Pradesh (b), Araku Valley (c), and Padmapuram Botanical Garden (d)

It houses a large variety of indigenous plants, horticulture crops etc (figure 2). Vegetation surrounding the study site primarily consists of deciduous forests, with patches of moist deciduous, evergreen to semi-evergreen forests, grasslands, and agricultural land (Basha and Reddy, 2017) [6]. The area is characterized by an undulating topography. The soils are medium-to-heavy-textured red loamy and coastal alluvial types with poor-to-medium fertility, rendering them prone to moderate-to-heavy erosion.

The temperature drops to a mean minimum of 4°C in January, then reaches a mean maximum of 34°C by the end of May; April to June are the warmest months. The area experiences an average annual rainfall of 1781 mm.

Fig 2: Photographs of the study area that consists of herbs, shrubs and trees

Survey Technique

For sampling, field surveys were carried out from 9:00 am to 1:00 pm and 3:30 pm to 5:30 pm in March, 2026, during good weather periods. The counts were made through walking along fixed transects of about 0.5 km, consisting of smaller sections. The surveys recorded all butterflies in an imaginary box of 2.5 meters to their left, 2.5 meters to their right, 5 meters above them and 5 meters 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) [27, 22, 12]. Specimen collection was strictly avoided during the present study. All common English names and scientific names followed Varshney and Smetacek (2015) [46] 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) [39], Simpson index of Dominance (Simpson, 1964) [40] and Pielou's Evenness index (Mulder *et al*., 2004) [32], Margalef's Index for Richness (Margalef, 1958) [30] 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) [7]

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) [9]

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; RA>3.5), C (common; RA>1.5-3.5), NR (not rare; RA>0.5 to 1.5), R (rare; RA≤0.5) to indicate the rarest to the most common butterfly species (Agase *et al*., 2022) [1] and denoted in Table 1 as status.

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	Nymphalidae	Common Evening Brown	*Melanitis leda*	2.52	100.00	C	
2		Blue Pansy	*Junonia orithya*	0.64	33.33	NR	
3		Yellow Pansy	*Junonia hierta*	0.60	33.33	NR	
4		Lemon Pansy	*Junonia lemonias*	2.18	100.00	C	
5		Grey Pansy	*Junonia atlites*	0.71	22.22	NR	
6		Peacock Pansy	*Junonia almana*	0.34	11.11	R	
7		Chocolate Pansy	*Junonia iphita*	4.21	100.00	VC	
8		Great Eggfly	*Hypolimnas bolina*	1.99	77.78	C	
9		Danaid Eggfly	*Hypolimnas misippus*	2.10	55.56	C	Schedule II
10		Blue Tiger	*Tirumala limniace*	0.94	44.44	NR	
11		Glassy Tiger	*Parantica aglea*	0.60	33.33	NR	
12		Common Lascar	*Pantoporia hordonia*	0.71	44.44	NR	
13		Common Jester	*Symbrenthia hippoclus*	0.45	11.11	R	
14		Common Crow	*Euploea core*	2.18	88.89	C	
15		Plain Tiger	*Danaus chrysippus*	0.71	55.56	NR	
16		Striped Tiger	*Danaus genutia*	0.60	33.33	NR	
17		Common Palmfly	*Elymnias hypermnestra*	1.09	44.44	NR	
18		Common Five-ring	*Ypthima baldus*	2.07	100.00	C	
19		Common Four-ring	*Ypthima huebneri*	1.16	55.56	NR	
20		Common Three-ring	*Ypthima asterope*	0.53	11.11	R	
21		Common Sailer	*Neptis hylas*	4.43	100.00	VC	
22		Dark Evening Brown	*Melanitis phedima*	2.29	77.78	C	
23		Joker	*Byblia ilithyia*	0.26	11.11	R	
24		Painted Lady	*Vanessa cardui*	0.71	33.33	NR	
25		Common Leopard	*Phalanta phalantha*	0.79	55.56	NR	
26		Baronet	*Symphaedra nais*	1.31	55.56	NR	
27		Common Baron	*Euthalia aconthea*	0.79	44.44	NR	Schedule II
28		Common Nawab	*Polyura athamas*	0.60	22.22	NR	Schedule II
29		Common Castor	*Ariadne merione*	2.33	88.89	C	
30		Angled Castor	*Ariadne ariadne*	0.68	22.22	NR	
31		Tawny Coster	*Acraea violae*	2.37	66.67	C	
32		Bamboo Treebrown	*Lethe europa*	0.86	33.33	NR	
33		Common Bushbrown	*Mycalesis perseus*	0.71	44.44	NR	
34		Black Rajah	*Charaxes solon*	0.04	11.11	R	Schedule II
35	Pieridae	Common Jezebel	*Delias eucharis*	1.35	66.67	NR	
36		Hill Jezebel	*Delias belladonna*	0.19	11.11	R	
37		Common Emigrant	*Catopsilia pomona*	3.27	100.00	C	
38		Mottled Emigrant	*Catopsilia pyranthe*	2.40	77.78	C	
39		Common Grass Yellow	*Eurema hecabe*	1.92	77.78	C	
40		Small Grass Yellow	*Eurema brigitta*	0.64	22.22	NR	
41		Pioneer	*Belenois aurota*	0.75	33.33	NR	
42		Common Gull	*Cepora nerissa*	1.73	77.78	C	
43		Common Wanderer	*Pareronia valeria*	1.24	66.67	NR	

44		Common Albatross	*Appias albina*	1.69	66.67	C	Schedule II
45		Striped Albatross	*Appias libythea*	0.45	33.33	R	Schedule IV
46		Large Salmon Arab	*Colotis fausta*	0.30	11.11	R	
47		Small Salmon Arab	*Colotis amata*	0.41	22.22	R	
48		Psyche	*Leptosia nina*	0.83	77.78	NR	
49		White Orange Tip	*Ixias marianne*	0.64	22.22	NR	
50		Dark Colourded Yellow	*Colias fieldii*	0.86	22.22	NR	
51		Plain Orange-tip	*Colotis aurora*	0.49	22.22	R	
52	Papilionidae	Common Mormon	*Papilio polytes*	0.83	77.78	NR	
53		Blue Mormon	*Papilio agenor polymnestor*	0.53	44.44	NR	
54		Lime Butterfly	*Papilio demoleus*	0.68	33.33	NR	
55		Red Helen	*Papilio helenus*	0.08	11.11	R	
56		Common Mime	*Papilio clytia*	0.64	33.33	NR	Schedule II
57		Common Banded Peacock	*Papilio crino*	1.09	33.33	NR	Schedule II
58		Common Jay	*Graphium doson*	1.46	44.44	NR	
59		Tailed Jay	*Graphium agamemnon*	2.07	100.00	C	
60		Spot Swordtail	*Graphium nomius*	0.64	22.22	NR	
61		Common Bluebottle	*Graphium sarpedon*	0.79	44.44	NR	Schedule II
62		Common Rose	*Pachliopta aristolochiae*	0.98	33.33	NR	
63		Crimson Rose	*Pachliopta hector*	0.15	11.11	R	Schedule II
64	Lycaenidae	Tiny Grass Blue	*Zizula hylax*	2.89	100.00	C	
65		Pale Grass Blue	*Pseudozizeeria maha*	1.61	66.67	C	
66		Zebra Blue	*Leptotes plinius*	0.60	22.22	NR	
67		Common Silverline	*Cigaritis vulcanus*	0.90	44.44	NR	
68		Lime Blue	*Chilades lajus*	0.64	33.33	NR	
69		Hedge Blue	*Acytolepis puspa*	0.60	33.33	NR	
70		Plain Cupid	*Chilades pandava*	0.83	33.33	NR	
71		Grass Jewel	*Chilades trochylus*	0.68	33.33	NR	
72		Forget-me-not	*Catochrysops strabo*	0.64	55.56	NR	
73		Monkey Puzzle	*Rathinda amor*	0.11	11.11	R	
74		Common Cerulean	*Jamides celeno*	0.71	44.44	NR	
75		Dark Cerulean	*Jamides bochus*	0.60	33.33	NR	
76		Common Lineblue	*Prosotas nora*	0.79	33.33	NR	
77		Gram Blue	*Euchrysops cnefus*	0.53	33.33	NR	
78		Pea Blue	*Lampides boeticus*	0.75	55.56	NR	
79		Common Pierrot	*Castalius rosimon*	0.49	11.11	R	
80	Hesperiidae	Indian Palm Bob	*Suastus gremius*	1.20	33.33	NR	
81		Grass Demon	*Ancistroides folus*	1.39	55.56	NR	
82		Common Redeye	*Matapa aria*	0.68	22.22	NR	
83		Chestnut Bob	*Lambrix salsala*	0.94	22.22	NR	
84		Tree Flitter	*Hyarotis adrastus*	0.79	33.33	NR	
85		Small-Branded Swift	*Pelopidas mathias*	1.54	55.56	C	
86		Indian Skipper	*Spialia galba*	1.16	44.44	NR	
87		Brown Awl	*Badamia exclamationis*	0.79	22.22	NR	
88		Common Banded Awl	*Hasora chromus*	0.64	22.22	NR	
89		Rice Swift	*Borbo cinnara*	1.61	77.78	C	
90		Dark Palm-Dart	*Telicota bambusae*	0.94	22.22	NR	
91		Grizzled Skipper	*Pyrgus malvae*	0.71	44.44	NR	
92		Tricolour Pied Flat	*Coladenia indrani*	0.68	33.33	NR	

VC (very common; RA>3.5), C (common; RA>1.5-3.5), NR (not rare; RA>0.5 to 1.5), R (rare; RA≤0.5) to indicate the rarest to the most common butterfly species(Agase *et al*., 2022) WPA- Species enlisted in Indian Wildlife Protection Act, 1972.

Results

In Padmapuram Botanical Garden during the study period, a total number of 92 species of butterflies belonging to 64 different genera and 5 different families were recorded (Table.1). Of the 92 species recorded, Nymphalidae was recorded as the most dominant family represented by 34 species followed by Pieridae with 17 species, Lycaenidae with 16 species, Hesperiidae with 13 species, Papilionidae with 12 species (Table 1).

While relative abundance (RA) of the recorded butterfly species was considered, it was found that Common Sailer (*Neptis hylas*; RA: 4.43) was the most abundant species followed by Chocolate Pansy (*Junonia iphita*; RA: 4.21), Common Emigrant (*Catopsilia pomona*; RA: 3.27). Observed relative abundances for the 28 butterfly species ranged between 1 and 3. The remaining butterfly species exhibited a relative abundance below 1. The study found that *Junonia iphita*, *Junonia lemonias*, *Neptis hylas*, *Ypthima baldus*, *Melanitis leda*, *Catopsilia pomona*, *Graphium agamemnon* and *Zizula hylax* had the highest occurrence frequency during the study period (100%) (Table 1).

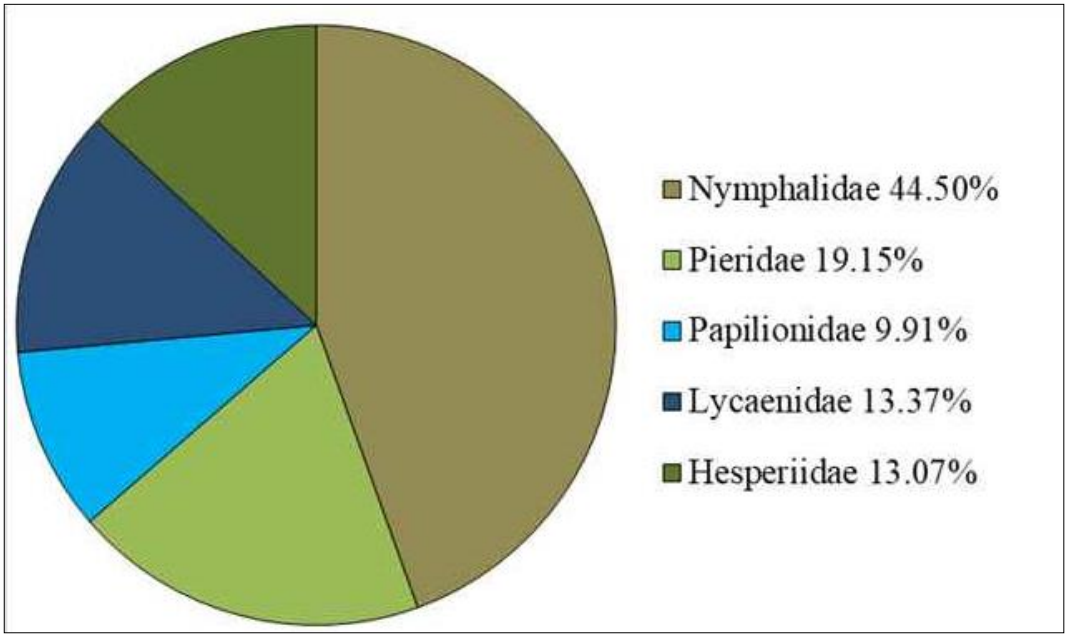
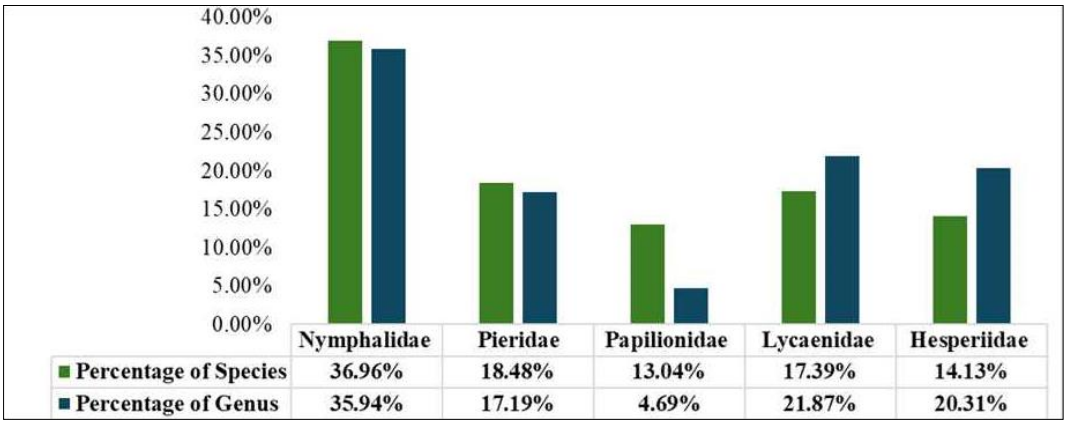


Fig 3: Percentage composition of five families of butterflies in the study area



	Nymphalidae	Pieridae	Papilionidae	Lycaenidae	Hesperiidae
Percentage of Species	36.96%	18.48%	13.04%	17.39%	14.13%
Percentage of Genus	35.94%	17.19%	4.69%	21.87%	20.31%

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

An analysis of the percentage composition of the five butterfly families observed at the study site revealed that 44.50% of the total butterflies counted belonged to the family Nymphalidae, followed by the Pieridae (19.15%), Lycaenidae (13.37%), Hesperiidae (13.07%), Papilionidae (9.91%) (figure 3). Analysis of the proportional composition of genera revealed that the family Nymphalidae contained the highest number of genera (35.94%), followed by the Lycaenidae (21.87%), Hesperiidae (20.31%), Pieridae (17.19%), Papilionidae (4.69%). Species proportion analysis showed that the Nymphalidae family accounted for the maximum number of butterfly species (36.96%), followed by the Pieridae (18.48%), Lycaenidae (17.39%), Hesperiidae (14.13%) Papilionidae (13.04%) (figure 4).

Within the family Nymphalidae, the Common Sailer (*Neptis hylas*) was found to be the most abundant butterfly species followed by Chocolate Pansy (*Junonia iphita*), Common Evening Brown (*Melanitis leda*), Tawny Coster (*Acraea violae*), Common Castor (*Ariadne merione*), Dark Evening Brown (*Melanitis phedima*) whereas, Black Rajah (*Charaxes solon*) was counted in least number. Common Emigrant (*Catopsilia pomona*) was found to be the most abundant butterfly species for the family Pieridae, whereas Hill Jezebel (*Delias belladonna*) was observed in least numbers. For the family Papilionidae, the Tailed Jay (*Graphium agamemnon*) had the highest count, while the Red Helen (*Papilio helenus*) had the lowest count. Within the family Lycaenidae, the Tiny Grass Blue (*Zizula hylax*) was recorded in the highest numbers, while the Monkey Puzzle (*Rathinda amor*) was recorded in the lowest numbers. Finally, for the family Hesperiidae, Rice Swift (*Borbo cinnara*) was the most abundant species, while Common Banded Awl (*Hasora chromus*) was recorded in the lowest numbers (Table 1).

Most of the butterfly species sampled at the study site were 'common' and 'generalist' and none of the species studied are comes under Schedule-I as per Indian Wildlife (Protection) Act, 1972 amended in 2022. Of the butterfly species observed at the study site, ten were found to be protected under various schedules of the Wildlife Protection Act, 1972. Regarding these butterfly species, nine are protected under Schedule II, including the Danaid Eggfly (*Hypolimnas misippus*), Common Baron (*Euthalia aconthea*), Common Nawab (*Polyura athamas*), Black Rajah (*Charaxes solon*), Common Albatross (*Appias albina*), Common Mime (*Papilio clytia*), Common Banded Peacock (*Papilio crino*), Common Bluebottle (*Graphium sarpedon*), and Crimson Rose (*Pachliopta hector*), whereas the Striped Albatross (*Appias libythea*) is protected under Schedule IV (Table 1).

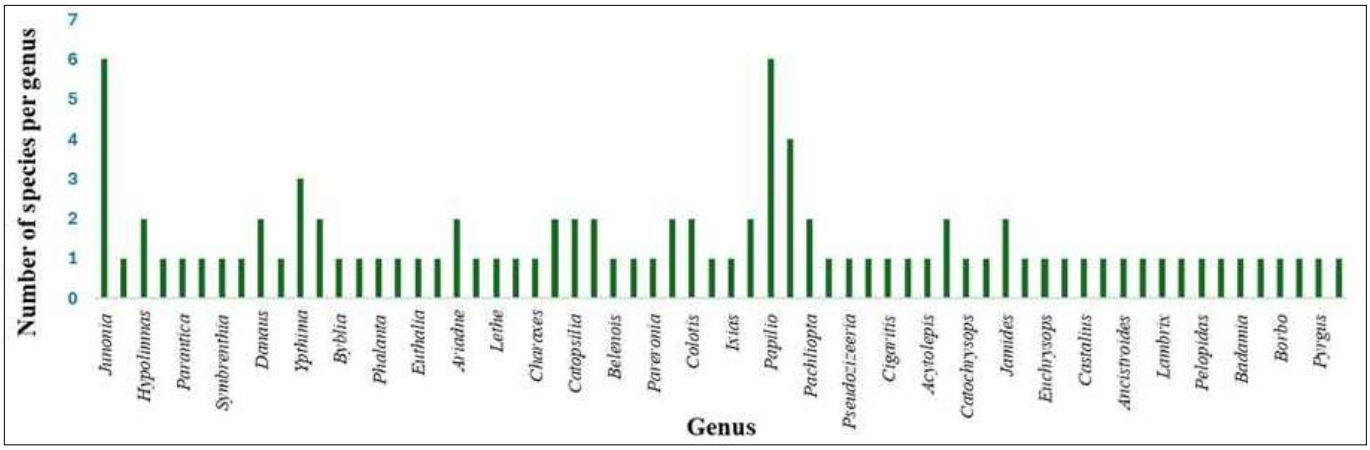


Fig 5: Species richness of the recorded butterfly genera of the study site

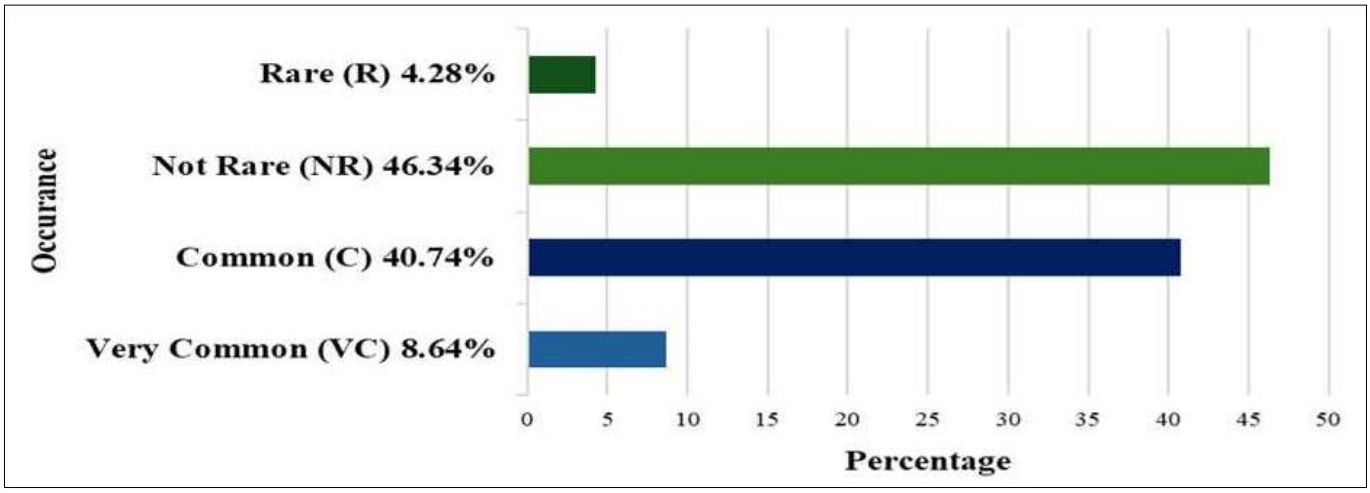


Fig 6: Occurrence of different butterfly species in the study area

Within the Nymphalidae family, the genus *Junonia* was dominant, comprising six species: *J. atlites*, *J. almana*, *J. lemonias*, *J. orithya*, *J. hierta*, and *J. iphita*. Similarly, for the family Papilionidae, the genus *Papilio* was dominant, also comprising six species: *P. polytes*, *P. agenor*, *P. demoleus*, *P. helenus*, *P. clytia*, and *P. crino*. The genus *Graphium* is composed of four species, namely *G. doson*, *G. agamemnon*, *G. nomius*, and *G. sarpedon*. The genus *Ypthima* is composed of three species: *Y. baldus*, *Y. huebneri*, and *Y. Asterope*. Two species were recorded for each of the following genera: *Danaus, Melanitis, Ariadne,* and *Hypolimnas* (family Nymphalidae); *Delias, Eurema, Appias, Colotis, Colias,* and *Catopsilia* (family Pieridae); *Pachliopta* (family Papilionidae); and *Chilades* and *Jamides* (family Lycaenidae). The remaining 47 genera were all found to have only one species each (figure 5). Species-genus ratio was observed 1.44 from the current study. The study revealed that 46.34% of the total counted butterflies belonged to the NR category, 40.74% to the C category, 8.64% to the VC category, and lastly, 4.28% to the R category. (figure 6).

The high Shannon diversity index value (H' = 4.28) indicated high species richness and diversity of the butterfly fauna at the sampled site (Table 2). The value of the Simpson's index (Ds = 0.02) was found to be close to 0, indicating high species abundance and low dominance within the community. The calculated Simpson's index of diversity (D=0.98) signifies high species abundance with low dominance within the butterfly fauna. The high value of Pielou's evenness index (J'=0.95), being very close to 1, indicates that the butterfly species in the studied community are very evenly distributed. A Margalef's Richness Index value of 11.54 suggests that the ecosystem is rich, healthy, and resilient. While the value of Simpson's reciprocal index (Dr=59.92) emphasizes a good species diversity in the surveyed butterfly community, it also suggests low dominance by any single species. Thus, the values of various diversity indices suggest that the butterfly community is highly diverse, characterized by high abundance and high evenness (Table 2).

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})
4.28	0.95	0.02	0.98	11.54	59.92	0.04

Shannon diversity index (H') values for the five recorded butterfly families ranged from 2.28 to 3.25. The family Nymphalidae was recorded with the highest value due to its greater species richness, followed by the Pieridae (2.59),

Lycaenidae (2.57), Hesperiidae (2.51), Papilionidae (2.28). Shannon H_{max} was found to be highest in the family Nymphalidae (3.53), with decreasing values in Pieridae (2.83), Lycaenidae (2.77), Hesperiidae (2.56) and Papilionidae (2.49). A high Pielou's evenness index (J′) of 0.98 was recorded for the Hesperiidae, indicating an even distribution of species in this family. A similar distribution was noted for the families Nymphalidae, Pieridae, and Papilionidae, with each recording a consistent value of 0.92. 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=0.95 and Dr=21.26, respectively), revealing that this family is the most diverse one in the sampled fauna (Table 3).

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	3.25	3.53	0.92	0.05	0.95	21.26	0.10
Pieridae	2.59	2.83	0.92	0.09	0.91	11.39	0.17
Papilionidae	2.28	2.49	0.92	0.11	0.89	8.85	0.21
Lycaenidae	2.57	2.77	0.93	0.09	0.91	10.78	0.22
Hesperiidae	2.51	2.56	0.98	0.08	0.92	12.12	0.12

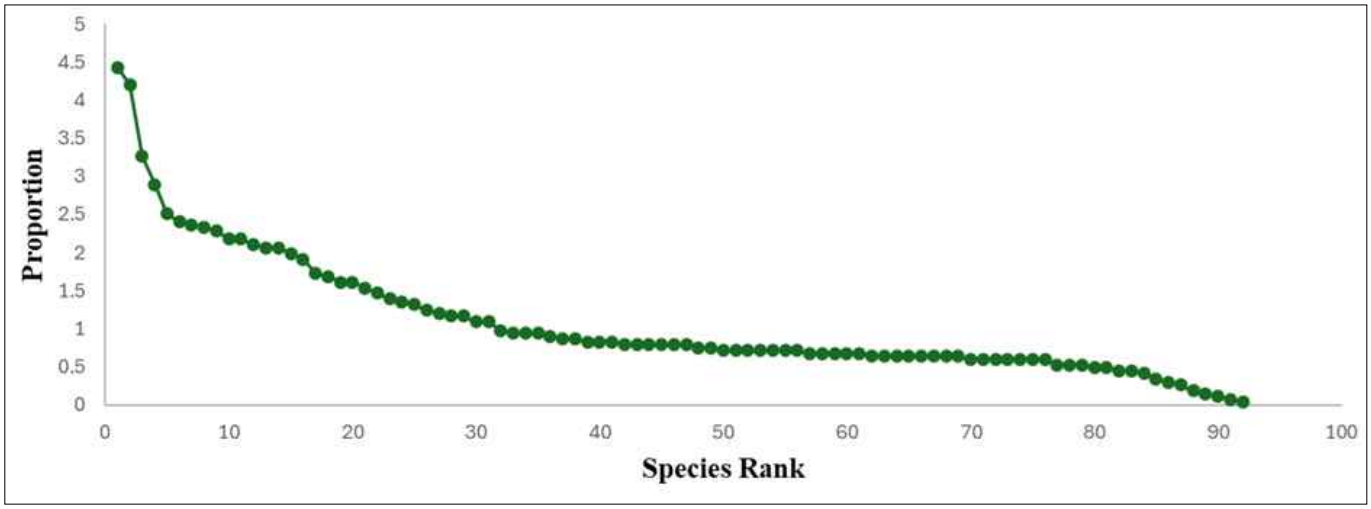


Fig 7: Rank abundance curve of 92 species of butterfly in the study area

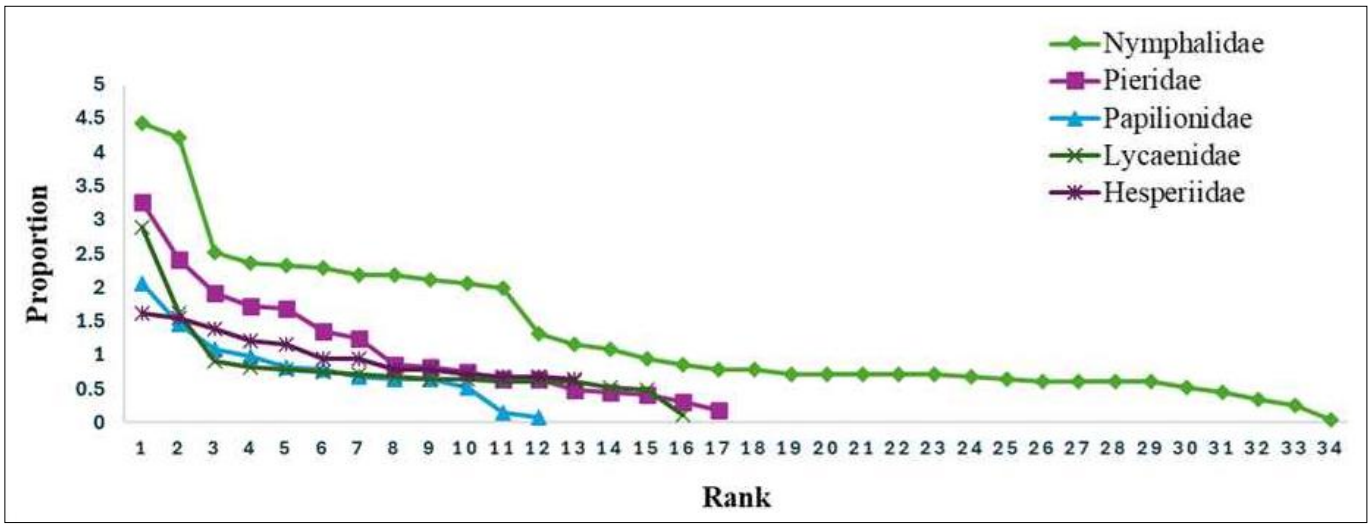


Fig 8: Rank abundance curve of five families of butterfly in the study area

The Whittaker plot showed a steep slope for the first five butterfly species sampled at the study site (figure 7 and figure 8). Compared with the remaining species, these five butterfly species occurred in high abundance and with lower evenness. From species rank sixteen onwards, the abundance of the observed butterfly species decreased, corresponding with increased evenness among the recorded species in the study areas. Analysis of the family-wise rank abundance curve revealed that Hesperiidae exhibited the highest species evenness, followed by Lycaenidae, while Nymphalidae, Pieridae, and Papilionidae showed similar, relatively lower levels of evenness (figure 8).

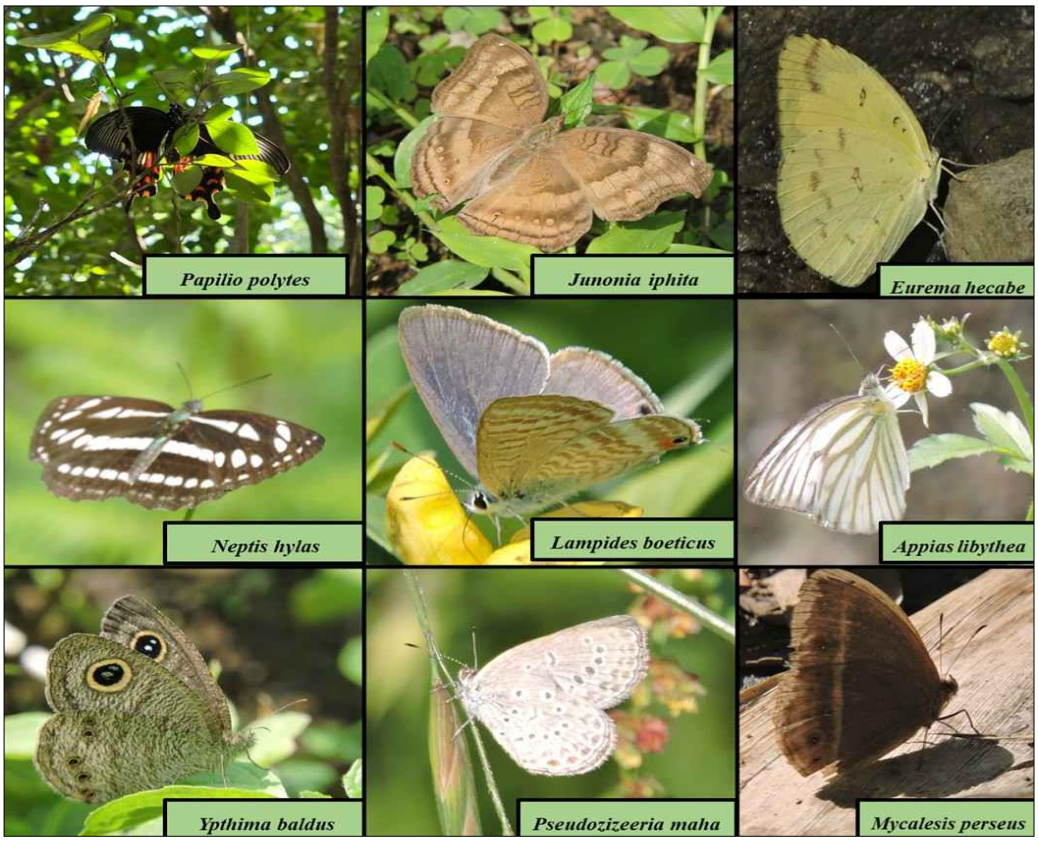


Fig 9a: Photographs of different butterfly species recorded in the study area

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

Discussion

Butterflies, which are remarkable creatures, not only possess immense aesthetic value, but their diversity of an area also depicts its habitat quality, necessitating their conservation in their natural habitat (Patil *et al*., 2017; Kumar *et al*., 2023) [35, 24]. Hence, Monitoring the diversity of butterfly species in a specific region is crucial for understanding the health of ecosystem of that region. Rapid urbanization and population growth, driven by anthropogenic activities, create pollution that significantly alters butterfly habitats and distribution patterns.

Northern Eastern Ghats region, owing to its proximity to the eastern Himalayan, Indo-Malayan, and Western Ghats biodiversity hotspots, acts as a transitional zone blending the characteristics of these distinct eco-regions (Kumar *et al*., 2023) [24]. Consequently, the northern Eastern Ghats region boasts a rich diversity of flora and fauna, featuring numerous rare, endemic, and threatened species (Kumar *et al*., 2023) [24]. Diverse vegetation offers a perfect habitat for many insects and butterflies (Alfred *et al*., 2002; Agarwala *et al*., 2010) [3, 2]. Despite the rich biodiversity of the northern Eastern Ghats in Andhra Pradesh, very few studies have focused on the butterfly fauna of this region, which has therefore remained comparatively under-explored. Various authors have provided checklists of butterflies for this region over time. Gunathilagaraj *et al*. (1998) [15] documented 150 butterfly species in the entire Eastern Ghats area; Goswami *et al*. (2018) [14] reported 102 species from the Northern Eastern Ghats. From Visakhapatnam District, Ramamurty *et al*. (2021) [38] reported 105 Species of butterflies, while Bhulasa *et al*. (2024) [8] reported 190 Species. Rao (2004) [37] reported 89 species from Nagarjunasagar, Srisailum Reserve Forest, Andhra Pradesh. Venkata Ramana (2010) [47] and Harinath *et al*. (2014) [19] reported 85 species of butterflies from Kadapa hills regions and Suryanarayana *et al*. (2018a) [42] reported 94 species from Nallamala hills, Southern Andhra Pradesh, Eastern Ghats. From Seshachalam Bio reserve forest, Guptha *et al*. (2014) [17] reported 96 species, Guptha *et al*. (2012) [18] reported 50 species, Suryanarayana *et al*. (2018b) [43] reported 82 species of butterfly. In the present study, a total of 92 butterfly species were found from Padmapuram Botanical Garden, Araku Valley, Visakhapatnam district, Ananthagiri and Sunkarimetta reserved forests, Andhra Pradesh.

In the Seshachalam Biosphere Reserve and Nagarjunasagar, Srisailam Tiger Reserve, observed dominant family was Nymphalidae, followed by Lycaenidae (Guptha *et al*., 2012; Rao *et al*., 2004) [18, 37]. Similarly, in the Seshachalam hills and Nallamala hills Nymphalidae was the dominant one followed by Pieridae, Lycaenidae (Suryanarayana *et al*., 2018b) [43]. Bhulasa (2024) [8] reported that in the Eastern Ghats of Visakhapatnam District, Nymphalidae family was the most dominant, followed by Lycaenidae. Consistent with previous finding, in the current study, Nymphalidae was the dominant family, followed by Pieridae, Lycaenidae. The dominant nature of the butterflies of the Nymphalidae family might be due to their polyphagous nature, which enables them to survive in all habitats. Furthermore, several species within this family possess powerful wings, enabling them to forage over wide distances (Easwaran and Pramod, 2005; Krishnakumar *et al*., 2008) [13, 23].

Andhra Pradesh, with its diverse landscapes ranging from coastal regions to hills and forests, boasts a rich biodiversity, including a variety of butterfly species. In this regard, Mukherjee *et al*. (2015) [31] stated that heterogeneity of the habitats supports the rich butterfly diversity and Tiple (2009) [45] reported that increased availability of diverse host plants, favorable climate conditions, and varied vegetation, including herbs, shrubs, and trees for nectar, may all contribute to higher butterfly diversity. Compared to urban areas, the butterfly diversity in suburban and rural areas was reported to be higher, increasing with the availability of green space and the heterogeneity of plant species (Ockinger *et al*., 2009; Mukherjee *et al*., 2015) [34, 31]. The highly diverse butterfly community found in the study area is likely due to the rural, less-disturbed habitat with a variety of herbs, shrubs, and plants that provide essential food resources.

The presence of a highly diverse community of 92 butterfly species indicates a healthy habitat in the study area. In order to maintain and improve the habitat quality, it is essential to adopt conservation and management policies for sustainable development. Moreover, further studies on host plants and nectar plants of this region will play a key role in conservation of butterfly community.

As the present study is confined to a limited area, further long-term extensive studies of butterfly fauna from the other regions of Ananthagiri and Sunkarimetta reserved forests, may include more species in the checklist in near future.

Conclusion

The present study documented 92 species of butterflies belonging to 64 genera, identifying the study site as one of the biodiversity-rich areas in the Northern Eastern Ghats. Family Nymphalidae is the dominant one, comprising almost 45% of the total butterfly species. The result of this study would be useful to adopt policies for the conservation of natural habitat of lepidopteron diversity and such studies will assist in identifying no-go areas for developmental activities, high-intensity extraction, and habitat transformation.

To accurately assess current butterfly biodiversity in Padmapuram Botanical Garden, Araku Valley, systematic surveys are required. While significant efforts have focused on protected areas, it is imperative to initiate monitoring in other forests, hills, and parks, where exploration and investigation are crucial.

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