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Exploring Butterfly Species Diversity and Richness around Mukundra Hill Tiger Reserve, Rajasthan, India

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Abstract:

The study on the diversity of butterflies was conducted in the vicinity of Mukundra Hill Tiger Reserve (MHTR). Over the course of the study, a comprehensive survey documented a total of 41 butterfly species spanning four taxonomic families. Notably, five of these species are afforded protection under various schedules of the Indian Wildlife (Protection) Act, 1972. The family Nymphalidae emerged as the most dominant, encompassing 17 species, followed by Pieridae (14 species), Lycaenidae (06 species), and Papilionidae (04 species). Diversity metrics reveal that Nymphalidae exhibited the highest richness, characterized by a Shannon–Wiener Diversity Index (H′) of 2.6904 and a Pielou's Evenness Index (J) of 0.9496. In contrast, Papilionidae displayed the lowest diversity, with a Shannon–Wiener Diversity Index (H′) of 1.3226 and a Pielou's Evenness Index (J) of 0.9541. These metrics underscore the varied ecological roles and population dynamics within the surveyed butterfly families. The findings underscore MHTR's role as a habitat supporting notable butterfly diversity, although the current documentation remains incomplete. Of particular concern are the five identified threatened species, which benefit from legal protection under existing conservation frameworks. Hence, there exists an urgent imperative for further comprehensive research initiatives aimed at bolstering the conservation and sustainable management strategies for butterfly populations in this region.

Key words: Shannon–Wiener Diversity Index, Pielou's Evenness Index, Mukundra Hill Tiger Reserve, Butterflies, Nymphalidae, Pieridae, Lycaenida, Papilionidae

Background:

Butterflies, members of the order Lepidoptera, constitute one of the largest insect groups, encompassing approximately 150,000 species worldwide. This taxonomic order includes both butterflies and moths, with butterflies alone numbering around 17,820 species (Shields, 1989). Globally, their diversity exceeds 1700 species, with India hosting 1504 species (Gaonkar, 1996; Smetacek, 1992; Kunte, 2000; Roy *et al*., 2010).

Beyond their taxonomic significance, butterflies are renowned for their conspicuous size, vibrant coloration, and photophilic behavior. These attributes have historically captivated cultural and scientific interest, particularly in literature and natural history studies, reflecting their pervasive influence, especially on youthful imaginations. Furthermore, butterflies play a pivotal role as effective pollinators, crucially influencing floral population dynamics in diverse ecosystems. Studies underscore that approximately 35% of global food crops rely on insect pollination, predominantly facilitated by butterflies (Klein *et al*., 2007).

Scientific investigations have highlighted butterflies as pivotal subjects in ecological research, notably in landscape ecology (Thomas & Malorie, 1985). Moreover, they serve as indispensable biological indicators, offering critical insights into habitat quality and overall environmental integrity (Larsen, 1988; Kocher & Williams, 2000; Sawchik *et al*., 2005). Their role extends to ecosystem stability through intricate predator-prey dynamics, thereby functioning as sentinel species for monitoring environmental disturbances such as pollution, resource depletion, and habitat encroachment, particularly pertinent in rapidly urbanizing regions like India (Khairunnisa *et al*., 2015).

The intricate ecological relationships of butterflies render them vulnerable to climate change impacts, given their specific requirements for temperature, humidity, host plants, and oviposition sites (Forister and Shapiro, 2003; Gonzalez-Megias *et al*., 2018). Consequently, ongoing monitoring efforts are essential to gauge butterfly diversity within various habitats, facilitating assessments of their ecological roles and responses to climate change. Such monitoring initiatives also serve as crucial tools for managing human-induced impacts in urbanized, protected, industrial, and managed landscapes (Wilson, 1997).

There exists a crucial need for the systematic surveillance of butterfly populations within various forest reserves. The surveillance of species diversity serves to not only their potential ecological roles within their habitats but also to assess the impacts of climatic variability upon the habitat. Furthermore, such initiatives function as pivotal tools in the management of anthropogenic disturbances and environmental pollutants within urbanized, protected, industrial, and managed landscapes (Wilson, 1997). Despite the considerable biodiversity of the region, it remains inadequately investigated. Consequently, the current investigation was undertaken to document the diversity of butterfly species, with a pronounced emphasis on their conservation status.

Methods:

Study area:

The study was conducted during 2022-2023 at forest area around Mukundara Hills Tiger Reserve (MHTR) (24°47' N, 76° 0' E), Rajasthan. The reserve encompasses three wildlife sanctuaries: Darrah National Park, Chambal Wildlife Sanctuary, and Jaswant Sagar Wildlife Sanctuary. Positioned on the eastern bank of the Chambal River, MHTR derives its name from the Mukundara mountain range. Historically, this area was known as Darrah Wildlife Sanctuary, serving as a royal hunting preserve for the Kota royal family (Bhagat, 2020). The climate of the study area is arid and have annual rainfall of around 600 mm. The area is characterized by dry deciduous forests (Champion & Seth, 1968), The region supports a rich faunal, avifaunal and floral diversity irrespective of its harsh conditions.The vegaetation is characterized by Anogeissus pendula, Anogeissus latifolia, Acacia catechu, Acacia leucophloea, Ziziphus mauritiana, and Flacourtia indica. The mammalian fauna recorded in this region includes leopards, Indian wolves, sloth bears, hyenas, jungle cats, Indian foxes, desert cats, ratels, pangolins, chitals, sambars, nilgais, and chinkaras (Jhala *et al*., 2015), along with numerous bird and reptile species.

Method of study:

A modification of the line transect count (Pollard, 1977) was used to determine species richness and abundance of butterfly communities at 5 transects laid at the study sites. Transect surveys were conducted between 9:00 am and 4:00 pm. A uniform pace of walking in a fixed transect of 200 m using a nylon rope was followed and data was recorded on all butterflies , moving 2.5 m either sides of the transect for one hour. Transects were counted once to twice daily. The transects were specifically selected perpendicular to the forest road deep inside the forests, near to the reservoirs and in areas rich with forest under- growth. Sampling sites were surveyed for total 10 times, one morning and one evening time. The most of the species were identified. No species were harm during the study; Species were photographed in the field using Nikon DSLR camera, most of the specie were identified in the field itself. The species were identified with help of books and literature by Evans, 1932; Kehmikar, 2008; Kumar *et al*., 2016; Kunte, 1997; Sunil *et al*., 2016).

Statistical methods used:

The total number of species of each family is considered as the species richness which was 41. While the species diversity and species evenness (relative abundance) was calculated with the given formulas.

A. Species diversity was calculated using the Shannon Diversity Index, which pools the number of species within a site with the relative abundance of each species (Shannon, 1948; Magurran, 1988, Odum, 1997; Krebs, 1989).

   $H' = - \Sigma\ pi \ln pi$ Here,

pi is the proportion of the ith species in the total sample.

The number of species (species richness) in the community and their evenness in abundance (or equitability) are the two parameters that define H'.

B. Pielou's Evenness Index (Equitability) or J': The species evenness is the relative abundance or proportion of individuals among the species. Species evenness were calculated using the formula (Pielou, 1969)
J' =H'/ ln S
Here, H'= Value of Shannon- Wiener index, while S is the number of species present in the site. The value of J' ranges from 0 to 1. The less variation in communities between the species, the higher the value of J'.

Result:

In this study, a total of 41 butterfly species from four families were recorded around the MHTR. Among these families, Nymphalidae was the most dominant, comprising 17 species (41.4%), followed by Pieridae with 14 species (34.1%), Lycaenidae with 6 species (14.6%), and Papilionidae with the least, having 4 species (9.7%) (Table 1, Fig. 1).

The diversity of butterfly species was assessed using the Shannon-Weiner Diversity Index (H′), yielding values of 2.6904 for Nymphalidae, 2.5851 for Pieridae, 1.7976 for Lycaenidae, and 1.3226 for Papilionidae. Species evenness within these families was evaluated using Pielou's Evenness Index, with values of 0.9496, 0.9795, and 1.0032 respectively, indicating a balanced ecosystem (Table 2, Figure-2).

During the study 05 species of Butterflies belongs to different Schedules of the Wildlife Protection Act-1972, India was also observed ie., Schedule -1 (*Hypolimnas misippus*, *Castalius rosimon*); Schedule-II (*Lampides boeticus*, *Euchrysops cnejus*) and Schedule- IV (*Euploea core*)

Discussion:

During the course of this study, a total of 41 species from four families were documented. The family Nymphalidae was predominant, represented by 17 species. This predominance of Nymphalidae is consistent with findings from other regions in India. For instance, in the Rowa Wildlife Sanctuary, Tripura, Nymphalidae was the most abundant family, with 22 species comprising over 89 individuals (Lodh & Agarwala, 2016). In Titabar, Jorhat, Assam, out of 158 butterfly species observed, 61 belonged to Nymphalidae, 38 to Lycaenidae, 29 to Hesperiidae, 17 to Pieridae, 11 to Papilionidae, and 2 to Riodinidae (Konwar & Bortamuly, 2021). Similarly, in the Manas World Heritage Site, 252 species were recorded, with Nymphalidae being the dominant family (101 species), followed by Lycaenidae (63), Hesperiidae (35), Pieridae (27), Papilionidae (24), and Riodinidae (2) (Bhattacharjee & Ahmed, 2020). In the Dibru-Saikhowa Biosphere Reserve, 45 species of Nymphalidae were reported, followed by Lycaenidae (21), Pieridae (17), Papilionidae (15), and Hesperiidae (7) (Joshi & Dhyani,

2014). In Dehing Patkai National Park, 92 species were recorded, including 41 from Nymphalidae, 17 from Papilionidae, 16 from Lycaenidae, 10 from Hesperiidae, and 8 from Pieridae (Gogoi *et al.,* 2023). The Trishna Wildlife Sanctuary in Tripura reported 59 butterfly species, including 21 distinctive species and 9 in the threatened category (Majumder et al., 2012). Islam *et al*. (2022) documented 150 butterfly species across six families in Raimona National Park, Assam, with the family distributions as follows: Nymphalidae (44.89%), Lycaenidae (23.12%), Pieridae (12.24%), Hesperiidae (10.20%), Papilionidae (8.16%), and Riodinidae (1.36%). Furthermore, Chahar et al. (2021) recorded 39 species of butterflies from five families in the NES Ratnam College campus and Kukreja residential complex in Mumbai, with Nymphalidae being the dominant family (14 species). The observed diversity highlights the ecological importance of these habitats, which support both cultivated and wild plants serving as host and nectar sources for butterflies.

The highest species richness was observed in the Nymphalidae family, with a Shannon-Wiener Diversity Index (H) of 2.6904 and an Evenness index of 0.9496. Conversely, the Papilionidae family exhibited the lowest species richness, with a Shannon-Wiener Diversity Index (H) of 1.3226 and an Evenness index of 0.9541. These results indicate that the study area supports a high diversity of butterfly species. The presence of a variety of microhabitats and diverse vegetation likely contributes to the high species richness and diversity observed (Sreekumar & Balakrishna, 2001). Furthermore, the Pielou's Evenness (J) values suggest a nearly uniform distribution of butterfly species across the four families, with values ranging from 0.94 to 1.00 (Table 2). Similar findings were reported by Basavarajappa et al. (2018), where the Shannon diversity index ranged from 4.49 to 4.59, and the Shannon Evenness indices were between 0.94 and 0.98, indicating even distribution among the six forest ranges.

Conclusion:

Understanding the ecological significance of butterflies, both as indicators of environmental health and as pollinators of angiosperms, is essential for promoting sustainability and conserving floral biodiversity. The presence or absence of butterfly species can provide critical insights into the health and stability of ecosystems. In this study, a total of 41 butterfly species were recorded in the vicinity of the Mukundra Hill Tiger Reserve. Among the documented families, Nymphalidae was the most prevalent, followed by Pieridae, Lycaenidae, and Papilionidae, with the latter being the least represented. Notably, five butterfly species were listed under various schedules of the Indian Wildlife (Protection) Act, 1972, indicating their protected status. Given their pivotal ecological roles and notable occurrences, it is imperative to formulate effective conservation strategies for these species.

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List of Abbreviations:

H = Shannon-Wiener Diversity Index

J= Pielou's Evenness Index

MHTR = Mukundara Hills Tiger Reserve

WPA= Wildlife Protection Act-1972

Declarations:

- Availability of data and material: All data is included in the article
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Table-1 : List of butterflies reported during the study

S N	Family	Common Name	Scientific Name	Abundance
1.	Papilionidae	Common Rose	*Pachliopta aristolochiae* (Fabricius, 1775)	U
2.	Papilionidae	Common Mormon	*Papilio polytes romulus* Cramer, [1775]	C
3.	Papilionidae	Lime Butterfly	*Papilio demoleus* Linnaeus, 1758	U
4.	Papilionidae	Tailed Jay	*Graphium agamemnon* (Linnaeus, 1758)	C
5.	Pieridae	Mottled Emigrant	*Catopsilia pyranthe* (Linnaeus, 1758)	R
6.	Pieridae	Common Emigrant	*Catopsilia pomona* (Fabricius, 1775)	A
7.	Pieridae	Common Grass Yellow	*Eurema hecabe* (Linnaeus, 1758)	A
8.	Pieridae	Spotless Grass Yellow	*Eurema laeta* (Boisduval, 1836)	A
9.	Pieridae	White Orange-tip	*Ixias marianne* (Cramer, [1779])	C
10.	Pieridae	Yellow Orange-tip	*Ixias pyrene* (Linnaeus, 1764)	R
11.	Pieridae	White Arab	*Colotis phisadia vestalis* (Butler, 1876)	R
12.	Pieridae	Little Orange-tip	*Colotis etrida* (Boisduval, 1836)	A
13.	Pieridae	Crimson-tip	*Colotis danae* (Fabricius, 1775)	C
14.	Pieridae	Small Salmon Arab	*Colotis amata* (Fabricius, 1775)	R
15.	Pieridae	Common Albatross	*Appias albina* (Boisduval, 1836)	R
16.	Pieridae	Pioneer	*Belenois aurota* (Fabricius, 1793)	VR
17.	Pieridae	Common Gull	*Cepora nerissa* (Fabricius, 1775)	R
18.	Pieridae	Great Orange-tip	*Hebomoia glaucippe* (Linnaeus, 1758)	VR
19.			*Spindasis vulcanus*	

	Lycaenidae	Common Silverline	(Fabricius, 1775)	U
20.	Lycaenidae	Peablue	*Lampides boeticus* (Linnaeus, 1767)	VR
21.	Lycaenidae	Zebra Blue	*Leptotes plinius* (Fabricius, 1793)	R
22.	Lycaenidae	Common Pierrot	*Castalius rosimon* (Fabricius, 1775)	R
23.	Lycaenidae	Pierrot	*Tarucus* Butler, 1886 sp.	VR
24.	Lycaenidae	Gram Blue	*Euchrysops cnejus* (Fabricius, 1798)	R
25.	Nymphalidae	Plain Tiger	*Danaus chrysippus* (Linnaeus, 1758)	A
26.	Nymphalidae	Common Tiger	*Danaus genutia* (Cramer, 1779)	A
27.	Nymphalidae	Glassy Tiger	*Parantica aglea* (Stoll, [1782])	A
28.	Nymphalidae	Common Crow	*Euploea core* (Cramer, [1780])	C
29.	Nymphalidae	Common Evening Brown	*Melanitis leda* (Linnaeus, 1758)	A
30.	Nymphalidae	Dark-branded Bushbrown	*Mycalesis mineus polydecta* (Cramer, [1777])	VR
31.	Nymphalidae	Common Sailer	*Neptis hylas varmona* Moore, 1872	U
32.	Nymphalidae	Common Leopard	*Phalanta phalantha* (Drury, [1773])	U
33.	Nymphalidae	Angled Castor	*Ariadne ariadne indica* (Moore, 1884)	U
34.	Nymphalidae	Yellow Pansy	*Junonia hierta (Fabricius, 1798)*	R
35.	Nymphalidae	Lemon Pansy	*Junonia lemonias (Linnaeus, 1758)*	U
36.	Nymphalidae	Grey Pansy	*Junonia atlites (Linnaeus, 1763)*	C
37.	Nymphalidae	Peacock Pansy	*Junonia almona (Linnaeus, 1758)*	U
38.	Nymphalidae	Blue Pansy	*Junonia orithya (Linnaeus, 1758)*	R
39.	Nymphalidae	Danaid Eggfly	*Hypolimnas misippus (Linnaeus, 1764)*	C
40.	Nymphalidae	Great Eggfly	*Hypolimnas bolina (Linnaeus, 1758)*	U
41.	Nymphalidae	Tawny Coster	*Acraea violae (Fabricius, 1793)*	U

Figure-1: Percentage occurrence of Butterflies under four different families

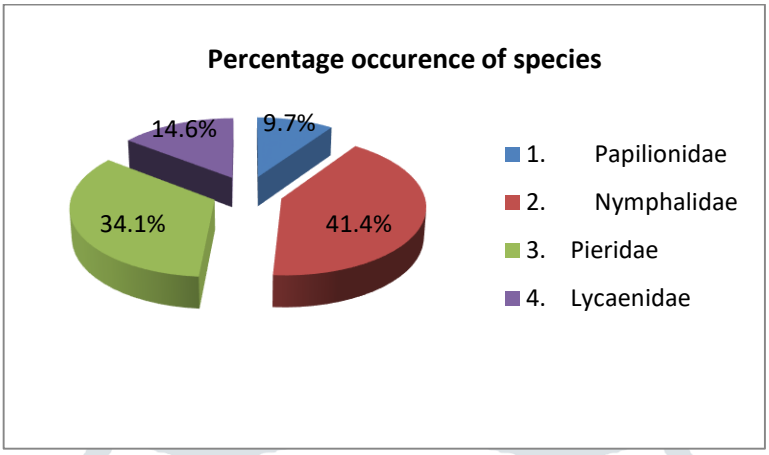

Table-2: Shannon Diversity Index and Pielou's Evenness index (Equitability))

S.No	**Families**	**Number of species**	**Number of Individuals**	H'(Diversity Index)	J (Evenness Index)
1.	Nymphalidae	17	227	2.6904	0.9496
2.	Pieridae	14	260	2.5851	0.9795
3.	Lycaenidae	6	67	1.7976	1.0032
4.	Papilionidae	4	36	1.3226	0.9541

Fig-2 : Species Diversity and Richness in terms of Diversity Index and Evenness Index