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***Research Article** (Open Access)*

STUDY ON ABUNDANCE AND DIVERSITY OF BUTTERFLIES AT DEHING PATKAI NATIONAL PARK IN NORTH-EAST INDIA: A SEASONAL APPROACH

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ABSTRACT

The study was carried out to determine the relationship between butterfly diversity and both seasonality and climatic conditions within the Soraipung range of Dehing Patkai National Park of northeast India, eastern Himalaya. The study was conducted from September 2021 to September 2023. A comprehensive survey revealed the presence of 60 species (1197 individuals) of butterflies belonging to 41 genera under 6 families. The present study indicates that the Nymphalidae family exhibited the greatest species richness, with a total of 31 species followed by Pieridae (9 species), Papilionidae (8 species), Lycaenidae (7 species), Hesperiidae (4 species), and Riodinidae (1 species). The presence of the Riodinidae family had not been previously documented in the study site area. *Zemeros flegyas flegyas*, *Troides helena cerberus*, and *Cethosia cyane cyane* were recorded for the first time from the study site. Out of the total of sixty butterfly species, twenty are classified as protected under the Wildlife Protection Act of 1972. For the year 2021-22 in the Nymphalidae family, the Shannon diversity index(H') of diversity was found highest in pre-monsoon (2.99) followed by monsoon (2.88), and the lowest degree of diversification was noticed during winter (2.56) season. For the year 2022-23 the Shannon diversity index(H') of diversity was found highest in monsoon (3.06) followed by post-monsoon (3.05) and the lowest degree of diversification was noticed during the winter (2.53) season. The regression analysis showed that the abundance of butterfly individuals was significantly related to maximum temperature.

Keywords: *Butterflies, Significant sightings, Wet evergreen forest, Indo-Malayan hotspot, Eastern Himalaya*

INTRODUCTION

The majority of land-based living forms, both in terms of the total number of individuals and the total Insects constitute the predominant terrestrial organisms in terms of both population size and species diversity, exhibiting a global distribution across many habitats. They are part of a unique classification known as the phylum Arthropoda; a term derived from the Greek language meaning "jointed foot."

The order Lepidoptera is widely recognized as one of the largest and most prominent insect orders globally. It encompasses several species, including moths, as well as three distinct superfamilies of butterflies: skipper butterflies, moth-butterflies, and monarch butterflies (Chakraborty, 2015). This group showcases an extensive array of species, rendering it one of the most diversified within the insect kingdom. According to Radhakrishnan *et al.,* (1989), the northeastern region of India is estimated to harbor a diverse range of 3600 butterfly and moth species. The study conducted by Williams *et al.,* (2015) documented around 18,500 species of butterflies. India has a reported total of over 1,500 butterfly species, whereas the state of Assam alone has documented 962 butterfly species from five distinct families (Evans, 1957; Kumar *et al.*, 2014).

Butterfly diversity in Northeast India is very high due to its suitable climate contributing to the diverse species distribution. The Dehing Patkai National Park situated in the Northeast region of India, is known for

its rich diversity of butterflies. This national park comes under the Indo-Malayan biodiversity hotspot with endemic species diversity. The national park is situated at the foothills of the Patkai hills and falls under the sub-tropical wet evergreen forest which makes the park different from other national parks of Assam. The national park is located on the southern bank of the Brahmaputra River, which acts as a natural barrier for restricting the influence of flora and fauna of the Burma region (Gogoi, 2013)

Butterflies aid in pollination of the flowering plants. The pollens are spread from one blossom to another by the butterflies as they consume nectar. In this way, butterflies play a significant role in facilitating the growth of fruits and seeds, so contributing to the process of plant reproduction. Butterflies are frequently considered an indicator species due to their ability to offer valuable insights into the overall condition of an ecosystem through their presence or absence. The fluctuations in butterfly populations can serve as an indicator of environmental alterations, including but not limited to habitat degradation, pollution, and climate change. The assessment of ecosystem health can be conducted by researchers and environmentalists through monitoring the butterfly population. Climate change can exert a substantial influence on various aspects of butterflies' life cycles, habitats, and populations. Climate change has the potential to disrupt the timing of natural phenomena such as plant flowering and insect emergence, leading to incongruous occurrences. The life cycles of butterflies are subject to the influence of diverse environmental conditions, including temperature and the duration of daylight. According to Kumar (2017), fluctuations in temperature might influence the emergence patterns of butterflies, potentially causing them to appear earlier or later than optimal for their food plants. This temporal mismatch between the availability of nectar and suitable host plants may have detrimental effects on their survival and reproductive success. Butterfly larvae, akin to caterpillars, commonly feed on certain host plants. The phenomenon of climate change has the potential to modify the quantity and spatial arrangement of these host plants, thus impacting the availability of sustenance for butterfly larvae. Consequently, this phenomenon may have an effect on the biodiversity of butterfly species. Once more, certain species of butterflies exhibit extensive migratory behavior, covering significant distances throughout their journeys. The potential impact of temperature and wind patterns on migratory success is subject to variations. The reproductive and survival capacities of these species may be impacted by migration-related concerns. Overall, the threat posed by climate change to butterfly populations is significant due to changing habitats, an increase in environmental stresses, and disruption of life cycles. In order to offset the consequences and protect butterfly biodiversity, it is imperative to implement conservation measures aimed at securing butterfly habitats, promoting native plant diversity, and maintaining butterfly populations.

MATERIALS AND METHODS

Study site

Soraipung Reserve Forest is one of the few remnants of tropical forest in the eastern Assam, which is a integral component of the Eastern Himalaya biodiversity hotspot zone. The area is home to a wide variety of butterflies, including endemic species and the species that are endangered globally due to its distinctive environmental characteristics and topographical features. The geographical extent of the area under consideration encompasses between 27.3115° N latitude and 95.4694° E longitude, specially located within the Tinsukia and Dibrugarh district of Assam. It is a tropical wet lowland evergreen forest that covers an area of 231.65 sq. km and is dominated by Hollong (*Dipterocarpus spp.)*, Singori (*Castanopsis indica*), Nahor (*Mesua* sp.), and other trees. The climate in the area has an annual rainfall of over 4,000 mm (Gogoi, 2013). The vegetation is made up of many flowering plants like *Mesua ferrea*, *Amoora wallichi*, *Dysoxylum binectiferum*, *Dipterocarpus macrocarpus*, etc. as well as trees like *Dipterocarpus retusus*, which predominate in the emergent layer of this rainforest. Because of its varied vegetation and annual rainfall, the area supports a vast diversity of flora, wildlife, and avifauna. The primary source of water is the Dehing River, a tributary of the Brahmaputra River that flows around 6 kilometers within the national park.

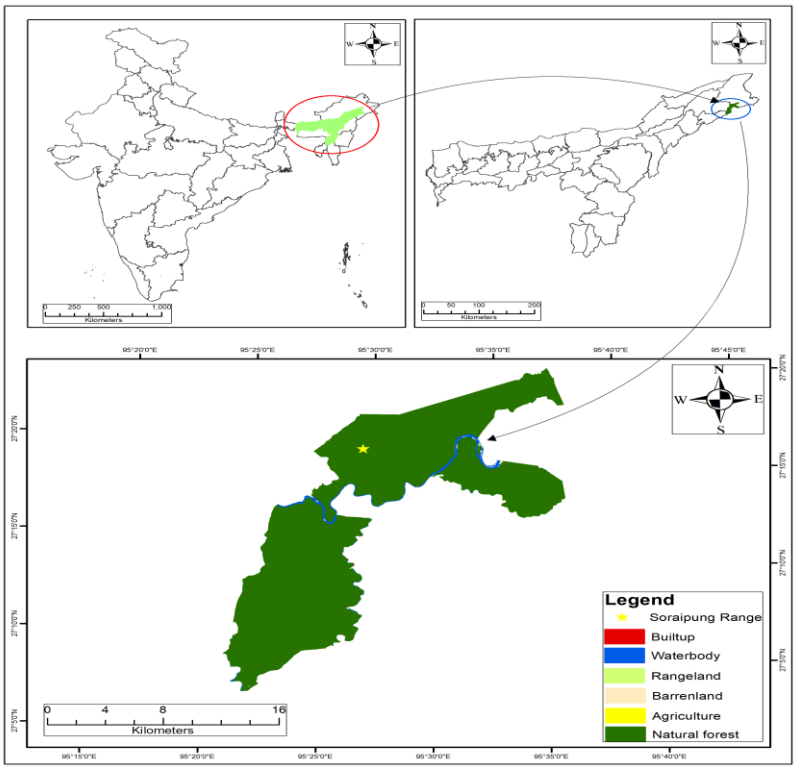

Figure 1: Soraipung Range of Dehing Patkai National Park, Assam, India

Methodology

The research was conducted using a seasonal survey extending from mid-September 2021 to July 2023, encompassing all four seasons, namely post-monsoon, winter, pre-monsoon, and monsoon. The study was conducted using both predetermined transects and random sampling techniques. The researchers walked slowly between the hours of 9:00 and 15:00 to ensure maximum observation of butterfly activity, as butterflies were most active during this period. A Nikon binocular and camera were used to aid in these observations. Photographs depicting butterflies were obtained with the intention of conducting a thorough identification process. During the fieldwork, butterflies were predominantly recognized using field guides, specifically employing the identification keys provided by Evans (1932), as well as utilizing photographic guides by Peter Smetacek (2018) and Aniruddha Dhamorikar (2016). Additionally, photography was employed as a subsequent method of identification.

RESULTS AND DISCUSSION

A comprehensive inventory of butterfly species found in the Soraipung range of the Dihing Patkai National Park, located in the Tinsukia area of Northeast India, was compiled through an assessment of butterfly diversity. A total of 60 butterfly species were identified, belonging to 42 genera under 6 families. Of these, Nymphalidae family had the highest number of species (31species) followed by Pieridae (9 species), Papilionidae (8 species), Lycaenidae (7 species), Hesperiidae (4 species) while Riodinidae (1 species). The genera *Junonia* and *Graphium* were represented by 4 species each followed *Papilio*, *Atheyma*, and *Euploea* had 3 species each. *Ypthima*, *Lexias*, *Kallima*, *Tagiades*, *Eurema*, and *Cepora* had 2 species each and there were other genera with 1 species each. The family-wise dominant index of butterflies is given in Table 1. A prior study was done at Jeypore Reserve Forest presently referred to as Dehing Patkai National Park's Jeypore range, a total of 292 species of butterflies were recorded during the years 2010-2011. Furthermore, the research revealed that the Nymphalidae family had the highest number of butterfly species (Gogoi, 2013).

The Nymphalidae family had the greatest level of dominance (41 species) among the five families of butterflies, as shown in the Soraipung area of Dehing Patkai National Park (Gogoi *et al.*, 2023). The dominance of Nymphalidae butterflies extended beyond Dehing Patkai National Park to several other regions. Research conducted from 2014 to 2016 in the non-protected region of Titabar, Assam documented a total of 158 butterfly species from six families, with the Nymphalidae family being the most prevalent, with 61 species (Konwar and Bortamuly 2021). A further investigation conducted within the Dibru-Saikhowa Biosphere Reserve showed the prevalence of the Nymphalidae family, which accounted for 45 species (42.85%) out of the total 105 butterfly species (Kumar and Dhyani 2014).
According to Gogoi *et al.*, (2016), out of the 343 species observed in the Barail Wildlife Sanctuary in Assam, a total of 125 species were classified under the Nymphalidae family. These studies indicate the dominance of Nymphalidae butterflies, which account for more than one-third of the total species variety.

Table 1: Family wise dominant index of butterflies showing individuals, genera, and species recorded from Dehing Patkai National Park, Assam

Family	Total no. of individuals	Individual (%)	Total genera	Genera (%)	Total Species	Species (%)
Nymphalidae	2870	48.37	21	50.00	31	51.67
Lycaenidae	1105	18.62	7	16.67	7	11.67
Hesperiidae	226	3.81	2	4.76	4	6.67
Pieridae	1229	20.71	8	19.05	9	15.00
Papilionidae	400	6.74	3	7.14	8	13.33
Riodinidae	103	1.74	1	2.38	1	1.67

Out of sixty butterfly species, twenty are classified as protected under the Wildlife Protection Act of 1972 (Table 2). Four species namely Euploea sylvester hopei (C. & R. Felder, 1865), Hypolycaena othona othona (Hewitson, 1865), Doleschallia bisaltide indica (Moore, 1899), and Papilio clytia clytia (Linnaeus, 1758) are protected under scheduled I. The following butterfly species are listed as protected under scheduled-II: *Euripus consimilis* (Westwood, 1851), *Athyma kanwa phorkys* (Fruhstorfer, 1913), *Tanaecia lepidea lepidea* (Butler, 1868), *Lexias dirtea* (Fabricius, 1793), *Euploea midamus rogenhoferi* (C. & R. Felder, 1865), *Charaxes bernardus hierax* (C. & R. Felder, 1867), *Vindula erota erota* (Fabricius, 1793), *Zeltus amasa amasa* (Hewitson, 1865), *Lampides boeticus* (Linnaeus, 1767), *Tagiades japetus* (Stoll, 1781), *Pareronia avatar* (Moore, 1858), *Appias lyncida eleonora* (Boisduval, 1836), *Cepora nerissa nerissa* (Fabricius, 1775), and *Cepora nadina nadina* (Lucas, 1852). Additionally, *Euploea radamanthus* (Fabricius, 1793) and *Pelopidas assamensis* (de Nicéville, 1882) are protected under scheduled-IV. In the Garo hills of Meghalaya, northeastern India fall under the Indo-Myanmar Biodiversity Hotspot, Kunte *et al.*, (2012) reported 298 species of butterflies. Among these species, 8 species are legally protected under Schedule I, while 33 species under Schedule II of the Indian Wildlife (Protection) Act, 1972. According to Konwar and Bortamuly (2021), twenty-two species found in the non-protected areas of Titabar, Assam are protected under various schedules of the Indian Wildlife (Protection) Act, 1972. One species listed under Schedule I, seventeen species listed under Schedule II, and four species listed under Schedule IV. Thirteen species were recorded from the Dehing Patkai area were identified under different Schedules of the act viz. *Elymnias pealii* Schedule-I, *Acytolepis puspa gisca* Schedule-I, *Discophora sondaica zal* Schedule-I, *Spindasis lohita himalayanus* (Moore, 1884) ScheduleII, *Melanitis zitenius zitenius* Schedule-II, *Elymnias vasudeva* Schedule-II, *Athyma ranga ranga* ScheduleII, *Charaxes bernardus hierax* Schedule-II, *Chersonesia intermedia rahrioides* Schedule-II, *Rhinopalpa Polynice birmana* Schedule-II, *Euploea radamanthus radamanthus* Schedule-IV, *Pelopidas assamensis* Schedule-IV and *Appias galba* Schedule-IV

(Gogoi *et al.*, 2023). Out of 252 species of butterflies 49 species are protected under the Wildlife Protection Act, 1972 (Bhattacharjee and Ahmed 2020).

Table 2: Checklist, IUCN/Local status and occurrence of butterfly species found in the study area

Common Name	Scientific Name	Family	IUCN/ Local status	Occurrence							
				POM 2021	WIN 2021	PRM 2022	MN 2022	POM 2022	WIN 2022	PRM 2023	MN 2023
Lemon pansy	*Junonia lemonias* (Linnaeus, 1758)	Nymphalidae	NE/NLP	√	√	√	√	√	√	√	√
Glassy tiger	*Parantica aglea* (Stoll, 1782)	Nymphalidae	NE/NLP	√	√	√	√	√	-	√	√
Commander	*Moduza procris* (Cramer, 1777)	Nymphalidae	NE/NLP	√	√	√	√	√	√	√	√
Common four ring	*Ypthima huebneri* (Kirby, 1871)	Nymphalidae	NE/NLP	√	√	√	√	√	√	√	√
Painted courtesan	*Euripus consimilis* (Westwood, 1851)	Nymphalidae	NE/WP A-II	√	-	√	√	-	√	√	√
Dot-dash sergeant	*Athyma kanwa phorkys* (Fruhstorfer, 1913)	Nymphalidae	NE/WP A-II	√	√	√	√	√	√	√	√
Himalayan orange staff surgent	*Athyma cama cama* (Moore, 1858)	Nymphalidae	NE/NLP	√	√	√	√	√	-	√	√
Grey count	*Tanaecia lepidea lepidea* (Butler, 1868)	Nymphalidae	LC/WP A-II	√	√	√	√	√	√	√	√
Grey pansy	*Junonia atlites* (Linnaeus, 1763)	Nymphalidae	NE/NLP	√	√	√	√	√	√	√	√
Blue Tiger	*Tirumala limniace* (Cramer, 1775)	Nymphalidae	NE/NLP	√	√	√	√	√	-	√	√
chocolate	*Junonia iphita* (Cramer,	Nymphalidae	NE/NLP	-	-	√	√	√	√	√	√

pansy	1779*)*										
Common sergeant	*Athyma perius* (Linnaeus, 1758)	Nymphalidae	NE/NLP	√	√	√	√	√	-	√	√
Yellow-tipped Archduke	*Lexias pardalis* (Moore, 1878)	Nymphalidae	NE/NLP	√	√	√	√	√	√	√	√
Common five ring	*Ypthima baldus* (Fabricius, 1775)	Nymphalidae	NE/NLP	√	√	√	√	√	√	√	√
Dark archduke	*Lexias dirtea* (Fabricius, 1793)	Nymphalidae	NE/WP A-II	√	√	√	√	√	√	√	√
Common bushbrown	*Mycalesis perseus* (Fabricius, 1775)	Nymphalidae	NE/NLP	√	√	√	√	√	√	√	√
Large yeoman	*Cirrochroa aoris* (Doubleday, 1847)	Nymphalidae	NE/NLP	-	√	√	√	√	-	√	√
Dark blue tiger	*Tirumala septentrionis* (Butler, 1874)	Nymphalidae	NE/NLP	√	√	√	√	√	-	√	√
Common lascar	*Pantoporia hordonia* (Stoll, 1790)	Nymphalidae	NE/NLP	-	-	√	√	√	√	√	√
Common glider	*Neptis sappho* (Pallas, 1771)	Nymphalidae	LC/NLP	√	√	√	√	√	√	√	√
Peacock pansy	*Junonia almana* (Linnaeus, 1758)	Nymphalidae	LC/NLP	√	√	√	√	√	√	√	√
Double branded crow	*Euploea sylvester hopei* (C. & R. Felder, 1865)	Nymphalidae	LC/WP A-I	√	-	√	√	√	√	√	√
Assam blue spotted crow	*Euploea midamus rogenhoferi* (C. & R. Felder, 1865)	Nymphalidae	NE/WP A-II	-	-	-	-	√	√	√	√
Oriental map	*Cyrestis thyodamas thyodamas* (Doyère,	Nymphalidae	NE/NLP	√	√	√	√	√	-	√	√

	1840)										
Indian Nawab	*Charaxes bharata* (C. & R. Felder, 1867)	Nymphalidae	NE/NLP	√	√	√	√	√	-	√	√
Magpie crow	*Euploea radamanthus* (Fabricius , 1793)	Nymphalidae	NE/WP A-IV	√	√	√	√	√	√	√	√
Orange oakleaf	*Kallima inachus inachus* (Doyère, 1840)	Nymphalidae	NE/NLP	-	-	-	-	√	√	-	√
Autumn Leaf	*Doleschallia bisaltide indica* (Moore, 1899)	Nymphalidae	NE/WP A-I	-	-	-	-	√	-	-	√
Bengal Leopard Lacewing	*Cethosia cyane cyane* (Drury, 1773)	Nymphalidae	NE/NLP	-	-	-	-	√	-	√	√
Variable tawny rajah	*Charaxes bernardus hierax* (C. & R. Felder, 1867)	Nymphalidae	NE/WP A-II	-	-	-	-	√	√	√	√
Thai Cruiser	*Vindula erota erota* (Fabricius, 1793)	Nymphalidae	NE/WP A-II	-	-	-	-	-	√	√	√
Silvery Hedge Blue	*Celastrina gigas* (Hemming, 1928)	Lycaenidae	NE/NLP	√	√	√	√	√	√	√	√
Himalayan Purple Sapphire	*Heliophorus epicles latilimbata* (Fruhstorfer, 1908)	Lycaenidae	NE/NLP	√	√	√	√	√	√	√	√
Slate flash	*Rapala manea schistacea* (Moore, 1879)	Lycaenidae	NE/NLP	√	√	√	√	√	√	√	√
Variable Malayan	*Megisba malaya sikkima* (Moore, 1884)	Lycaenidae	NE/NLP	√	√	√	√	√	√	√	√
Indian Fluffy Tit	*Zeltus amasa amasa* (Hewitson, 1865)	Lycaenidae	NE/WP A-II	√	√	√	√	√	√	√	√
Oriental	*Hypolycaena othona othona* (Hewitson,	Lycaenidae	NE/WP	√	√	√	√	√	√	√	√

Orchid Tit	1865)		A-I								
Pea Blue	*Lampides boeticus* (Linnaeus, 1767)	Lycaenidae	LC/WP A-II	√	√	√	√	-	-	√	√
Common Snow Flat	*Tagiades japetus* (Stoll, 1781)	Hesperiidae	NE/WP A-II	-	√	√	√	√	√	√	√
Sylhet Water Snow Flat	*Tagiades litigiosa litigiosa* (Möschler, 1878)	Hesperiidae	NE/NPA	-	√	√	√	√	√	√	√
Great swift	*Pelopidas assamensis* (de Nicéville, 1882)	Hesperiidae	NE/WP A-IV	-	√	√	√	√	√	√	√
Indo-Chinese Common Banded Demon	*Notocrypta paralysos asawa* (Fruhstorfer, 1911)	Hesperiidae	NE/NPA	-	-	-	-	√	√	√	√
Common grass yellow	*Eurema hecabe hecabe* (Linnaeus, 1758)	Pieridae	NE/NPA	√	√	√	√	√	√	√	√
Sylhet Three-spot Grass Yellow	*Eurema blanda silhetana* (Wallace, 1867)	Pieridae	NE/NPA	√	√	√	√	√	√	√	√
Large cabbage white	*Pieris brassicae* (Linnaeus, 1758)	Pieridae	NE/NPA	√	√	√	√	√	√	√	√
Pale Wanderer	*Pareronia avatar* (Moore, 1858)	Pieridae	NE/WP A-II	√	-	√	√	√	-	-	√
Lemon Emigrant	*Catopsilia pomona* (Fabricius, 1775)	Pieridae	NE/NPA	√	√	√	√	√	√	√	√
Indo-Chinese Chocolate	*Appias lyncida eleonora* (Boisduval, 1836)	Pieridae	NE/WP A-II	√	√	√	√	√	√	√	√

Albatross											
Oriental Great Orange-tip	*Hebomoia glaucippe glaucippe* (Linnaeus, 1758)	Pieridae	NE/NPA	√	√	√	√	√	√	√	√
Common gull	*Cepora nerissa nerissa* (Fabricius, 1775)	Pieridae	NE/WPA-II	√	√	√	√	√	√	√	√
Khasi Lesser Gull	*Cepora nadina nadina* (Lucas, 1852)	Pieridae	NE/WPA-II	√	√	√	√	√	√	√	√
Khasi Yellow Helen	*Papilio chaon* (Westwood, 1845)	Papilionidae	NE/NPA	√	√	√	√	√	√	√	√
Oriental Common Mime	*Papilio clytia clytia* (Linnaeus, 1758)	Papilionidae	NE/WPA-I	√	√	√	√	√	-	-	√
Indian Common Mormon	*Papilio polytes romulus* (Cramer, 1775)	Papilionidae	LC/NPA	√	√	√	√	√	√	√	√
Himalayan Common Jay	*Graphium doson axionides* (Page & Treadaway, 2014)	Papilionidae	NE/NPA	√	√	√	√	√	√	√	√
Oriental Tailed Jay	*Graphium agamemnon agamemnon* (Linnaeus, 1758)	Papilionidae	NE/NPA	√	√	√	√	√	√	√	√
Common bluebottle	*Graphium sarpedon sarpedon* (Linnaeus, 1758)	Papilionidae	LC/NPA	√	√	√	√	√	√	√	√
Himalayan Five-bar Swordtail	*Graphium antiphates nebulosus* (Butler, 1881)	Papilionidae	NE/NPA	√	√	√	√	√	√	√	√
Khasi Common Birdwing	*Troides helena cerberus* (C. & R. Felder, 1865)	Papilionidae	NE/NPA	-	-	-	-	√	√	-	√

Himalayan Punchinello	*Zemeros flegyas flegyas* (Cramer, 1780)	Riodinidae	NE/NPA	√	√	√	√	√	√	√	√

Note: WPA: Wildlife Protection Act; I/II/IV: Schedule under WPA; NE: Not Evaluated; NLP: Not Legally Protected ***[MN- Monsoon; PRM- Pre monsoon; Win- Winter; POM-Post monsoon]***

In the Nymphalidae family, the Shannon diversity index (H') exhibited its maximum value in September 2021 (Pre-monsoon) (H' = 2.99), followed by August 2022 (monsoon) (H' = 2.88). Conversely, the lowest level of diversification was observed during the winter season of December 2022 (H' = 2.56). The Shannon diversity index (H') in Lycaenidae exhibited its maximum value in April 2022 (Pre-monsoon) at 1.80, followed by August 2022 (Monsoon) at 1.61. However, the lowest level of diversification was observed in September 2021 (Post-monsoon) at 1.53. The Shannon diversity index (H') exhibited its highest value in the family Hesperiidae during the winter season of December 2021 (H' = 0.82). In the family Pieridae, the highest H' value was observed during the monsoon season of August 2022 (H' = 2.02), while in the family Papilionidae, the highest H' value was also recorded during the monsoon season of August 2022 (H' = 1.873).

In the Nymphalidae family, the Shannon diversity index (H') exhibited its maximum value in June 2023 (Monsoon) at 3.06. This was closely followed by November 2022 (Post-monsoon) with a value of 3.05. Whereas the lowest level of diversification was observed during the Winter season in December 2022, with a value of 2.53. The Shannon diversity index (H') in Lycaenidae exhibited its maximum value in March 2022 (Pre-monsoon) at 1.85, followed by June 2023 (Monsoon) at 1.63. Conversely, the lowest level of diversification was observed in November 2022 (Post-monsoon) at 1.55. The Shannon diversity index (H') was observed to be highest in the family Hesperiidae during the month of June 2023, which corresponds to the monsoon season (H' = 1.25). Similarly, the family Pieridae exhibited the highest diversity index during the pre-June 2023 period, also coinciding with the monsoon season (H' = 1.82). Lastly, the family Papilionidae displayed the highest diversity index in November 2022, which falls within the post-monsoon period (H' = 2.03). These present findings suggest that the monsoon season is a particularly favorable time for all butterfly families observed in the study sites (Figure 2). The likely cause of this phenomenon might be attributed to the widespread presence of abundant vegetation that provided ample nutrition for the growth stages of butterflies. Gogoi *et al.,* (2023) reported the Shannon diversity index (H') for the five butterfly families, namely Nymphalidae, Lycaenidae, Papilionidae, Pieridae, and Hesperiidae having 3.60, 2.59, 2.68, 1.93, and 2.20, respectively.

In the Nymphalidae family, the Pielou's Evenness Index (E) exihibited its maximum value in November 2022 (Winter) at 0.55, followed by 0.52 in March 2023 (Pre-Monsoon) and this was closely followed by 0.51 in December 2023 (Winter). The Pielou's Evenness Index (E) in Lycaenidae exhibited its maximum value in March 2023 (Pre-monsoon) at 0.47, followed by December 2022 (Monsoon) at 0.41. Conversely, the lowest level of diversification was observed in August 2022 (Monsoon) at 0.28. The Pielou's Evenness Index (E) was observed to be highest in the family Hesperiidae during the month of June 2023, which corresponds to the monsoon season (E = 0.38). Similarly, the family Pieridae exhibited the highest evenness index during the Winter-December 2022 period. Lastly, the family Papilionidae displayed the highest evenness index in September 2021, which falls within the post-monsoon period (E = 0.39). These present findings suggest that the ecosystem of the study site was moderately favourable for all butterfly families observed in site (Figure 3). Additionally, Pielou's Evenness Index (E) was also determined to be within the range of 0.93-0.97, indicating a favorable state of the ecosystem (Gogoi *et al.,* 2023). The findings of Ashraf *et al.,* (2018) suggest that the diversity indices demonstrate a moderate level of species diversity. However, there seems to

be a much higher species richness, with the greatest peak occurring during the pre-monsoon period and the lowest during the monsoon period.

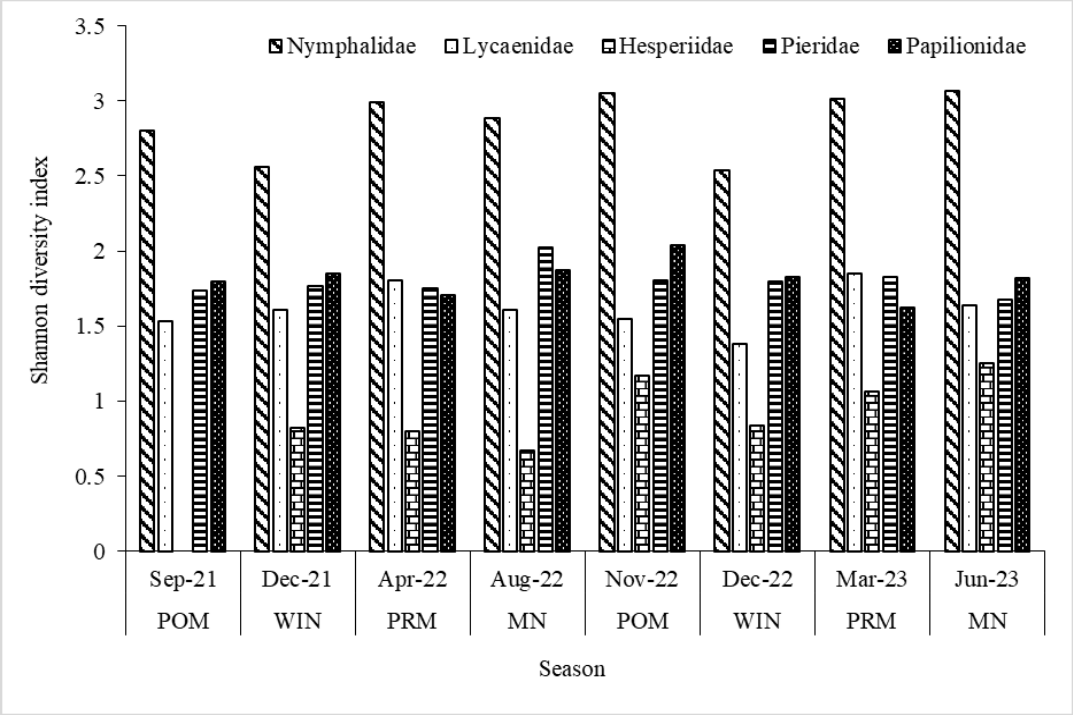

Figure 2: Season wise Shannon diversity index of butterfly families for the study period (2021-2023) [MN- Monsoon; PRM- Pre monsoon; Win- Winter; POM-Post monsoon]

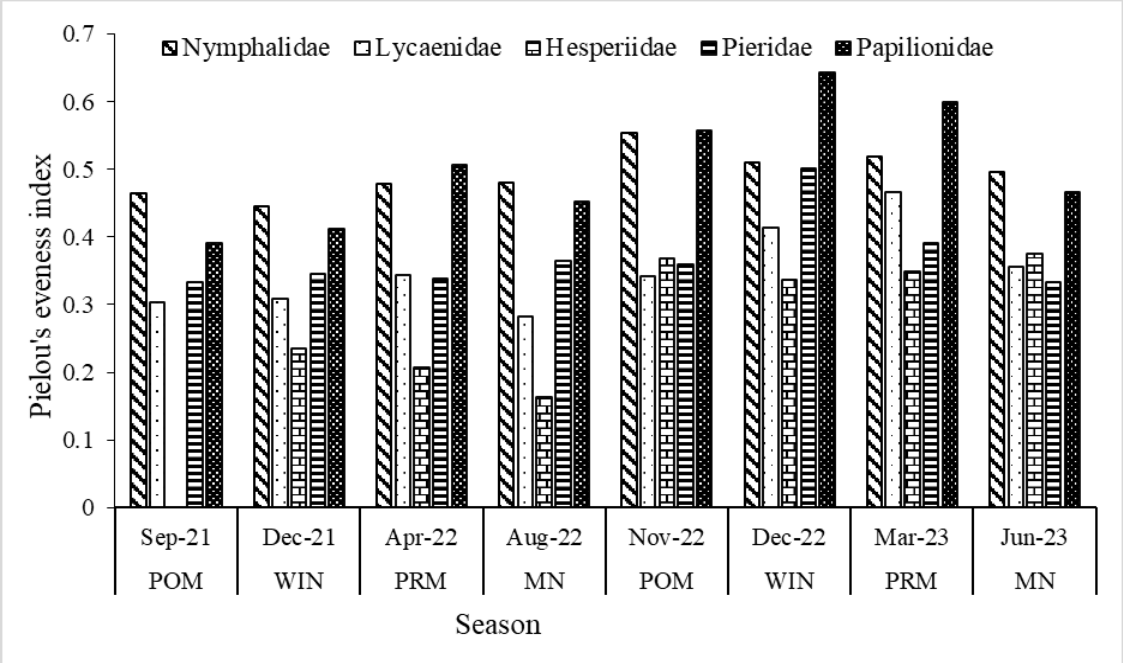

Figure 3: Season wise Pielou's evenness index of butterfly families for the study period (2021-2023) [MN- Monsoon; PRM- Pre monsoon; Win- Winter; POM-Post monsoon]

Out of 60 species of butterflies 34 species were present throughout the whole season is shown in Table 2. Increase the species abundance from the beginning of pre-monsoon, the peak reached in monsoon, and decline the species abundance from late December–February (Winter). This variation of abundance of butterfly individuals with climatic factors is shown in Figure 4.

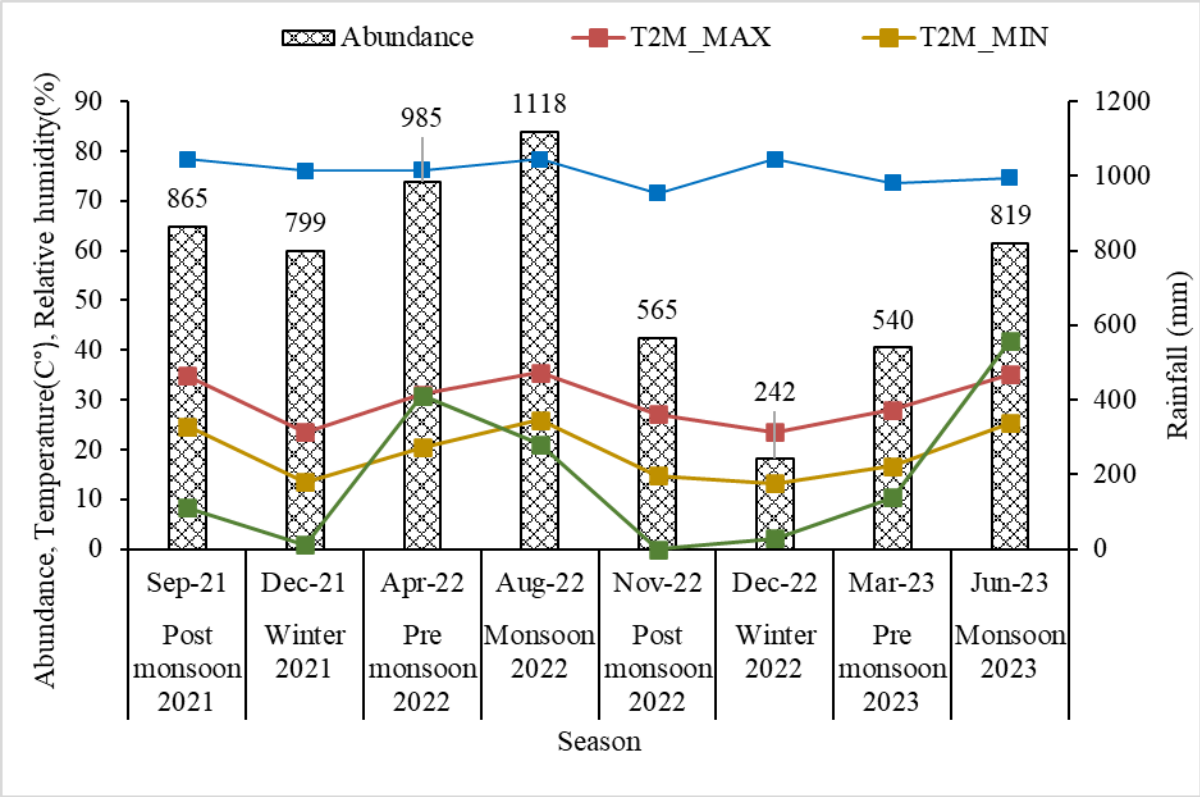

Figure 4: The seasonal variation of abundance of butterfly individuals with climatic factors

The maximum number of butterfly species (158) and maximum number of individuals (2480) was recorded highest in monsoon season. The Shannon Index of diversity (H'=4.96) and the evenness index of species distribution (E=0.98) also exhibited the highest values during monsoon. (Sengupta *et al.*, 2014). A study conducted in the Siruvani forest of the Western Ghats revealed that the population of butterflies was found to be highest in the month of August, while the lowest numbers were observed in March (Arun, 2003). It has been reported that the diversity of butterfly species richness and the abundance of individuals are influenced by seasonal variations (Hamer *et al.*, 2005). The abundance of the species exhibited an increase from the pre-monsoon period and thereafter reached its maximum during the monsoon season. A decrease in species abundance was seen from the late post-monsoon period until the end of winter. The observed correlation between species richness and the rainy season may possess a distinct association with the habitat of the national park (Gogoi, 2013). The study conducted by Tiple *et al.*, (2009) evaluated the species richness (flight periods) of eight sites located in and around Nagpur city. The findings revealed that the highest species richness occurred during the monsoon season, followed by a gradual drop in abundance until late winter.

The results of the regression analysis indicate a significant relationship between the abundance of butterfly individuals and the maximum temperature ($y = 40.31x - 461.02$), as depicted in Figure 5. According to

Farooq *et al.,* (2021), during the study period from 2017 to 2019, there was a positive correlation between the number of butterfly individuals and temperature ($r = .883$, $p < 0.01$ in the first year and $r = .63$, $p < 0.05$ in the second year), relative humidity ($r = .624$, $p < 0.05$ in the first year and $r = .882$, $p < 0.01$ in the second year), and rainfall ($r = .887$, $p < 0.01$ in the first year and $r = .905$, $p < 0.01$ in the second year). Another study also shown a positive correlation between the monthly average temperature and the number of butterfly species ($r=0.417$, $df=22$, $p=0.04$). But, both monthly average humidity ($r=-0.50$, $df=22$, $p=0.01$) and rainfall ($r=-0.43$, $df=22$, $p=0.03$) exhibited negatively correlated with the number of species found in that month (Ashraf *et al.,* 2018). The presence of flowers in the forest is influenced by its patchy nature, resulting in a continuous availability of flowers from various plant species throughout the year. However, the production of flowers is strongly correlated with the amount of rainfall received each month ($r=0.68$, $df=22$, $p=0.03$) (Ashraf *et al.,* 2018). On the other hand, Acharya & Vijayan, (2015) observed a declined trend in species richness along the elevation gradient ($R2=0.835$; $P<0.01$), which can be attributed to a direct correlation with temperature, as well as other environmental factors and habitat variables.

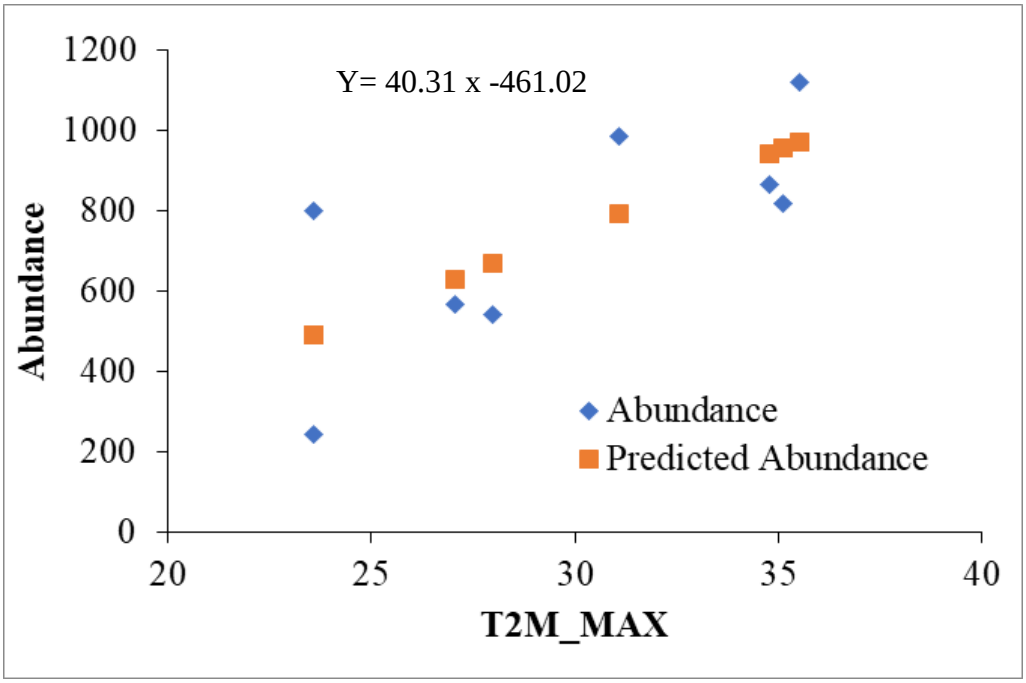

Figure 5: Regression analysis of seasonal abundance of butterfly individuals and temperature (T-max in C˚) of study site

To ascertain the distribution patterns of abundance across all species, a mean abundance curve was constructed. Figure 6 displays the curve representing the abundance-rank relationship. A few species are showing higher abundance and larger number of species are rare in occurrence. Among the observed species, 11 exhibited a relatively high overall abundance, with more than 150 sightings. Following these, 10 species were considered common, with a range of 100 to 150 sightings. Additionally, 18 species were classified as not rare, with a sighting range of 50 to 100. In general, further research pertaining to butterflies is necessary, particularly in the areas of host plants, habitat, and ecology. The findings of the present study reveal the importance of butterflies as an indicator of climate change, the dependence of butterflies on climatic variables, and the fluctuations in the seasonal abundance of butterfly populations. These results have implications for butterfly conservation efforts and provide valuable insights for future research endeavors in the Soraipung Range of Dehing Patkai National Park in particular and other habitat in general.

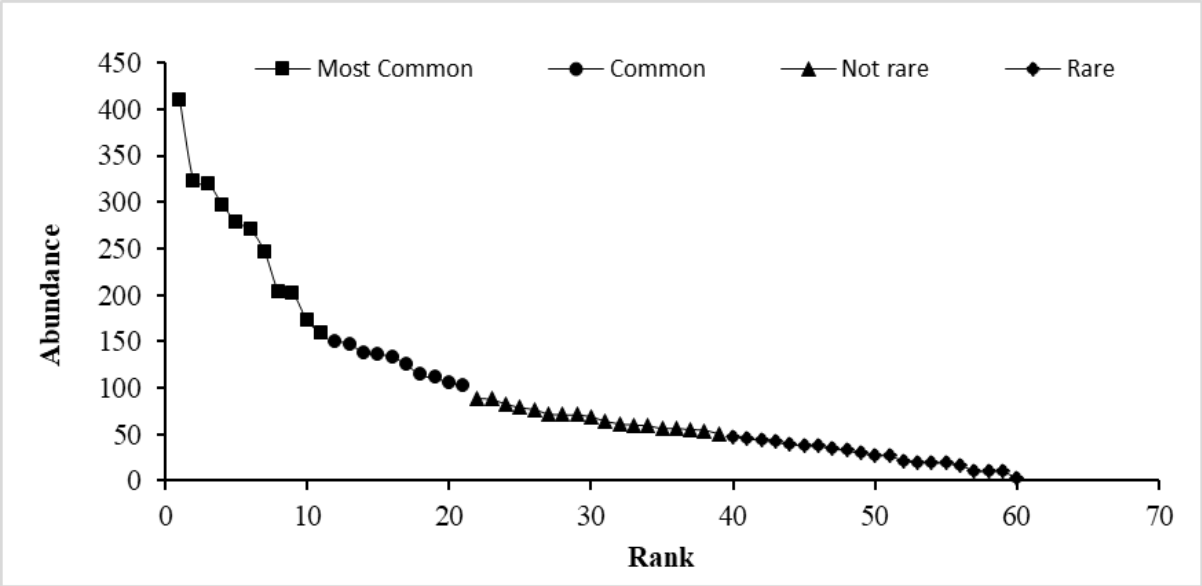

Figure 6: Rank-abundance curve of overall species found in the study site.

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