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Cover: Watercolour illustrations—Striped Tiger *Danaus genutia*, Common Silverline *Cigaritis vulcanus*, Tamil Lacewing *Cethosia mahratta*. © Mayur Nandikar.

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ARTICLE

Conservation imperatives for swallowtail butterflies (Lepidoptera: Papilionidae): a case study in the north bank landscape of river Brahmaputra, Bodoland Territorial Region, India

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Abstract: The decline of swallowtail butterflies in forest habitats, which was not a significant concern about two decades ago, has now garnered attention worldwide, leading to their designation as globally endangered by the International Union for Conservation of Nature. A recent study conducted in the north bank landscape (NBL) of river Brahmaputra, specifically under the Bodoland Territorial Region in India, has shed light on the remarkable diversity of swallowtail butterfly species in the area. The study documented a total of 35 species representing eight different genera. Notably, three species are endemic to northeastern India, and 12 enjoy federal protection. The findings suggest that the studied landscape plays a crucial role in supporting larval host plants and adult resources of swallowtail butterflies along with the other abiotic factors. These butterflies depend on 25 plant species from six families as essential food sources. Unfortunately, these host plants, valued for their traditional medicinal properties, are being overexploited. Urgent conservation measures are imperative to safeguard the habitats of swallowtail butterflies and other wildlife in the NBL under Bodoland Territorial Region, as they face significant threats from practices such as agriculture, illegal tree felling, forest fires, and cattle farming.

Keywords: *Aristolochia*, Bodoland, endangered, habitat, host plants, landscape, Papilionidae, protected, rare, wildlife.

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INTRODUCTION

Butterflies are closely associated with the landscape in various ways, and the characteristics of the surrounding environment can influence their presence, abundance, and diversity. They are excellent candidates for ecological studies in any landscape and serve as valuable indicators for evaluating biological conservation efforts (Nadeau et al. 2017). Within the vast diversity of insects, butterflies hold particular significance as they are well-suited for ecological research (Tomas & Mallorie 1985; Pollard & Yates 1993). Butterflies, in general, play a crucial role in a landscape because of their ecological contributions. Studies consistently show a positive relationship between butterfly diversity, specifically swallowtail butterflies, and environmental variables (Tomas & Mallorie 1985; Spitzer et al. 1997; Rossi & Halder 2010; Hill et al. 2021). Swallowtails, named for their swallow-like hindwing extensions, include both tailed & tailless species. While predominantly tropical, some extend into cooler temperate zones in both hemispheres (New et al. 1995). New (1991) reported that eastern and southeastern Asia's equatorial rainforests host a remarkable diversity of swallowtail butterflies. Collins (1987) documented India, Mexico, Taiwan, Malaysia, and Papua New Guinea as significant regions for swallowtails, collectively housing over two-thirds of global species, each with distinct geographic distributions.

The global count of swallowtail butterfly species stands at 573, inclusive of the Queen Alexandra's Birdwing *Ornithoptera alexandrae* Rothschild, 1907 found in Papua New Guinea's rainforests (Collins & Morris 1985). India hosts 77 swallowtail species, with only six being endemic (Collins & Morris 1985). Historically, northeastern India was noted for hosting 69 swallowtail species (Evans 1932), emphasizing its significance in swallowtail diversity. The International Union for Conservation of Nature and Natural Resources (IUCN) has designated northeastern India as a 'swallowtail-rich zone' under the Swallowtail Conservation Action Plan (MOEF 1990).

The study focused on evaluating species richness, distribution, and conservation status of swallowtail butterflies and their larval host plants in protected areas along the north bank landscape (NBL) of the Brahmaputra River in Bodoland Territorial Region (BTR), northeastern India. It also aimed to identify potential threats impacting populations of these globally threatened butterflies.

MATERIALS AND METHODS

Study Area

BTR, also previously known as Bodoland Territorial Council (BTC), is an autonomous council area unraveled from the northern part of western Assam under the sixth schedule of the constitution of India in 2003. It lies between 26.1200 N and 26.7972 E, covering an area of 8,970 km2, of which 40% is covered with forests. The river Pachnoi of Sonitpur district is the easternmost boundary and river Sankosh in the west, Bhutan in the north, and Dhubri, Bongaigaon, Barpeta, Nalbari, and Kamrup Districts in the south (Figure 1). The area of BTR extends over the NBL, is flat with some hills to the north, and is contiguous with the Royal Manas National Park (1,023 km^2) of Bhutan. This is at the confluence of Indo-Gangetic, Indo-Malayan, and Indo-Bhutan realms and a key conservational area of the Jigme Dorji Manas-Bumdeling conservation landscape in the eastern Himalayan eco-region (Wikramanayake et al. 2000). The NBL forests under BTR constitute major forest types such as the eastern Himalayan Bhabhar upper & lower Sal forest, eastern Terai Sal forest, eastern heavy alluvium plain Sal forest, eastern hill Sal forest, northern secondary moist mixed deciduous forest, evergreen forest, low alluvial savannah woodland, eastern wet alluvial grassland, riparian fringing forest, Khair-Sissoo forests, secondary bamboo brakes, and cane brakes (Champion & Seth 1968). The soil in this area is primarily dry sandy loam with a thin layer of humus and frequent surface stones. The temperature in the area can range from 7–34 ^{o}C. The site experiences fluctuating levels of rainfall throughout the year, with the winter season witnessing minimal precipitation of approximately 15 mm, while the wet season receives significantly higher rainfall, reaching up to 1,162 mm.

Sampling Methods

The butterfly population was surveyed using strip transects, following the slight modification of the method proposed by Pollard & Yates (1993). This involved counting individuals observed within a standardized 5 × 5 × 5 m in front of the observer. The observer maintained a consistent pace while walking through various habitats, including areas near water sources, damp patches within the forest, open sunny areas, and blooming flowers. Moreover, opportunistic searches were conducted within the catchment areas of streams and along their entire length, from top to bottom, to ensure a comprehensive record of the maximum number of species. The observed individuals were identified and

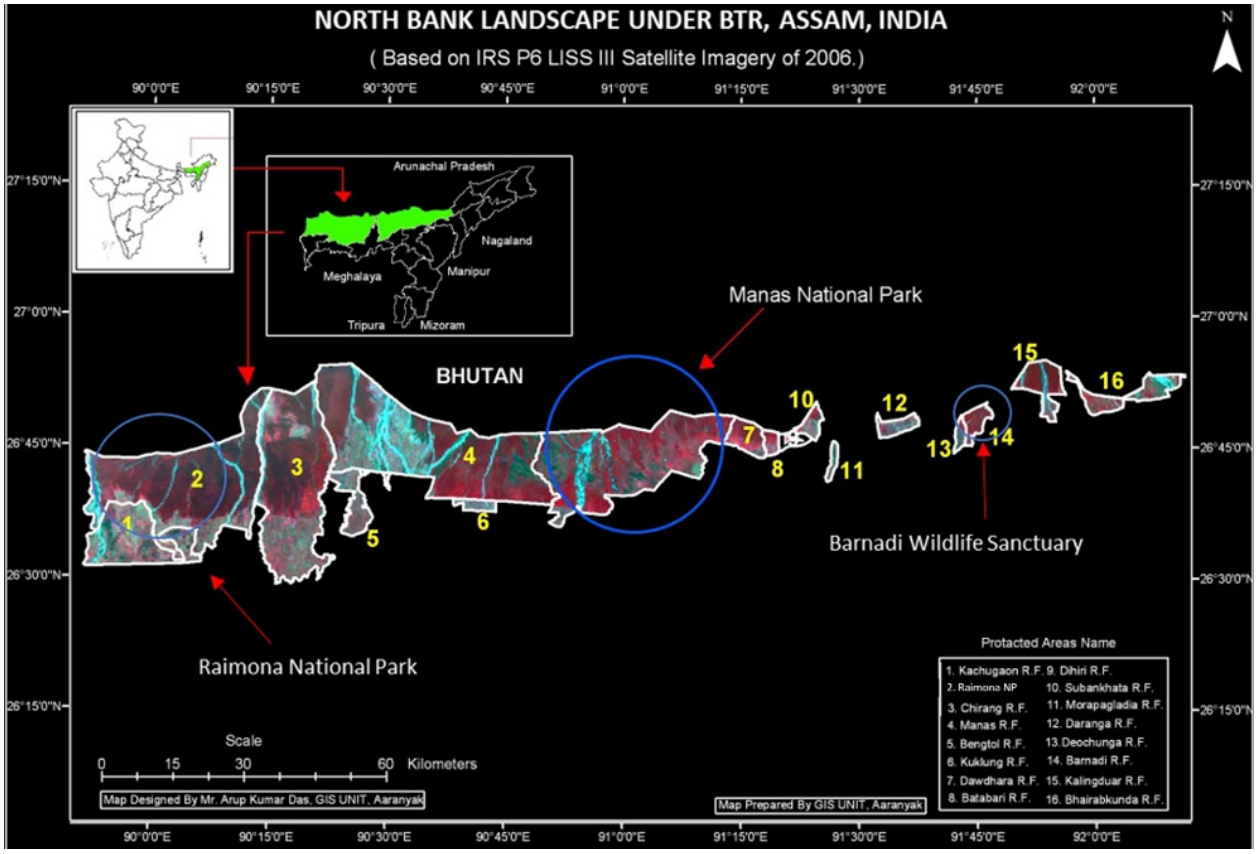

Figure 1. The study area with protected areas in the North Bank Landscape under Bodoland Territorial Region, Assam, India.

recorded. In cases where immediate identification was not possible, representative specimens were captured with the help of an insect net and photographed, then released without any injury for accurate identification.

The surveys were carried out during sunny conditions, specifically between 0900 h and 1600 h, as this is the time when butterflies are most active. The identification of butterflies was carried out with the help of identification keys available in the literature (Evans 1932; Wynter-Blyth 1957).

The basic technique for identifying larval host plants involves directly observing the egg-laying behaviors of female butterflies in the field, followed by a rigorous search for larvae on those plants. Subsequently, plant identification is accomplished using regional and local floras, including references such as Kanjilal et al. (1934–1940), and Borthakur et al. (2018).

RESULTS

In the study, 35 species of swallowtail butterflies from eight genera were recorded in the study area. These butterflies had a combined abundance of 4,267 individuals. Table 1 provides the recorded species' information, including their wing span, larval food plants, global distribution, local distribution, local status, and status in the Wild Life (Protection) Amendment Act, 2022.

Among the recorded species, eight belonged to the 'red-bodied' group, which encompassed three genera: *Atrophaneura* Reakirt (consisting of four species), *Pachliopta* Boisduval (with one species), and *Triodes* (with two species). The group characterized by 'black-bodied' species, including the genera *Papilio* Linnaeus and *Graphium* Scopoli, displayed the highest species richness, with each genus containing 11 species. Additionally, the genera *Chilasa* Moore were represented by four species, while the genera *Lamproptera* Gray, *Pachliopta* Boisduval, and *Meandrusa* Moore had the lowest species count, with only one species each (Figure 2). Within the documented species, one particular

Table 1. List of swallowtail butterflies recorded in the North Bank Landscape (NBL), under Bodoland Territorial Region (BTR), Assam, India along with their common name, scientific name, wing span, global distribution, larval host plants, local distribution, local conservation status, and status in the Wild Life (Protection) Amendment Act, 2022.

	Common name	Scientific name	Wing span (mm)	Geographical range	Larval food plants	Local distribution	Local status	WL (P) Act
1	Lesser Batwing	*Atrophaneura aidoneus* Doubleday, 1845	120–162	India (Uttaranchal to Arunachal Pradesh, Meghalaya), Nepal, Bhutan, and Myanmar	*Aristolochia bracteolata* *Aristolochia indica* *Aristolochia tagala*	Bhairabkunda RF, Chirang RF, Barnadi WS, and Khungring RF	Rare	
2	Common Batwing	*Atrophaneura varunaastorion* West Wood, 1842	88–136	India (Uttaranchal to Arunachal Pradesh, Meghalaya), Nepal, Bhutan, Myanmar, and Bangladesh	*Aristolochia bracteolata* *Aristolochia indica* *Aristolochia tagala*	Chirang RF, Barnadi WS, and Khungring RF.	Rare	
3	Great Windmill	*Atrophaneura dasaradadasarada* Moore, 1857	100–140	India (Jammu & Kashmir to Arunachal Pradesh), Nepal, Bhutan, Myanmar, and Bangladesh	*Aristolochia bracteolata* *Aristolochia indica* *Aristolochia tagala*	Chirang RF, BarnadiWS, and Khungring RF.	Very Rare	
4.	Common Windmill	*Atrophaneura philoxenuspolyeuctus* Doubleday, 1842	110–140	India (J&K to north-east), Nepal, Bhutan, Myanmar, and Pakistan.	*Aristolochia bracteolata* *Aristolochia indica* *Aristolochia tagala*	Chirang RF, and Khungring RF.	Occasional	
5	Tailed Jay	*Graphium agamemnon agamemnon* Linn, 1758	85–110	India, Nepal, Bhutan, Bangladesh, Sri Lanka, and Myanmar	*Michelia champaca* *Polythia longifolia* *Annona squamosa*	Chirang RF, Barnadi WS, and Khungring RF	Frequent	
6	Common Jay	*Graphium dosonaxion* C & R Felder, 1864	70–80	India, Sri Lanka, Nepal Bhutan, and Myanmar.	*Polyalthia simiarum* *Polylthia longifolia* *Michelia champaca* *Magnolia grandiflora* *Cinnamomum* spp.	Chirang RF, Barnadi WS, and Khungring RF.	Frequent	
7	Great Jay	*Graphium eurypylus* Linn, 1758	75–100	India (Sikkim-Arunachal, north-east, West Bengal (northern hills), Andaman), Bhutan, Bangladesh, and Myanmar	*Magnolia grandiflora* *Polyalthia longifolia*	Chirang RF, Barnadi WS, and Khungring RF.	Frequent	Sch-II
8	Common Blue Bottle	*Graphium sarpedon sarpedon* Linn, 1758	80–95	India, Sri Lanka, Nepal, Bhutan, and Bangladesh.	*Polyalthia longifolia* *Cinnamomum tamala* *Saraca indica* *Cinnamomum zeylanicum* *Litsea chinensis* *Annona squamosa*	Chirang RF, Barnadi WS, and Khungring RF.	Frequent	Sch-II
9	Fivebar Swordtail	*Graphium antiphates pompilus* Fabricius, 1787	80–95	India, Nepal, Bhutan, Bangladesh, and Myanmar.	*Michelia champaca* *Annona squamosa* *Desmos dunalii*	Chirang RF, BarnadiWS, and Khungring RF.	Frequent	
10	Spot Swordtail	*Graphium nomius nomius* Esper, 1785-98	75–90	India, Nepal, Bhutan, Sri Lanka, Bangladesh, and Myanmar	*Annona squamosa* *Polyalthia longifolia*	Chirang RF, Barnadi WS, and Khungring RF.	Rare	
11	Fourbar Swordtail	*Graphium agetes agetes* Westwood, 1843	75–90	India, Nepal, Bhutan, Bangladesh, and Myanmar.	*Annona squamosa* *Michleia* spp.	Barnadi WS, and Khungring RF.	Rare	Sch-II
12	Chain Swordtail	*Graphium aristeus anticrates* Doubleday, 1846	70–80	India (Sikkim to Assam), and Myanmar.	*Annona squamosa* *Michleia* spp.	Chirang RF.	Rare	Sch-II
13	Great Zebra	*Graphium xenocles xenocles* Doubleday, 1842	85–120	India (Uttaranchal to north-east), Nepal, Bhutan, Bangladesh, and Myanmar.	*Annona squamosa* *Michelia* spp.	Chirang RF, and Barnadi WS.	Rare.	
14	Glassy Bluebottle	*Graphium cloanthus* Westwood, 1841	85–95	India (J&K to north-east), Nepal, Bhutan, Myanmar, and Pakistan.	*Michelia* spp.	BarnadiWS, and Khungring RF.	Rare	Sch-II
15	Lesser Zebra	*Graphium macareus lioneli* Fruh, 1902	80–100	India (Uttaranchal to northeastern India), Nepal, Bhutan, Bangladesh, and Myanmar.	*Annona squamosa* *Michelia* sp.	Chirang RF, Barnadi WS, Raimona NP, Chirang RF, Manas NP, and Kuklung RF.	Very Rare	
16	Common Birdwing	*Troides helena cerberus* C. & R. Felder, 1865	140–170	India (Orissa, Sikkim to Arunachal Pradesh and Andaman & Nicobar Islands), Nepal, Bhutan Bangladesh, and Myanmar.	*Aristolochia bracteolata* *Aristolochia indica* *Aristolochia tagala*	Raimona NP, Chirang RF, Manas NP, Kuklung RF, Barnadi WS, Kalingduar RF, Bhairabkunda RF, and Deochunga RF.	Occasional	

	Common name	Scientific name	Wing span (mm)	Geographical range	Larval food plants	Local distribution	Local status	WL (P) Act
17	Golden Birdwing	*Troides aeacusaeacus* C. & R. Felder, 1860	119–188	India (Uttaranchal to Arunachal Pradesh and Andaman & Nicobar Islands), Nepal, Bhutan Bangladesh, and Myanmar.	*Aristolochia bracteolata* *Aristolochia indica* *Aristolochia tagala*	Raimona NP, Chirang RF, Manas NP, Kuklung RF, Dawdhara RF, Barnadi WS, Kalingduar RF, Bhairabkunda RF, Deochunga RF, and Daranga RF.	Rare	Sch-II
18	Red Helen	*Papili ohelenus helenus* Linn, 1758	110–130	India, Nepal, Bhutan, Bangladesh, Myanmar, and Sri Lanka.	*Toddalia asiatica* *Zanthoxylum* spp. *Paramignya griffithii* *Aegle marmelos* *Citrus* spp.	Raimona NP, Chirang RF, Manas NP, Kuklung RF, Dawdhara RF, Barnadi WS, Kalingduar RF, Bhairabkunda RF, Deochunga RF, Daranga RF, and Subankhata.	Frequent	
19	Yellow Helen	*Papilio nepheluschaon* Westwood, 1845	115–130	Odisha, northeastern India, Nepal, Bhutan, Bangladesh, and northern Myanmar.	*Aegle marmelos* *Toddalia asiatica* *Zanthoxylum* sp. *Citrus* spp. *Paramignya griffithii* *Murraya koenigii*	Raimona NP, Chirang RF, Manas NP, Kuklung RF, Dawdhara RF, Barnadi WS, Kalingduar RF, Bhairabkunda RF, Deochunga RF, Daranga RF, and Subankhata RF.	Frequent	
20	Common Raven	*Papilio castor polas* Jordan, 1909	80–120	Northeastern India, Bhutan, Bangladesh, and northern Myanmar.	*Toddalia asiatica* *Glycosmis pentaphyla* *Zanthoxylum* sp. *Citrus* sp.	Chirang RF, Kachugaon RF, Khungring RF, and Barnadi WS.	Occasional	
21	Great Mormon	*Papilio memnonagenor* Linn, 1758	120–150	India (Sikkim to north-east, West Bengal, Andaman & Nicobar Island), Nepal, Bhutan, Myanmar, and Bangladesh.	*Paramignya griffithii* *Murraya koenigii* *Citrus medica* *Citrus* spp. *Glycosmis entaphylla* *Evodiameliaefolia* *Zanthoxylum* spp.	Raimona NP, Chirang RF, Manas NP, Kuklung RF, Dawdhara RF, Barnadi WS, Kalingduar RF, Bhairabkunda RF, Deochunga RF, Daranga RF, and Subankhata.	Frequent	
22	Common Mormon	*Papilio polytes romulus* Cramer, 1775	90–100	India, Nepal, Bhutan, Sri Lanka, Myanmar, Bangladesh, and Pakistan.	*Aegle marmelos* *Citrus* spp. *Murraya koenigii* *Glycosmis entaphylla* *Evodiameliaefolia* *Zanthoxylum nitdum* *Citrus medica* *Citrus aurantfolia* *Citrus sinensis* *Correa* sp. *Glycosmis* sp. *Triphasia* sp. *Zanthoxylum* sp.	Raimona NP, Chirang RF, Manas NP, Kuklung RF, Dawdhara RF, BarnadiWS, Kalingduar RF, Bhairabkunda RF, Deochunga RF, Daranga RF, and Subankhata.	Frequent	
23	Spangle	*Papilio protenor euprotenor* Fruhstorfer, 1908	100–130	Northern Pakistan, Jammu & Kashmir, Garhwal Himalaya, Sikkim, Assam, Bangladesh, Burma, southern China (including Hainan), northern Vietnam, northern Laos, Taiwan, North Korea, South Korea, and Japan.	*Zanthoxylum* sp. *Citrus* sp. *Zanthoxylum nitdum* *Citrus medica* *Zanthoxylum alatum*	Raimona NP, Chirang RF, Manas NP, Kuklung RF, Barnadi WS, Kalingduar RF, Daranga RF, and Subankhata.	Rare	
24	Yellow Crested Spangle	*Papilio elephenor elephenor* Doubleday, 1886	110–130	Northeastern India (Assam).	Data deficient	Raimona NP	Vary Rare	Sch-I

	Common name	Scientific name	Wing span (mm)	Geographical range	Larval food plants	Local distribution	Local status	WL (P) Act
25	Paris Peacock	*Papilioparisparis* Linn, 1758	90–140	The Himalaya from Kumaon to Sikkim, Nepal and Bhutan; the hills of Assam, Burma and Tenasserim, extending to China, Siam, and the Malay Peninsula.	*Citrus* spp.	Raimona NP, Chirang RF, Manas NP, and Kuklung RF, Dawdhara RF, Barnadi WS, Kalingduar RF, Bhairabkunda RF, Deochunga RF, Daranga RF, and Subankhata.	Occasional	
26	Common Peacock	*Papilio polyctor ganesa* Doubleday, 1832	90–130	India (J&K to north-east) Nepal, Bhutan, Myanmar, Afghanistan, and Pakistan	*Zanthoxylum* spp. *Citrus* spp. *Clausena* spp. *Zanthoxylum oxyphyllum Zanthoxylum hamiltonianum*	Khungring RF.	Rare	
27	Redbreast	*Papilio alcmenor* C. & R. Felder, 1864	110–130	India (Uttaranchal to north-east), Nepal, Bhutan, Bangladesh, and Myanmar.	Data deficient	Chirang RF and Khungring RF.	Rare	
28	Lime Butterfly	*Papilio demoleus demoleus* Linn, 1758	80–100	India, Nepal, Bhutan, Bangladesh, Pakistan, Sri Lanka, Afghanistan, and Myanmar.	*Solanum nigram Aegle marmelos Citrus* spp. *Murraya koenigii Glycosmis pentaphyla*	Chirang RF, Kachugaon RF, Barnadi WS, and Khungring RF.	Frequent	
29	Common Mime	*Chilasa clytia clytia* Linn, 1758	90–120	India, Nepal, Bhutan, Pakistan, Bangladesh, Sri Lanka, and Myanmar.	*Cinnamomum tamala Litsea chinensis Alseodaphne semecarpifolia, Cinnamomum verum Litsea glutnosa, Persea gamblei, Ocotea lancifolia Sarcosperma arboreum*	Raimona NP, Chirang RF, Manas NP, Kuklung RF, Dawdhara RF, Barnadi WS, Kalingduar RF, Bhairabkunda RF, Deochunga RF, Daranga RF, and Subankhata.	Occasional	Sch-II
30	Lesser Mime	*Chilasa epicydes epicydes* Hewitson, 1862	70–90	Northeastern India, Myanmar.	*Cinnamomum* sp.	Barnadi WS.	Rare	Sch-II
31	Blue-Striped Mime	*Chilasa slateri slateri*, Hewitson, 1857	80–100	Northeastern India, Nepal, Bhutan, Bangladesh, and Myanmar.	*Cinnamomum* sp.	Chirang RF.	Very Rare	Sch-II
32	Great Blue Mime	*Chilasa paradoxa telearchus*Hewitson, 1852	120–150	India (Assam to Arunachal Pradesh), Nepal, Bangladesh, and Myanmar.	Data deficient	Chirang RF.	Very Rare	Sch-II
33	White Dragontail	*Lemproptera curius curius* Fabricus, 1787	40–45	India (Assam, Arunachal Pradesh), Bangladesh, and Myanmar.	*Lligera cordata*	Barnadi WS.	Rare	
34	Common Rose	*Pachliopta aristolochiae aristolochiae* Fabricius, 1775	90–110	India, Sri Lanka, Pakistan, Nepal, Bhutan, Myanmar, and Bangladesh.	*Aristolochia bracteolata Aristolochia indica Aristolochia tagala*	Raimona NP, Chirang RF, Manas NP, Kuklung RF, Dawdhara RF, Barnadi WS, Kalingduar RF, Bhairabkunda RF, Deochunga RF, Daranga RF, and Subankhata.	Frequent	
35	Yellow Gorgon	*Meandrus apayeni* Boisduval, 1836	11–130	India (Sikkim-Assam), Bhutan, southern Burma, northern Thailand, northern Vietnam, Laos, China, Malaysia, Indonesia, and Myanmar.	Data Deficient	Dawdhara RF.	Very Rare	

WL (P) Act—Wild Life (Protection) Amendment Act, 2022.

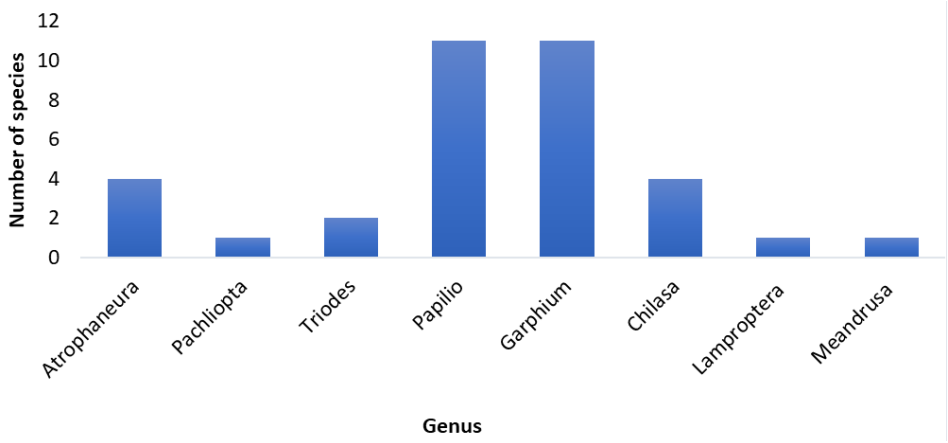

Figure 2. Dominant genera of swallowtail butterflies in the North Bank Landscape under Bodoland Territorial Region, Assam, India.

swallowtail butterfly species has been accorded the highest level of protection as Schedule I under the Wild Life (Protection) Amendment Act, 2022. Additionally, 11 other species have been recorded and designated as Schedule II under the same Act (Table 1, Image 1).

When assessing the abundance of swallowtail butterflies in the study area, the following scale was used: "Very rare" refers to a sighting or occurrence of 1–3 instances; "Rare" signifies a slightly higher occurrence, ranging 4–10 instances; "Occasional" represents a moderate frequency, encompassing 10–50 instances; and "Frequent" indicates a high frequency of occurrence, starting from 21 instances or more, indicating a significant presence of swallowtail butterflies (Table 1).

The larval host plants recorded in the study belonged to six different families of plant species. The family Rutaceae had the highest number of host plant species, with 12 species identified. Following Rutaceae, the family Lauraceae had four species, while the families Aristolochiaceae and Annonaceae each had three species. Magnoliaceae and Fabaceae had two species and one species, respectively (Figure 3).

DISCUSSION

The study documented a total of 35 species, which accounts for 45% of the total species reported in India by Evans (1932) and Talbot (1939). Out of the five endemic species found in the eastern Himalaya, according to Evans (1932) and Talbot (1939), three species were recorded during the study: Yellow-crested Spangle *Papilio elephenor elephenor* Doubleday, 1886, Lesser Zebra *Graphium macareus lioneli* Fruh, 1902, and Great Zebra *Graphium xenocles xenocles* Doubleday, 1842. Choudhury (2010) recorded Yellow-crested Spangle after several decades from Phipsu (presently Raimona National Park). This species is listed as endangered recently under the Wild Life (Protection) Amendment Act, 2022. There is minimal knowledge about its population dynamics because of its elusiveness. The Lesser Zebra *Graphium macareus lioneli* Fruh, 1902 was recorded in the forest trails of Barnadi WS, Chirang RF, and Raimona NP during June and July. A single individual of the Great Zebra was found alongside the Saralpara-Sarpang road under the Chirang Reserve Forest. Despite its typical occurrence at higher elevations between 1,000 m and 2,200 m, three individuals of the Lesser Mime *Chilasa epycides* Hewitson, 1862 was recorded in February near Saralpara under the Chirang RF, at 125 m. It is conceivable that these species may have migrated from Bhutan to seek refuge from the harsh winter temperatures, as the hills of Bhutan are contiguous with this particular land.

The Blue-striped Mime *Chilasa slateri slateri* Hewitson, 1857 was observed near the Kalanadi Forest Camp of Barnadi Wildlife Sanctuary, while the remaining species were found across all the reserves. Notably, the survey did not record any species from the *Teinopalpus* Hope and *Bhutanitis* Atkinson genera. This is significant as the Bhutan Glory *Bhutanitis lidderdalei* Atkinson, 1873 and Kaiser-I-Hind *Teinopalpus imperialis*, Hope 1843, already rare in the Assam region during the early 20th century, have not been observed for several years. Many researchers (Pollard 1979: Pollard 1988; Roy & Sparks 2000; Barua et al. 2010) stated that heavy showering and closed canopy are the two critical abiotic factors for the richness of swallowtail butterflies. Arguably, the seasonality of tropical insects is predominantly

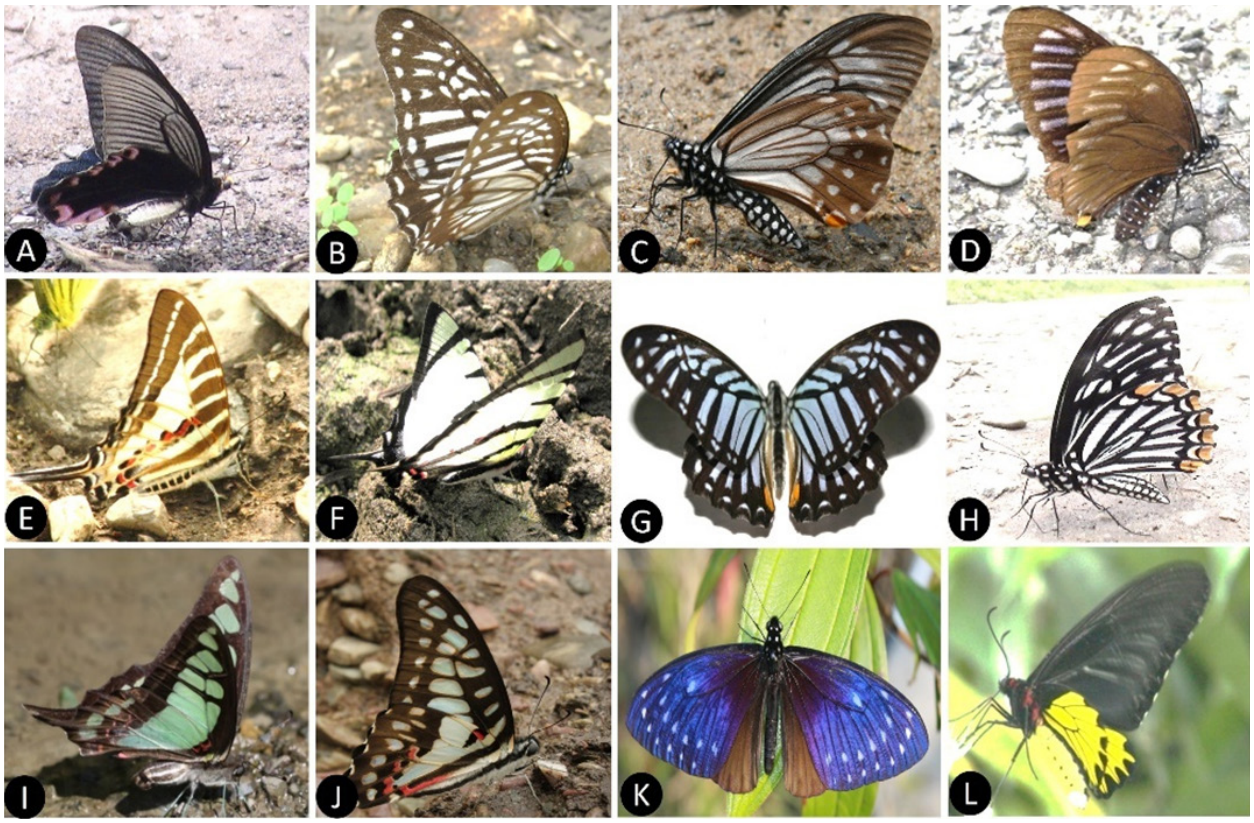

Image 1. Swallowtail butterflies protected by the Wild Life (Protection) Amendment Act, 2022 in India: A—*Papilio elephenor* | B—*Graphium macareus* | C—*Chilasa epicydes* | D—*Chilasa slateri* | E—*Graphium aristeus* | F—*Graphium agetes* | G—*Graphium xenocles* | H—*Chilasa clytia* | I—*Graphium cloanthus* | J—*Graphium eurypylus* | K—*Chilasa paradoxa* | L—*Triodes aeacus*. © Kushal Choudhury.

influenced by changes in rainfall patterns (Wolda 1989; Hill et al. 2003). According to Jain et al. (2012), there is evidence of a gradual decrease in rainfall across the entire northeastern region of India over several years, potentially contributing to the decline of swallowtail butterflies. Furthermore, the detrimental impacts of activities such as illegal tree felling, uncontrolled forest fires, tea gardening near protected areas, pesticide usage (Steffan-Dewenter et al. 2005), and the persisting issue of illegal cattle farming within these protected areas may be crucial factors contributing to the decline of these butterflies (Harrisson et al. 2012) (Image2).

The availability of host plants is one of the most critical factors for the survival of butterflies. The black-bodied species belonging to *Papilio* (including mormons, peacock, and helens) and *Graphium* (comprising jays and bluebottles) were observed to feed on six distinct plant families. The dominant plant families among these were Rutaceae, Lauraceae, and Magnoliaceae. Figure 3 shows varying levels of species richness among the different plant families, with Rutaceae being the most diverse one. According to Hajra et al. (1997), the study area is situated in the "Citrus belt of the world" and supports a diverse range of citrus species, including 17 species, 52 varieties, and six potential hybrid citrus species (Bhattacharya & Dutta 1956). This abundance of citrus plants may be linked to the richness of the *Papilio* genus, as these butterflies predominantly rely on citrus plants for their larval development. However, the population of citrus species, primarily found in the wild or semi-wild habitats, is declining due to the shrinkage of forested lands and overexploitation. As a result, these citrus species are now mainly confined to home gardens or backyard settings. This decline in the wild population of citrus species may be a possible reason for the disappearance of these butterfly species.

The butterfly genera *Atrophaneura* (Corbet & Pendlebury 1992), *Pachliopta* (Venkataramana et al. 2004), and *Triodes* (Parsons 1996, 1999) have a specialized diet, exclusively feeding on plants from the Aristolochiaceae family. Three species of the genus *Aristolochia* (*A. bracteolate*, *A. indica*, and *A. tagala*) were recorded within the study area. Due to their significant traditional medicinal value, these plants were extensively harvested from the wild, resulting in a sharp decline in their density (Mebs & Schneider 2002;

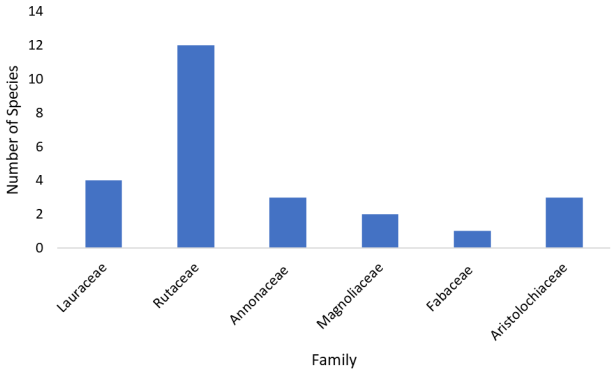

Figure 3. Dominant genera of larval host plants for swallowtail butterflies in the North Bank Landscape under Bodoland Territorial Region, Assam, India.

Heinrich et al. 2009; Michl et al. 2013). This decline directly affects the population of *Aristolochia* feeding swallowtail butterflies. In the family Magnoliaceae, which comprises 24 species from northeastern India, only two species, *Magnolia champaca* and *Magnolia grandiflora*, were recorded from the study area. Their density is declining daily, despite their great economic value, as they provide helpful wood for making boxes and musical instruments and yield excellent commercial timber known as 'white wood' or 'yellow poplar' (Pandey & Misra 2009). *Polyalthia simiarum*, *Annona squamosa*, and *P. longifolia* are representative species of the Annonaceae family. *Polyalthia longifolia* is commonly planted in urban areas as an ornamental plant. *P. longifolia* and *P. simiarum* hold tremendous medicinal value (Rashid et al. 1996; Kabir et al. 2013).

Lauraceae includes *Cinnamomum camphora*, *C. verum*, *C. zeylanicum*, *C. tamala*, and *Litsea chinensis*. Ahmad et al. (2022) reported the traditional use of *Cinnamomum camphora,* while *C. tamala* has been found to have beneficial effects on digestion and appetite stimulation (Hamidpour et al. 2013; Mehta et al. 2014). Pathak & Sharma (2021) emphasized the medicinal benefits of *Cinnamomum verum* and *C. zeylanicum*.

In the study, *Lamproptera* species were the only recorded monophagous specialists, relying on a single host plant, *Ligustrum cordatum,* under the family Oleaceae. In traditional medicine, certain parts of *Ligustrum cordatum* are believed to possess medicinal properties. On the other hand, the polyphagous *Graphium* species fed on plants from the Lauraceae and Magnoliaceae families. Koh et al. (2004) observed that host-specific butterflies are especially susceptible to localized fragmentation of their resources. The comparable environmental conditions in the study area might have played a role in the reduced or limited numbers of *Lamproptera* species observed within protected regions.

Unfortunately, our study did not reveal any identified host plants associated with Yellow-crested Spangle *Papilio elephenor* Doubleday, 1886*,* Redbreast *Papilio alcmenor* C. & R. Felder, 1864*,* Great Blue Mime *Chilasa paradoxa* Hewitson, 1852*,* and Yellow Gorgon *Meandrusa payeni* Boisduval, 1836 from the study area. The lack of related host plant resources for these

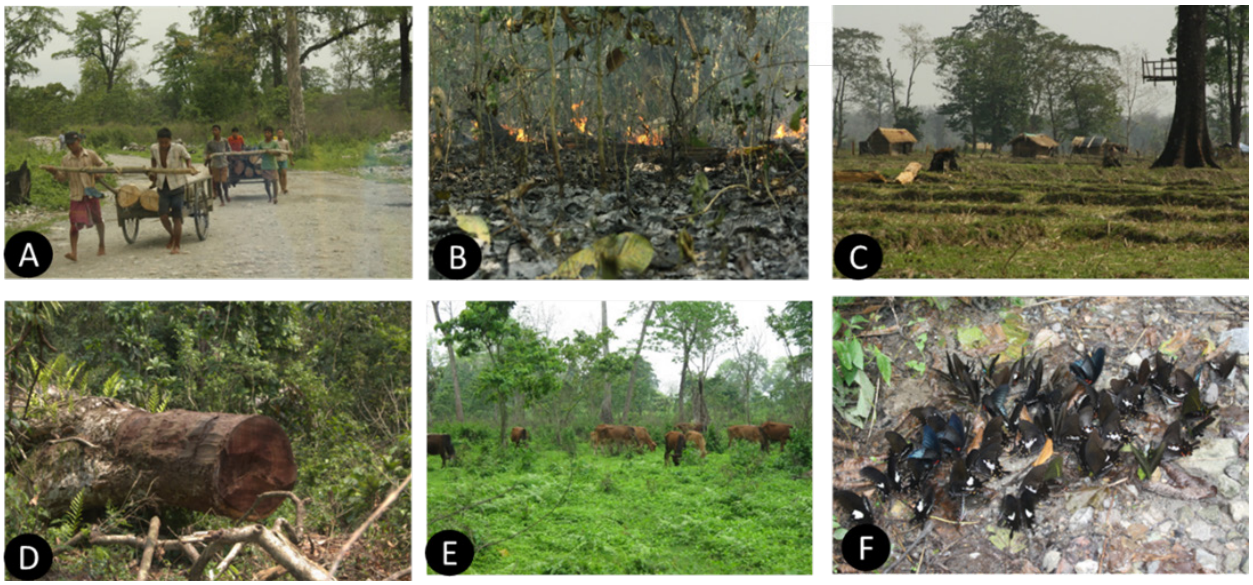

Image 2. Threats of swallowtail butterflies in the study area: A—collection of timber | B—unscientific forest fire | C—encroachment and agricultural practice | D—tree felling | E—cattle farming | F—puddling of swallowtail butterflies. © Kushal Choudhury.

species raises concerns about their long-term survival and ecological well-being. Host plants are fundamental to the lifecycle of many species, playing an essential role in their reproduction and sustenance.

While the study primarily focused on identifying essential plant families as larval food resources for swallowtail butterflies, the study area exhibited a diverse range of plant species that serve as good nectar sources. It is essential to mention that adult butterflies exhibit less specificity and more excellent opportunism in their feeding behaviors compared to their larval stages, as observed by Gilbert & Singer (1975). Prior research confirms that butterfly diversity and abundance are significantly influenced by floral and larval resources and climate's impact on plant phenology. Moreover, the local abundance and timing of nectar and host-plant resources can substantially affect butterfly populations more than their mere presence (Simonson et al. 2001).

The study findings have brought to light the importance of both global environmental changes (Swaay et al. 2010) and local factors in the decline of these threatened butterfly species. In order to revive their populations, it is crucial to focus on conserving their preferred microhabitats and the medicinal plants they rely heavily on. We can create a conducive environment for their recovery by preserving these plants and their habitats. Additionally, for critically endangered species that have dwindling numbers in the wild, implementing captive breeding programs can play a vital role in boosting their populations. Conducting an extensive survey is crucial for comprehending the present state of larval host plants, encompassing their abundance, distribution, and conservation status, which lays the groundwork for effective conservation strategies, and species preservation. Furthermore, micropropagation techniques facilitate the swift propagation of larval host plants, thereby supporting the conservation and expansion of rare populations.

CONCLUSION AND RECOMMENDATION

Habitat restoration and protection are crucial components of any conservation strategy. Initiatives should be undertaken to enhance the quality and availability of larval host plants, nectar sources, and breeding grounds. This includes reforestation efforts, native plant restoration, and reducing harmful activities such as illegal logging & forest fires. Collaboration with experts and institutions specializing in butterfly breeding is essential to establish successful breeding protocols and release strategies, providing a safety net against extinctions. The protection of medicinal plants serving as larval host plants should also be a priority, emphasizing promoting sustainable harvesting practices in collaboration with local communities and traditional medicine practitioners. Micropropagation techniques should be explored to ensure a sustainable supply of larval host plants, contributing to the conservation of rare plant species and the butterflies that depend on them. Education and awareness campaigns targeting local communities, schools, and the general public are critical to promote understanding of the ecological importance of swallowtail butterflies, their threats, and individual actions that can support their conservation. A long-term conservation plan with clear goals, milestones, and funding mechanisms is essential to ensure the sustainability of swallowtail butterfly conservation efforts, capable of adapting to changing circumstances.

Engaging local communities through capacity-building workshops, training programs, and employment opportunities related to butterfly conservation is vital for garnering their support and participation. By implementing these measures, we can significantly contribute to safeguarding swallowtail butterflies and preserving their ecological importance for current and future generations. These recommendations must be implemented promptly to reverse the decline of these beautiful and ecologically significant butterflies.

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