An assessment of butterfly species composition across a disturbance gradient in Garo Hills, North-east India

DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY IN PARTIAL FULFILMENT OF THE MASTER'S DEGREE IN ORNITHOLOGY & CONSERVATION BIOLOGY

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CERTIFICATE

This is to certify that **Ms. Subhiksha Lakshmi Maxima S.,** of Sálim Ali Centre for Ornithology and Natural History (SACON) has carried out an original research work titled, '***An assessment of butterfly species composition across a disturbance gradient in Garo Hills, North-east India***' in partial fulfilment of the M.Sc. (Ornithology & Conservation Biology) degree of Saurashtra University, Rajkot. This investigation was carried out under my supervision from December 2019 to August 2020. I also certify that this research work has not been submitted for any other degree to any university.

Date: 31 August, 2020
Place: Coimbatore

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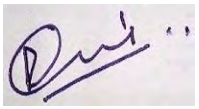

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CONTENTS

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LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Executive Summary

Shifting cultivation is a predominant form of land use in the hilly tracts of the tropics. Despite being under the scanner for one of the major causes of habitat degradation and forest cover loss, it is very much still prevalent in North-east India where it is one of the important sources of livelihood. Though a multitude of studies look at the nutrient and water losses and vegetation recovery in shifting agriculture lands, studies on the responses of fauna, following habitat alterations like slash and burn and further abandonment of the lands following cultivation are limited.

This study was conducted in the West Garo Hills district of Meghalaya in an intensive study area of approximately 230 km^2. A chrono-sequence approach was adapted in this study to look at how butterfly communities are distributed along four successional stages from clear-felled patches of land for cultivation to abandoned fallows after cultivation to older successional fallows. Vegetation recovery and habitat alterations were also examined in relation to butterfly community succession. Butterfly sampling was done in the four successional stages in 30-minute time-constrained counts and habitat variables were measured from 10 m circular radius plots.

Butterfly species composition of the current *jhum* patches varied significantly from the other three successional stages hosting a high number of open-country species. The species composition was highly dissimilar between the current *jhum* fallows and the older successional fallows (>8 years) attributed to the higher number of forest specialists in the older fallows. Forest development and habitat alterations such as clear-felling seemed to have a significant positive and negative effect on butterfly species richness, abundance and diversity respectively. The higher structural complexity of vegetation in the older fallows might contribute to more number of niches thus enabling higher number of species and forest specialists to inhabit these patches while clear-felled areas due to severe habitat alterations would enable only open-country species to persist. The family Nymphalidae was highly represented in all the successional stages as expected as it is the most speciose of butterfly families.

The study highlights the importance of heterogeneity in a shifting cultivation landscape contributing to higher species diversity on the whole. However, it strongly stresses on the importance of older successional fallows, which are increasingly diminishing in extent in the landscape, due to the shortening of fallow periods on account of increasing human population and demand. Further, the protection of such older fallows would also serve as refuges for species which are intolerant to habitat disturbances given the dynamic nature of shifting cultivation landscapes.

The conclusions drawn from the study are however, preliminary results as a higher sample size and seasonal data would add more clarity to the results and discussions attempted here.

1. INTRODUCTION

1.1 BACKGROUND

The conversion of natural ecosystems to varied land use systems is one of the major drivers of biodiversity loss (Nilsson *et al*., 2013). The effect is pronounced in highly diverse habitats like tropical forests and coral reefs where widespread habitat destruction has had negative effects on native biota (Wright & Muller-Landau, 2006). Tropical forest ecosystems are known to be highly speciose (Gentry, 1992; Dirzo & Raven, 2003) and are home to more than two-thirds of the terrestrial biodiversity (Gardner *et al*., 2009), in addition to which they offer a range of ecosystem services. These strongholds of biodiversity are, however, shrinking rapidly at alarming rates (Gentry, 1992). According to the State of the World's Forests Report, (2020), the net loss of forest area has decreased from 7.8 million hectares per year in the 1990s to 4.7 million hectares per year during 2010–2020, mostly as a consequence of forest conversion and degradation (Gibson *et al*., 2011).

Though high emphasis has been made on the irreplaceability of primary habitats for sustaining biodiversity (Gibson *et al*., 2011), the remaining tropical forests exist as effectively-managed Protected Areas or as remnant forest fragments in a matrix of human- dominated landuses (Wright & Muller-Landau, 2006; Ferraz *et al*., 2014). Establishing a PA network has been effective in conserving forested habitats (Geldmann *et al*., 2013) and in maintaining source populations for several species (Mansourian & Dudley, 2008). However, Protected Areas cover less than 8% of tropical forests (Rice *et al*., 2001) and though the area is on the rise, as most of these are surrounded by human-dominated landuses, these forest fragments are more susceptible to anthropogenic pressures. Thus, a large proportion of such Protected Areas (PAs), which exist as forest fragments in human-modified landscapes are fated to high levels of degradation unless properly managed (Gascon *et al.*, 2000). The effectiveness of protection has also been found to be variable as evidenced by habitat studies reviewed by Geldmann *et al.* (2013) as PAs with external threats are experiencing high habitat losses within their borders. It has been projected that as human populations continue to increase, most tropical forests in the future may be replaced by agriculture or secondary forests regenerating after clearing (Wright & Muller-Landau, 2006).

Thus, the future of biodiversity in the tropics may depend on the ability of native species to persist in a mosaic of relatively undisturbed and protected natural areas within human-modified landscapes such as agroforestry systems and secondary forests (McNeely & Schroth, 2006).

1.1.1 Secondary forests and Shifting Agriculture

Secondary forests make up an increasing proportion of total forest cover in the tropics (Dunn, 2004). Although there are varied definitions as to what are secondary forests, it can be understood that these are forests regenerating mostly through natural processes after a significant disturbance (either anthropogenic- shifting agriculture, pasture lands, clearing for agriculture or natural- forest fires/bush fires, cyclonic activity) of original vegetation that show a major difference in the structure or composition with respect to the primary forests of the site (Brown & Lugo, 1990; Chazdon *et al*., 2009). Secondary forests, especially in areas where mature forests are non-existent, hold great potential for biodiversity conservation by mitigating mass extinctions caused by the depletion of old-growth forests (Wright & Muller-Landau, 2006). They offer other conservation services like acting as buffers for reserves against climatic changes or exotic species invasions (Dunn, 2004). The recovery rate of various taxa however depend on a range of factors – the intensity of disturbance, the landuse history, the distance to source populations among others (Toky & Ramakrishnan, 1983; Dunn, 2004). Dunn (2004), in his review, noted that under optimal conditions where forest clearance is on a small scale and of a lower intensity, the species richness of certain taxa approached that of the mature forest in about 20-40 years as opposed to studies like Raman *et al.* (1998) who evidenced that even after 100 years of regeneration of secondary forests, some species found in mature forests were still absent. It is however important to assess the biodiversity potential of secondary forests and to protect them as they represent a “conservation bargain” and could potentially grow to mature forests (Dunn, 2004). Though secondary forests can have high conservation value (Chazdon, 2019), they are often re- cleared at young ages (Toky & Ramakrishnan, 1983; Raman *et al*., 1998; Ranjan & Upadhyay, 1999; Raman, 2001; Kurien *et al*., 2019). This is because most secondary formations are a consequence of shifting agriculture (Brown & Lugo, 1990).

Slash and burn agriculture is thought to have caused two-thirds of past deforestation in the tropics (Wright & Muller-Landau, 2006). Also termed as shifting or swidden cultivation (Kleinman *et al*., 1995; Raman, 2001), it has been depicted as unsustainable (Kleinman *et al*., 1995), evidenced by studies examining the soil quality, water and nutrient losses in such lands (Ranjan & Upadhyay, 1999). In India, majority of northeastern states practice shifting cultivation or "*jhum*" (Raman *et al*., 1998; Ranjan & Upadhyay, 1999, Raman, 2001). *Jhuming* typically involves selection of a forested site followed by felling and burning of vegetation, cultivation for a few years, abandonment of the site and return to the site for cultivation after a long fallow time. Reduction in the fallow periods due to the pressures of the ever-growing human population has resulted in ecological instability of the land (Ranjan & Upadhyay, 1999). However, there is growing literature on how, under conditions of low pressure on the land, *jhum* cultivation can be sustainable (Kleinman *et al*., 1995; Raman *et al*., 1998). Though there have been studies on the soil quality (Toky & Ramakrishnan, 1983) and secondary succession of vegetation (Toky & Ramakrishnan, 1983; Bowman *et al*., 1990; Ranjan & Upadhyay, 1999; KassiN'Dja & Decocq, 2008;), studies on the diversity of various taxa in these *jhumed* lands have been very few. Raman (2001) points out, "the responses of plants and animals to anthropogenic habitat disturbance and dynamic successional changes caused by *jhum* need to be examined".

1.1.2 Butterflies as Indicator Taxa

In the on-going global biodiversity crisis, insects as a group have been impacted the most, as many species perhaps go extinct even without proper taxonomic identification (Bonebrake *et al*., 2010). Of the known insect species, Lepidoterans, especially butterflies are best known ecologically and taxonomically. They are also a well- known (albeit imperfect) indicator of environmental perturbances (Gilbert & Singer, 1975; Bonebrake *et al*., 2010;). Although there have been conflicting views on the use of butterflies as an indicator taxon in studies of habitat disturbance and succession (Lawton *et al*., 1998; Kremen, 1992; Bonebrake *et al*., 2010), their sensitivity to environmental changes and their dependency on plants (for reproduction and sustenance) make them relatively more suitable for assessing habitat integrity, anthropogenic disturbance and climate change.

Though there are studies examining the effects of anthropogenic impacts such as shifting cultivation and subsequent succession on tropical forest ecosystems worldwide, limited number of them look at the recovery of faunal assemblages and even lesser on butterflies.

As the impact of these disturbances varies significantly across geographical sites (Wright, 2005), region-wise data across taxa is a requisite to identify patterns and processes which drive them.

In this context, an attempt has been made in the present study to assess the impact of shifting cultivation on butterfly community structure and composition of a heterogeneous landscape matrix in a gradient of forest succession. Typically succession studies favor long- term investigations. However, in the event of the limited resource of time, a chrono-sequence approach has been adopted.

1.2 OBJECTIVES

1) To assess the butterfly community structure and composition of successional landuse/landcover types created by shifting (*jhum)* cultivation.

2) To assess the habitat factors determining the butterfly communities of the successional landuse/landcover types studied.

3) To understand how the different butterfly families respond to the successional landuse/landcover types studied.

Study period: The field data were collected from February to March 2020.

1.3 LITERATURE REVIEW

1.3.1 Shifting Agriculture

In Northeast India, like other indigenous (human) community-dominated landscapes around the world, landuse intensity might be a direct consequence of the land tenure system. Ranjan and Upadhyay (1999) discuss how 10% of forest land in Asia was converted to shifting cultivation in a decade, 1980-1990. Eighty-five percent of the cultivation in Northeastern India

is by shifting cultivation (Ranjan & Upadhyay, 1999). In Meghalaya alone, according to the Forest Survey Report of 1997, 77% of forest cover is lost annually to shifting cultivation while only 20% is recovered (Meghalaya Biodiversity Board, 2017).

Jhum is the major source of livelihood for the Garos (Singh *et al*., 2011). Of the total number of families engaged in shifting cultivation in Meghalaya, 74% are from Garo Hills (Kaul *et al*., 2010). Recent studies such as Kurien *et al.* (2019) have substantiated the growing extent of shifting cultivation by demonstrating that shifting cultivation is the most extensive landuse in the region.

1.3.2 Effects of Shifting Cultivation on Habitat

A multitude of studies have looked at the effect of shifting cultivation on habitat characteristics such as vegetation structure, composition and soil properties. Predominantly, shifting cultivation has been under constant criticism due to its erosive impacts on the ecosystem in recent times. Though the shortening of fallow periods, the subsequent inadvertent loss of productive soils (Toky & Ramakrishnan, 1983; Ranjan & Upadhyay, 1999) and the negative impacts on biodiversity have led to the notion of slash and burn agriculture as unsustainable, contrasting views have also been put forward. A lesser extent of soil erosion and nutrient loss which does occur is countered by the fact that the shifting cultivation plots are small in proportion to the total area in the fallow rotation system (Kleinman *et al*., 1995). Views in support of shifting agriculture, stating the diversity in shifting agriculture systems and proper, active management of swiddens being more sustainable than the less diverse alternatives such as monoculture plantations have also been put forward (Kleinman *et al*., 1995; Padoch & Pinedo-vasquez, 2010). Also, in shifting cultivation landscape mosaics, individual fallows contain few species characteristic of the mature forest, but the heterogeneity among fallows contributes strongly to diversity at the landscape level (Finegan & Nasi, 2004).

In one of the oldest studies that look at vegetation succession following shifting agriculture in India, Toky and Ramakrishnan (1983) state that in the first five years, weed species dominate after which there was a rapid increase in species diversity up to 10 years following which the increase was slowed down. In this study, a notable linear relationship was observed

till 20 years with respect to community structure (from herbaceous vegetation to bamboo forests to woody species forests), litter production and primary productivity.

A similar pattern was reported by Raman *et al.* (1998), who observed that tree density, species richness and vertical stratification increased asymptotically while bamboo density increase till 25 years and declined afterward. He reported that the minimum threshold for woody plant species composition to reach that of the mature forest was 50-75 years.

Other studies also evidenced that although species richness reached that of the mature forests fairly rapidly (20-40 years), species composition however took several decades to recover (Toky & Ramakrishnan, 1983; Bowman *et al*., 1990; Raman *et al*., 1998; Dunn, 2004; Teegalapalli *et al*., 2009; Yirdaw *et al*, 2019)

1.3.3 Butterfly-Habitat Relationships

Larval host plants and adult resource interactions are some of the most important factors that influence butterfly diversity patterns in the tropics (Bonebrake *et al*., 2010). Butterfly communities are also known to be influenced by microclimatic variables such as light, temperature and relative humidity (Dolia *et al*., 2008; Checa *et al*.,2014). Butterflies are closely linked to microclimatic conditions and vegetation structure (which is directly related to climate) suggesting that habitat alteration and consequent effects on local climates and global climate change are likely to have much stronger effects on this taxon (Checa *et al*., 2014). Vertical stratification has also been seen in several studies with most of them investigating the effects of vertical stratification on fruit-feeding butterfly guild (Family – Nymphalidae). As evidenced by Molleman *et al.* (2006) and Gueratto *et al.* (2019) the level of vertical stratification in fruit-feeding butterfly species may be affected by vegetation structure, and thus by forest disturbance. Bobo *et al.* (2006) in his study of fruit-feeding butterfly communities across a successional gradient found that tree species density was found to be the best predictor of butterfly species richness. Tree species richness was only moderately correlated with butterfly species richness. Understorey plant species richness and density negatively influenced the abundance and species richness of fruit-feeding butterflies. A similar study in Southeast Asia showed an opposite trend with respect to tree density but vegetation layers and understorey plant diversity was positively correlated (Schulze & Steffan-Dewenter,

2004).

1.3.4 Butterflies in Disturbed Landscapes

Due to high diversity, short generation time, well studied ecology and relatively resolved taxonomy, butterflies are considered as "indicator taxa" (Kremen, 1992; Bonebrake *et al*., 2010). There have been numerous studies demonstrating how butterflies are impacted due to changing landuse and disturbance. Kremen (1992) demonstrated how butterfly species diversity can be a good indicator of landscape heterogeneity on the basis of topography and moisture while a moderate indicator of anthropogenic disturbance. Hill *et al*. (1995) and Ghazoul (2002) reported contrasting results with respect to the effect of logging on butterfly species diversity. While the former study states how butterfly species diversity decreases with increasing disturbance, the latter provides evidence for butterfly species diversity increasing with increasing disturbance. Of 20 studies reviewed by Koh (2007), seven showed higher butterfly species richness in undisturbed forests while nine showed the opposite trend. Strong focus on the "habitat level conservation approach" has resulted in studies that assess the indicator potential of butterflies throughout the tropics (Bonebrake *et al*., 2010). Though limited, research on the impact of invasive plants on butterflies shows evidence of effects such as oviposition "mistakes" and changes in behavior (Bonebrake *et al*., 2010) . According to a study by Ghazoul (2002) in Thailand, a shift in butterfly pollination activity has been seen, with canopy species visiting the understorey due to proliferation of an understorey herbaceous plant *Chromolaena odorata* (Bonebrake *et al*., 2010).

1.3.5 Butterflies and Forest Succession

Though a handful of studies examine the effects of shifting cultivation on butterfly communities, more look at the spatial variation of butterflies with respect to forest succession. A detailed review by Bowman *et al.* (1990) looked at the recovery of certain taxa including butterflies, following shifting agriculture. Butterfly species richness increased across the successional gradient. He concluded that this may be due to the floristic and structural simplicity of disturbed habitats. Another study that draws parallel conclusion is by Kitahara and Fujii (1994) where increasing species diversity correspond to decreasing degrees of human disturbance. This study also noted that human disturbance was negatively correlated

with the number of specialist species in a community. This finding is similar to that of Sáfián *et al.* (2011), who looked at the richness of "Wet Forest Species" (WEF) in degraded habitats rather than species that are tolerant to disturbance when computing community composition. However, Sáfián *et al.* (2011) reported contrasting results where clear-cut habitats where found to have a higher species richness. However when diversity values were computed, old-growth forests had a higher species diversity.

Bobo *et al.* (2006) and Nyafwono *et al.* (2014) who studied butterfly communities in Africa reported similar results with butterfly species richness peaking at intermediate stages. While in the former study, species richness was slightly higher in secondary forests than in a nearby primary forest, in the latter study, species richness significantly peaked at the intermediate succession stage. However in both the studies, species composition widely varied across successional stages.

A recent study from Mexico reported high species richness in highly disturbed habitats like pastures but showed a high species diversity in younger stages of succession reaching an intermediate level in mature stages of succession and lower species diversity in highly disturbed habitats. These studies (Bobo *et al*., 2006; Nyafwono *et al*., 2014; Martínez- Sánchez *et al.*, 2020) showcase the importance of young secondary forests in a landscape as this is the phase that connects the transition to mature secondary vegetation.

2. STUDY AREA

2.1 LOCATION AND PHYSICAL FEATURES

Meghalaya is one of the seven states of Northeast India, located between Assam and Bangladesh. The whole state along with Myanmar and other parts of Northeast India fall under the Indo- Burma Biodiversity hotspot (Critical Ecosystem Partnership Fund, 2012). The state has 11 districts, lying between 25˚4" - 26˚10" N latitude and 89˚ 45"– 92˚45" E longitude and covering an area of 22,429 km^2 (Meghalaya Biodiversity Board, 2017). Three geographical sub-regions are recognized – Khasi, Garo and Jaintia hills. The Garo Hills cover about a third of the extent of the state (Kunte *et al*., 2012) and comprise of five districts.

The district of West Garo Hills, where the study was conducted, has an area of 3677 km^2.The overall population of the district is 4,70,796 persons according to the 2011 census and the district is divided into 6 sub-districts or community and rural development (CRD) blocks `(http://westgarohills.gov.in/glance.html). The major indigenous tribes of the area are Garos whose chief agricultural practice is shifting cultivation or *jhum* cultivation (Singh *et al.*, 2011; Meghalaya Biodiversity Board, 2017). A detailed account of shifting cultivation and the associated secondary successional vegetation is given in section 3.1.1.

The landscape is characterized by an undulating terrain with the elevation ranging from 15 m up to 1400 m ASL (Kurien *et al*., 2019). The climate is humid sub-tropical at the lower ranges while sub-temperate in the higher ranges with an average rainfall of 330 cm (http://westgarohills.gov.in/glance.html). As a consequence of the prevailing land-tenure system, the state-owned forests - Tura Reserved Forest (4.19 km^2) and the Nokrek National Park (220 km^2) add up to only about 6% of the total geographical area of the district, the other forests such as private and village forests are under the District Autonomous Council and are community-owned lands called *A'khings*. According to the Forest Survey of India (2019), the forest cover in the district is 77.16%. However recent studies (Kurien *et al*., 2019) reported that shifting cultivation or *jhum* has been found to be the most dominant land-use (38.8%) followed by monoculture plantations (29.7%) with old-growth forests restricted to 9.7% of the area of the district. My intensive study area of approximately 230 km^2 is located within this larger, heterogeneous matrix (Figure 1).

2.2 VEGETATION

The natural vegetation of the area is Semi- Evergreen, Tropical Wet Evergreen and Moist Deciduous forests along with Secondary Bamboo Brakes (Forest Survey of India, 2019). A majority, fifty-nine percent of the intensive study area comprises of secondary successional stages of erstwhile forested patches cleared for shifting cultivation (locally known as *jhum* or *abba*). Patches of remnant old growth forests, sacred groves and older fallows (> 20 years comprise the fifteen percent of the area and are restricted to village forests, community reserves and the buffer of Nokrek Biosphere Reserve. Tracts of monoculture plantations, home gardens, paddy cultivation and human habitation are also the *landuse*s found in this landscape and make up the rest twenty six percent of the area (Figure 2 & 3).

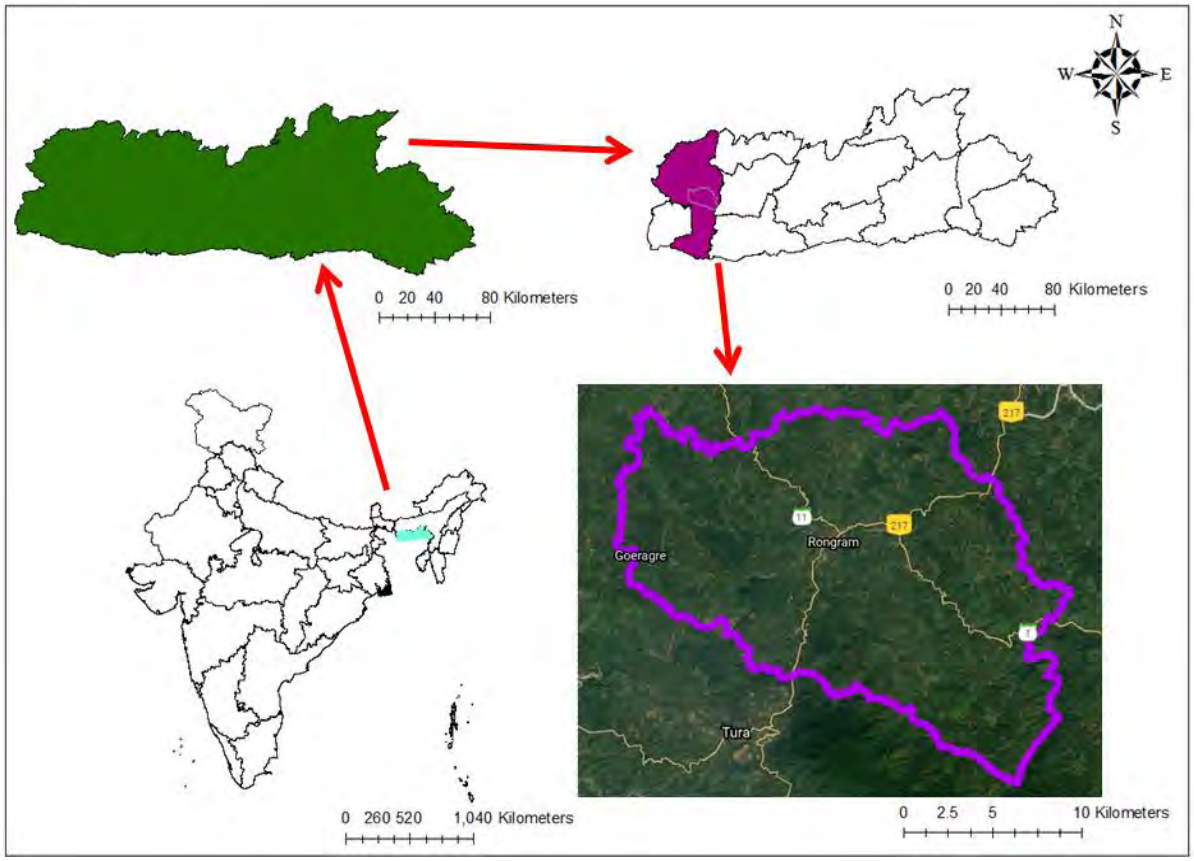


Figure 1: The study area in West Garo Hills district. The purple polygon represents the study area.

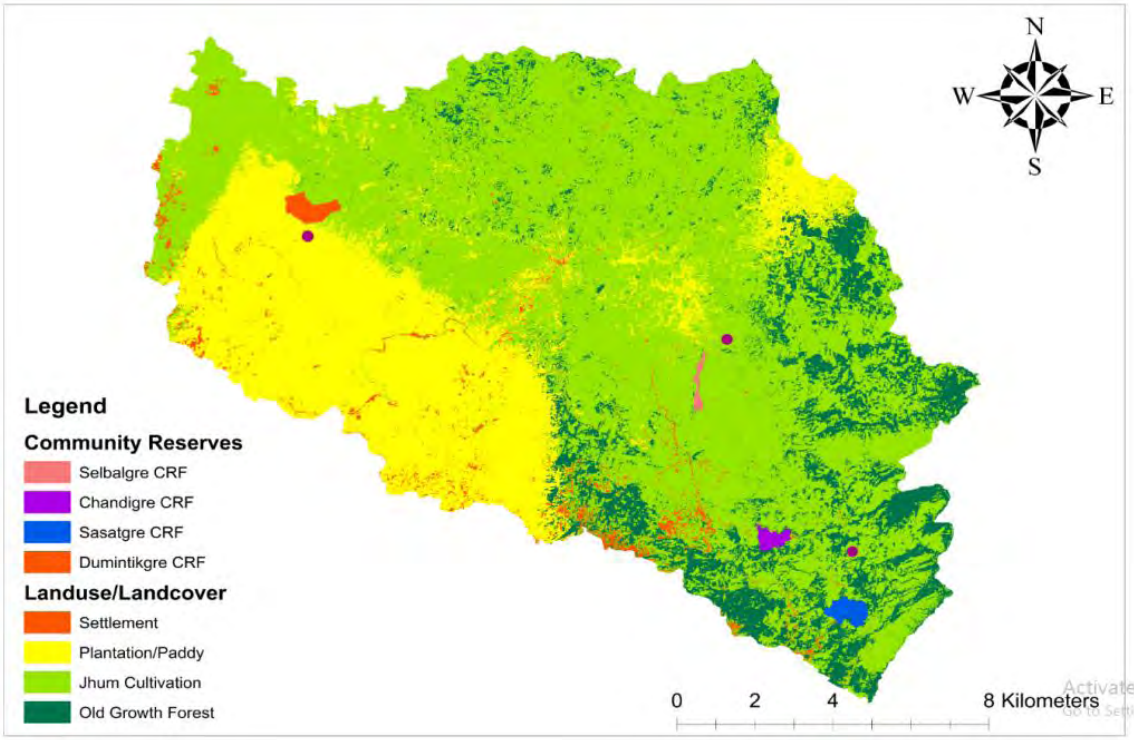


Figure 2: Study Area showing the compositional extent of shifting cultivation and Community Reserve forest. The pink dots represent sampling sites.

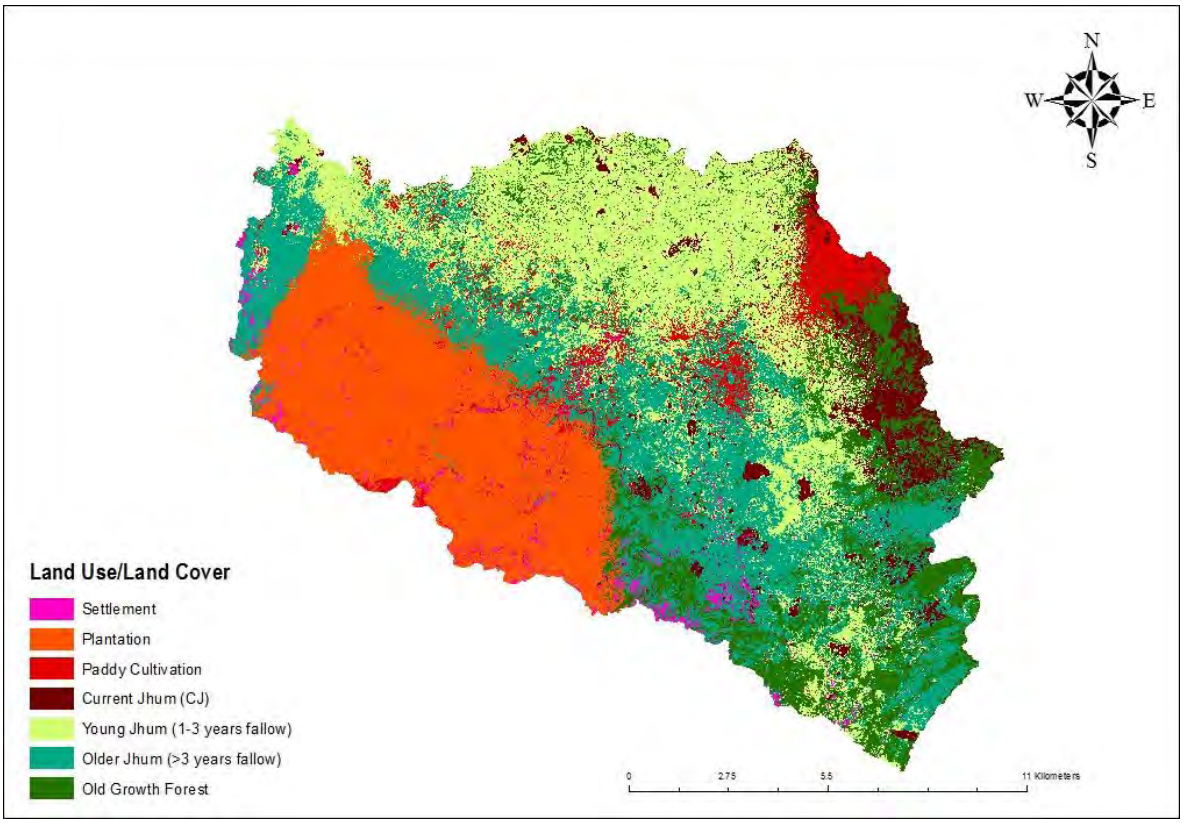


Figure 3: Study area showing the different landuse/landcover classes.

2.3 FAUNA`

The remnant old-growth patches of forests and protected forests harbor a rich faunal diversity in the face of anthropogenic impacts of forest dependence in the form of timber/bamboo and NTFP extraction, hunting and the extent as well as intensity of shifting cultivation (Kaul *et al*., 2010; Kunte *et al*., 2012). The landscape is home to diverse avian fauna including the Oriental Pied Hornbill *Anthracoceros albirostris*, Emerald Dove *Chalcophaps indica* and Hill Myna *Gracula religiosa*, all three of which face extensive hunting for food and ornamentation (Mohanto *et al*., 2009). The mammalian fauna of the area comprises of seven species of primates including the flagship species, Western Hoolock Gibbon *Hoolock hoolock*, an assemblage of small mammals including two species of threatened pangolins (Indian Pangolin *Manis crassicaudata* and the Chinese Pangolin *Manis pentadactyla*), four species of small cats, seven species of ungulates and large mammals like the Tiger *Panthera tigris*, Leopard *Panthera pardus*, Clouded Leopard *Neofelis nebulosa*, Asian Elephant *Elephas maximus* (Lyngdoh *et al*., 2019).

`2.3.1 Butterflies

Kunte (2020) reported 298 species of butterflies from Garo Hills, eight of which are protected under Schedule I and 33 under Schedule II of India's Wildlife (Protection) Act, 1972. Another report on the Butterflies of Meghalaya submitted to the Meghalaya Forest Department documented 382 species of butterflies in Garo Hills (Bora, 2017 *unpublished work*).

3. METHODS

3.1 STUDY DESIGN

3.1.1 Shifting Cultivation and Successional Strata

Jhum cultivation or shifting cultivation involves clearing an older fallow of secondary successional vegetation (bamboo forests and small trees) in the months of January-February, drying the felled/slashed area/vegetation and burning the patches immediately after in March. Crops are sown towards mid-March and April with the onset of the monsoon's first showers. A mixed-cropping system is followed where more than ten crops are sown in an area of 1-4 ha. In some parts of this area, two cycles of cultivation are followed, where, after the first harvest in November, the fields are prepared for another round of cultivation after which they are abandoned. Such fields may remain fallow for anywhere between 1-20 years. However, in the recent times, due to population pressure and increased demand, fields are being re-cultivated when they reach five years of fallow and patches greater than 8 years were rare in the study area.

A chrono-sequence of the successional sites was chosen after careful observation and extracting site histories from interviews with village elders. The successional strata that were sampled and the years in which they were abandoned are given below along with the general nature of vegetation. Botanical nomenclature in this paper follows Haridasan and Rao (1985).

1) Current *Jhum*: Older fallows that were being slashed and burnt for cultivation. It is to be noted that due to certain restraints in time, sampling could only be done in slashed fields.

2) 1st and 2nd year fallows (2019 and 2018): These fields were chiefly composed of a few stumps of burnt and dead trees, small bushes of upcoming trees, few surviving older trees, clumps of sprouting bamboo, grasses, weeds such as *Eupatorium odoratum*, *Mikania micrantha*, *Clerodendrum sp.*, and stalks of surviving crop plants – Tomato *Lycopersicon esculentum*, Chilli *Capsicum annum*, *Solanum sp.* such as Brinjal and 24 other similar species, stems of Tapioca *Manihot esculenta*, dried stalks of harvested Rice *Oryza sativa*, Banana *Musa sp.*, climbers and creepers belonging to the Pumpkin family, dried Sorrel stalks *Hisbiscus subdariffa* among other crops. The vegetation is mostly restricted to within 2 m from the

ground.

3) 3-7 years fallow (2017-2012): These were mostly dominated by dense bushes of invasive species like *Eupatorium odoratum, Mikania micrantha, Clerodendrum sp, Mucuna bracteata,* pioneering bamboo *Dendrocalamus sp.*, tall trees that survived the *jhum*ing process, upcoming tree species of the forest like *Grewia nervosa, Wrightia antidysentrica* along with pioneer trees like *Macaranga denticulata, Callicarpa arborea* and *Trema orientalis*. Vegetation was of uniform height of not more than 6 m with the exceptions of trees that had survived the *jhum*ing process. Vertical heterogeneity was visibly low. Bamboo clumps, emergent secondary growth was observed with most "trees" having 15-20 cm girth at breast height (GBH) on an average and visibly, if not significantly, lower invasive shrub cover.

4) > 8 years fallow excluding Community Reserves (abandoned since 2010 and before): These were disturbed sites mostly dominated by the presence of invasive shrubs – *Eupatorium odoratum, Eupatorium adenophorum, Mikania micrantha, Rubus sp., Clerodendrum sp.*, and some tall tree species along with tall bamboos. Though similar to the 7-year fallows, the general stature acquired by the trees and bamboos was greater.

Community Reserves (Dumintikgre, Selbalgre): It is to be noted that these Community Reserves are also abandoned fallows of more than ten years. Due to lesser disturbance, the tree species here had acquired a greater stature than the above mentioned classes and also a relatively closed canopy. The presence of invasive shrubs was much reduced and larger bamboo clumps were found along with trees such as *Castanopsis indica, Macaranga denticulata, Grewia nervosa, Bauhinia sp,* and *Michelia champaca*. Forest structure was considerably well-developed in comparison with the above explained classes and woody lianas as well as palms were present.

Sampling was done at two sites covering the extent of the study area and the four successional stages mentioned above, while keeping in mind the location of Community Reserves in the area. Sampling effort was distributed according to the extent of the successional stages in the study area.

3.2 BUTTERFLY SAMPLING

Butterfly sampling was done based on Kunte *et al.* (2012). Butterflies that included all individuals of the six families (Papilionidae, Nymphalidae, Pieridae, Lycaenidae, Hesperiidae and Riodinidae) in the sub-order Rhopalocera were enumerated in 30-minute time-constrained counts. The time-constrained method was adapted to the study on account of the hilly terrain and relatively high species diversity. This method is independent of the distance covered during a count. However, to account for equal sampling and detection in forested and open fallows, the pace of the walk in relation to the distance covered was standardized. Sampling was done only on hours favourable for butterfly species detection (09:00 am to 02:30 pm). Existing trails were walked at a slow pace approximately covering 0.50 km/hour on an average. During each 30- minute count, I walked alongside a field assistant and recorded all butterflies that were observed. Certain individuals belonging to complex genus (*Neptis* sp., *Mycalesis* sp., *Pantoporia* sp.) or those that could not be identified when in flight were captured using a hand-net, photographed and released immediately. To maximize detection in all the classes of successional strata, vegetation surrounding the path followed was disturbed with a stick to flush out individuals that may have been taking cover in the undergrowth. If a water body such as a river/stream was found to flow through Community Reserves and older fallows, care was taken to distribute counts along the water body and the forest. In this way, one limitation of the time-constrained method of not being able to account for individuals or species that fly at the canopy level was avoided as many (if not all) canopy-level fliers come down to the water bodies for basking or mud-puddling. The location and tracks of all counts were recorded using a handheld GPS device (Garmin Etrex 30).

Some data points had been replicated twice while some others, thrice. Due to this unequal replication, the two replicates (in points replicated thrice) with the higher species richness were retained for analyses.

Butterfly identification was done using latest field guides on the butterflies of the region – Kunte *et al* (2013), Kehimkar (2016) and Smetacek (2017). Individuals that were too fast to be identified without error and individuals belonging to cryptic groups of Sailers (genus Neptis) and Lascars (genus Pantoporia) whose accurate identification would have been possible only upon examination of certain morphological characters have been excluded from all analyses as they were not caught. Bushbrowns (genus Mycalesis) have been included in the analyses

as even though species-level identification was not possible, they constituted a considerable portion of the dataset. Species belonging to the *Neptis clinia / N. nata / N. soma* group have been treated to be a single unit as species-level identification is possible only with examination of genitalia. In the same way, unidentified individuals belonging to the genus Potanthus (darts) and Pelopidas (swifts) are also treated as a single unit, respectively.

Table 1: Summary of the counts done in the different successional strata across the two sites depicted as - No of data point sites (*No of replicates) Total number of counts

Site/LULC	**Current *Jhum* (CJ)**	**1-2 years fallow (1-2Y)**	**3-7 years fallow (3-7Y)**	**>8 year fallow (>8Y)**	**Community Reserve (>8Y)**
Dumintikgre	4(*3) 12	5(*3) 15	5(*3) 15		5(*3) 15
Selbalgre	3(*2) 6	7(*2) 14	9(*2)18	2(*2)4	5(*2) 10
Total number of counts	18	29	33	4	25
Total counts retained for analyses	14	24	28	4	20

Total number of counts in all successional strata – 109; after removal of replicates with lower species richness in the counts done in Dumintikgre, the total number of counts used for further analyses N = 45

3.3 HABITAT SAMPLING

A range of habitat variables were measured at the start and the end of a majority of counts. A few data point sites for which I could not measure habitat variables are excluded from relevant analyses.

i) Vegetation: All trees (> 20cm girth at breast height) and their respective heights were recorded in 10m circular plots and the tree species richness, tree density/ha and the average tree species height was calculated for each plot. The number of bamboo clumps was also recorded in the same plot. Canopy cover was measured with a spherical densiometer from four points inside the plot and % canopy cover for each plot was calculated (Lemmon, 1957). Vertical stratification for each plot was noted in the form of presence or absence of foliage at four points inside the plot in the following five height classes: <1m, 1-4m, 5-10m, 10-20m, >20m using a range-finder and quantified by averaging the number of presences in each plot

and dividing by the number of classes (5). This yielded an index with values ranging from 0-1 where 0 indicated no vertical heterogeneity while 1 indicated a high vertical stratification.
All shrubs (species excluding the seven invasive species that are accounted for as disturbance variables and tree saplings) were recorded in 5 m circular plots nested within the 10 m circular plot and the shrub species richness and shrub density/ha was calculated for each plot using the standard formula for density calculations.

ii) Disturbance: Two variables indicative of human disturbance were calculated for the 10 m circular plots mentioned above. Percentage cover of invasive species was calculated for *Eupatorium odoratum*, *Mikania micrantha*, *Mucuna bracteata* and *Clerodendrum* sp. respectively and the average (% cover) was calculated. The presence of logging and grazing was ascertained through observed number of cut/lopped branches and number of pellets/dung piles of cattle respectively. A human disturbance index with values ranging from 0 to 1 (0 – no disturbance and 1- highly disturbed) was formed by scoring the observed numbers with a cut off value and then averaged across the two scores of the two variables.

3.4 DATA ANALYSIS

To test for completeness of sampling, a species accumulation curve was computed using the software PAST. Ver.2.1. A measure of Estimated Species Richness (Chao-1), evenness (e^H/S) and diversity-Simpson's (1-D) were also computed.

Simpson's Index of diversity was chosen because of its sensitivity to changes in the most abundant species in the community as data is easier to obtain for such species (Magurran, 2004). To understand the variation of butterfly species richness (Observed Species Richness OSR and Estimated Species Richness ESR), abundance and diversity across successional strata, a One-way ANOVA was performed.

Butterfly species similarity between the four successional strata was measured using the Morisita Index. The Morisita Index was favoured because of its insensitiveness to small sample sizes (Magurran, 2004). A dendrogram was then generated using the matrix for representation. To test if there was significant variation in habitat variables between successional strata, a One-way ANOVA was performed.

A Principle Components Analysis was done with the measured variables (Tree Species Richness, Tree Species Density, Shrub Species Richness, Shrub Species Density, Invasive Species Cover and Canopy Cover Percent) and derived variables (Human Disturbance Index and Vegetation Tier Index) to derive a vegetation gradient by summarizing the variation in the data (Raman, Rawat, & Johnsingh, 1998). The analysis was done using the PAST software, with the variance- covariance matrix and 1000 bootstraps).

For analysis of successional trends in butterfly and habitat variables, the sites were ranked according to the successional age and Spearman's correlations (Zar, 1999) were performed with the extracted PC scores.

4. RESULTS

4.1 BUTTERFLY SPECIES COMMUNITY

A total of 1270 individuals of 124 positively identified species belonging to six families (Table2) (Papilionidae - 9 species, 36 individuals; Nymphalidae - 54 species, 626 individuals; Pieridae - 15 species, 340 individuals; Lycaenidae - 27 species, 130 individuals; Hesperiidae - 17 species, 41 individuals and Riodinidae - 2 species, 97 individuals) were recorded in 90 half-hour counts (45 hours) and 58 species were recorded more than two times overall. The species accumulation curve computed to check the completeness of sampling in the overall shifting cultivation landscape revealed that the sampling was not adequate enough yet to account for the species assemblages in the landscape.

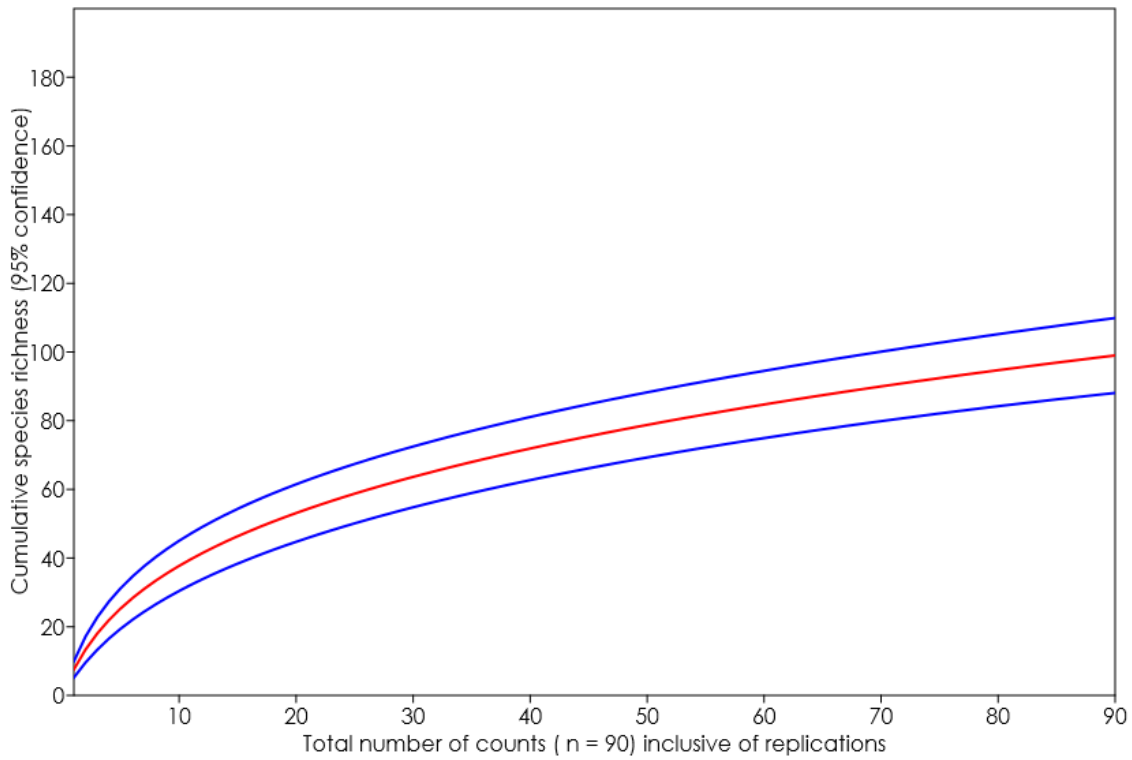


Figure 4: Computed sample rarefaction curve for the overall shifting cultivation landscape. N = 90 is the total number of samples across 45 data points, each replicated twice. (Bootstrap =1000 was done to generate the 95% confidence intervals).

Chao-1 species richness estimators (hereafter mentioned as Estimated Species Richness ESR) indicated that the studied species assemblages across the four successional stages were not yet completely recorded. Completeness of sampling ranged from 66.1% in the Current *Jhum* (CJ) class to 88.7% in 3-7 years fallow (3-7 Y) (Table 3).

Table 2: Species richness and species abundance across the six butterfly families.

Family	**No. of species**	**% of total species**	**No. of individuals**	**% of total number of individuals**
Hesperiidae	17	13.7	41	3.2
Lycaenidae	27	21.8	130	10.2
Nymphalidae	54	43.5	626	49.3
Papilionidae	9	7.3	36	2.8
Pieridae	15	12.1	340	26.8
Riodinidae	2	1.6	97	7.6

Table 3: Butterfly species richness, number of individuals, diversity and evenness across the four successional stages (N =45, each data point with two replications)

Successional Stage	**Number of samples (n)**	**Observed Species Richness (OSR)**	**Av. Species Richness± S.D**	**Estimated Species Richness Chao-1 (ESR)**	**Sample Coverage (%)**	**Number of individuals**	**Av. Abundance ±S.D**	**Diversity measure Simpson's 1-D**	**Evenness measure e^H/S**
Current *Jhum* (CJ)	7	24	4.6 ± 1.7	36.33	66.1	88	6.3 ± 2.6	0.79	0.39
1-2 years fallow (1-2 Y)	12	58	9.5 ± 2.6	75.5	76.8	334	13.5 ± 3.9	0.94	0.481
3-7 years fallow (3-7 Y)	14	69	10.3 ± 4.4	77.75	88.7	441	15.8 ± 6.6	0.94	0.435
>8 years fallow (8 Y)	12	93	11.4 ± 5.9	128.1	72.6	407	16.9 ± 8.2	0.96	0.45

Junonia lemonais Yellow Pansy (Nymphalidae) was found to be the most abundant species in the landscape representing 125 (9.8%) individuals of the total number of individuals observed, while *Zemeros flegyas* Punchinello (Riodinidae) was the second most abundant species overall accounting for 94 (7.4%) individuals (Table 4). 47 species occurred as single units; 31 species were detected more than 10 times in the overall landscape.

Table 4: A summary of the five most abundant species in the overall shifting cultivation landscape

Scientific name	Common Name	Family	Abundance	Relative abundance
Junonia lemonais	Lemon Pansy	Nymphalidae	125	9.8
Zemeros flegyas	Punchinello	Riodiniidae	94	7.4
Delias descombesi	Red-spot Jezebel	Pieridae	74	5.8
Neptis hylas	Common Sailer	Nymphalidae	61	4.8
Mycalesis sp.	Bushbrown sp	Nymphalidae	58	4.6
Appias lyncida	Chocolate Albatross	Pieridae	56	4.4

4.2 TRENDS OBSERVED WITH RESPECT TO FALLOW AGE

4.2.1 Butterfly Species Assemblages

It was found that species richness was considerably high in >8 years fallows with 93 (Observed Species Richness) and 128.1 (Estimated Species Richness) species and that the Current *Jhum* stage had the least species richness (mean 7 ± 1.9 S.D) (Table 3). Species abundance was found to be highest in >8 year fallows (mean 33.9 ± 14.7 S.D) and lowest in current *jhum* stages (mean 12.6 ± 4 S.D) Above 8 years fallows had the highest species diversity but only marginally when compared to 1-2 years fallows. Species evenness measure computed showed that Butterfly species frequencies were distributed more evenly in 1-2 years fallow. (Table 2).

Species richness and abundance varied significantly across the four successional stages (OSR: $\chi^2 = 16.14$, $p < 0.05$; abundance: $\chi^2 = 17.10$, $p < 0.05$) and showed significant positive correlations with fallow age (Spearman's correlation r_s – 0.496**, 0.480** and 0.377* with $p < 0.05$).

There was a clear variation in the butterfly species composition between successional stages (Appendix 1, Figure 5). Table 5 lists the three most abundant species in each successional stage. While *Junonia lemonais* is seen to be one of the most abundant species in each of the first three successional stages, it is not one of the abundant species in the >8 years fallows which have the *Mycalesis* sp., *Zemeros flegyas* and *Melanitis leda* representing the more abundant species in the stage signifying the presence of specialists in the later stages of succession.

To identify the forest specialist species, 20 butterfly species which were found in both the clear- cut (CJ) and early successional stage (1-2Y) were classified to be generalist species. 73 forest specialist species were then identified by removing the 20 classified generalist species from the 93 species detected in >8 year fallows (Appendix 1).

Table 5: Abundances and relative abundance of the three most detected butterflies in each successional strata

Successional Stages	**Scientific name**	**Species name**	**Family**	**Abundance**	**Relative Abundance**
CJ	*Junonia lemonais*	Lemon Pansy	Nymphalidae	27	0.31
	Zemeros flegyas	Punchinello	Riodinidae	12	0.14
	Delias descombesi	Red-spot Jezebel	Pieridae	11	0.13
1-2Y	*Pseudozizeeria maha*	Pale Grass Blue	Lycaenidae	38	0.11
	Junonia lemonais	Lemon Pansy	Nymphalidae	32	0.10
	Appias lyncida	Chocolate Albatross	Pieridae	24	0.07
3-7Y	*Junonia lemonais*	Lemon Pansy	Nymphalidae	56	0.13
	Zemeros flegyas	Punchinello	Riodinidae	40	0.09
	Neptis hylas	Common Sailer	Nymphalidae	31	0.07
>8Y	*Mycalesis sp*	Bushbrown sp	Nymphalidae	46	0.11
	Zemeros flegyas	Punchinello	Riodinidae	25	0.06
	*Melanitis leda**	Common Evening Brown*	Nymphalidae	22	0.05

**Melanitis leda* was tied *with Delias descombesi* and *Delias pasithoe* for being the third most abundant species in the >8Y fallow.

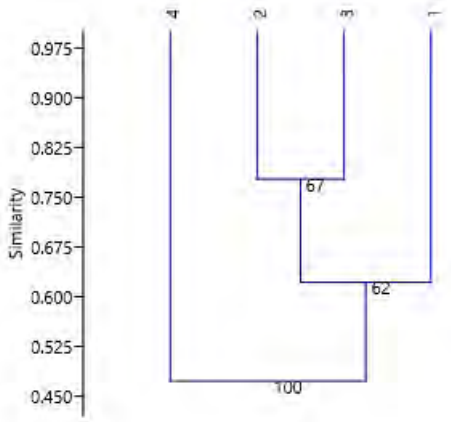


Figure 5: The dendrogram representing butterfly species compositional similarity computed using the Morisita Indices matrix. The sites 1, 2, 3 and 4 represent CJ, 1-2Y, 3-7Y and >8Y fallows respectively.

Species turnover through the successional stages was examined using a matrix of Morisita similarity indices computed with the overall species composition in each of the successional stages. A cluster analysis of the same was also performed for representation. As shown by Figure 5, the butterfly species compositions were least similar between the >8 years fallows and Current *Jhum* stages (Morisita Index 0.35) and less with the other two successional stages (0.43 and 0.62 similarity), supporting the previous result that the >8 years fallows harbour a significantly varied species assemblage from the other stages. The butterfly species compositional similarity between the 3-7 years fallow stages and the early successional stages (1-2 years fallows and Current *Jhum* stage) was high (0.77 – 0.72 similarity) which might be due to the breadth of the class or relatively higher sampling.

The number of species recorded in each butterfly family also varied across the successional strata (Table 6). Though Nymphalids were found to dominate across successional strata, a relatively higher number of species were found in >8 years fallows.

It was also seen that while Nymphalids seemed to dominate in each successional stage with respect to species richness (Figure 6) and abundances (Figure 7), however, lycaenids and pierids also seemed to do well Current *jhum* patches and 1-2 years fallows. With respect to abundances, lycaenids and pierids seemed have higher abundances in 1-2 years fallows when compared to other families.

Table 6: A summary of the number of species of each of the six families of butterflies sampled across the successional strata

Family	**CJ**	**1-2Y**	**3-7Y**	**>8Y**
Hesperiidae	1	3	7	13
Lycaenidae	6	13	14	16
Nymphalidae	7	26	31	42
Papilionidae	3	5	4	9
Pieridae	6	10	12	11
Riodinidae	1	1	1	2
Total number of species	24	58	69	93

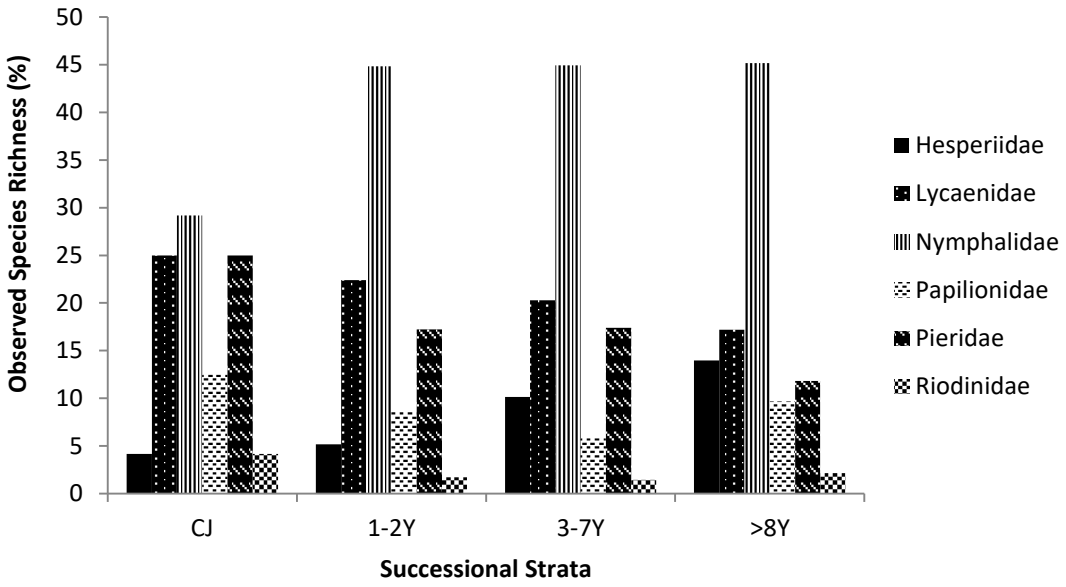


Figure 6: Family-wise proportion of species recorded in each successional stage.

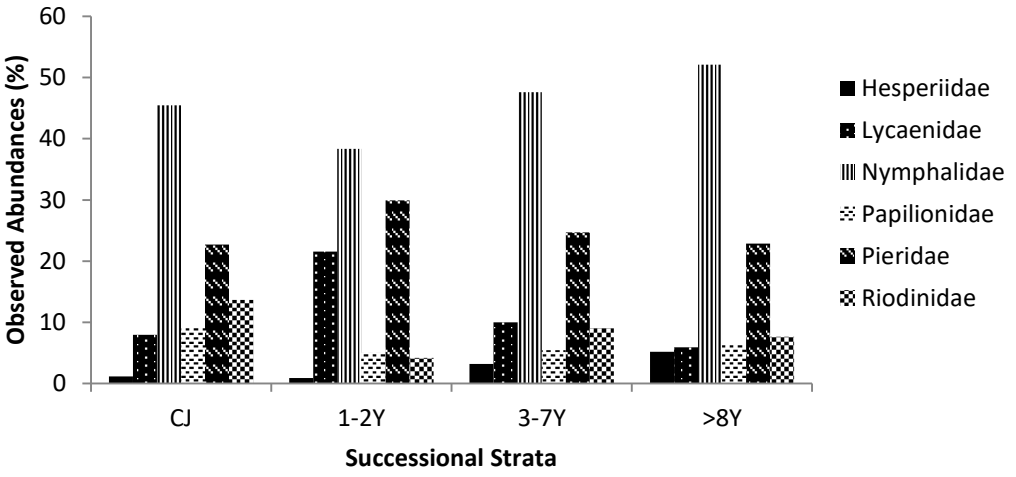


Figure 7: Family-wise proportion of butterfly abundances recorded in each successional stage.

4. 2. 2 Habitat Variables

a) Vegetation composition and structure

There was a marked difference in the measured and derived variables across successional strata. Habitat variables such as tree species richness (TSR), tree species density/ha (TSD), shrub species richness (SSR), shrub species density/ha (SSD), vegetation tier (which was a derived variable - VTI) and canopy cover in percentage (CCP) varied significantly across successional strata (TSR: $\chi^2 = 32.019$; TSD : $\chi^2 = 31.909$; SSR : $\chi^2 = 19.09$; SSD : $\chi^2 = 18.667$;

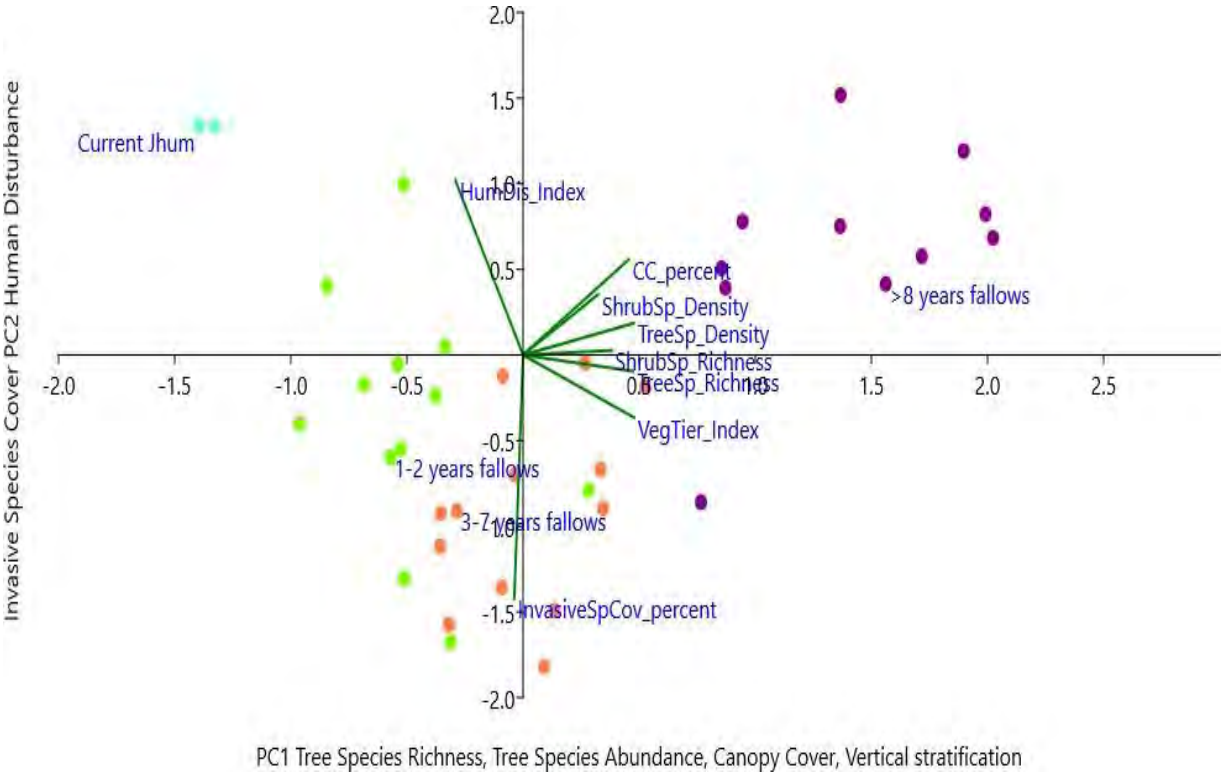
VTI : $\chi^2 = 33.313$; CCP : $\chi^2 = 34.482$) with $p < 0.05$ and increased significantly with fallow age (Spearman's r_s =0.868, 0.866, 0.655, 0.609, 0.886 and 0.891 respectively, $p < 0.05$).

b) Disturbance variables

The disturbance variables collected include, invasive species cover (ISC) and the human disturbance index (HDI) derived using the two measured variables (number of cut-stems and number of pellets/cow dung) varied significantly across the four successional strata (ISC: χ^2 = 25.876, $p < 0.05$; HDI : χ^2 = 18.548, $p < 0.05$)). There was a significant negative correlation of human disturbance with increase in the age of the successional strata (Spearman's correlation r_s = -0.541585, $p < 0.0501$) while the invasive species cover did not show any significant correlations with the fallow age.

4.3 PRINCIPAL COMPONENTS ANALYSIS (PCA) OF HABITAT VARIABLES

Principal Components which had an Eigen value >1 were taken into account (Table 6). The PCA extracted two components PC1, PC2 and PC3 which accounted for 86.98% of the variance in the dataset. While PC1 was positively correlated with tree species richness, tree density, shrub species richness, shrub species density, canopy cover and vertical stratification; PC3 also showed significant positive correlations with shrub species richness and shrub species density (Table 7). When factor loadings were checked, higher values (>0.4) for shrub species richness and shrub species density in PC3 than in PC1 were found (Table 8). However, since



the correlation values for shrub species richness and shrub species density were marginally higher for PC1 than PC3, only PC1 and PC2 were taken into account, thus, accounting for 74.42% of the variance in the dataset. PC1 was found to be significantly negatively correlated with human disturbance. PC2 was correlated positively with the human disturbance index and negatively with invasive species cover. The observed trends in habitat with respect to fallow age are summarized clearly when the study sites were ordinated in the PC1-PC2 graph (Figure 6).

Figure 8: Ordination of successional sites using Principal Components Analysis of the measured and derived habitat variables.

The majority of data points in each successional stage are adjacent to each other. This is explicitly seen in >8 year fallows (except one data point) and current *jhum* strata. However, with the 1-2 year fallows and the 3-7 years fallow data points, there seems to be a marginal overlap (Figure 6).

Table 7: Vegetation variables summarised after a PCA and the correlation values with the original variables.

	Principal Components		
	PC1#	PC2#	PC3
Eigen value	4.468	1.4846	1.00
Variance explained %	55.856	18.558	12.575
Cumulative variance explained %	56.856	74. 414	86.989
Factor loadings			
Tree Species Richness	0.428	-0.049	-0.303
Tree Species Density	0.430	0.096	-0.298
Shurb Species Richness	0.345	0.012	0.539
Shrub Species Density	0.291	0.183	0.665
Vegetation Tier Index	0.432	-0.190	-0.005
Canopy Cover Percent	0.418	0.290	-0.194
Invasive Species Cover	-0.034	-0.740	0.175
Human Disturbance Index	-0.264	0.533	0.129

#only these components were taken into account after looking at the correlation values

It can be seen that with increase in successional age starting from current *jhum* to 8 & >8 year fallows, tree species richness, tree density, vertical heterogeneity and canopy cover also increased. The current *jhum* stage can be observed to be located at the lowest values of PC1 and signifying high human disturbance. Though clear-cut patterns are not seen for the 1-2 years fallows and 3-7 years fallows, it can be seen that the majority of data points in younger fallows of 1-2 years have no significant or unique vegetation characteristics such as tree species richness, tree density, vertical heterogeneity and canopy cover. In the intermediate successional stages, invasive species cover dominate and reduce with increasing human disturbance (logging and grazing) and the variables that represent PC1.

Current *jhum* patches are found along the highest values of human disturbance. Thus, PC1 can be said to be associated with vegetation succession and forest development while PC2 can be said to represent disturbance of two types. Though these were the trends observed in the results, it is pertinent to note that the sample is low and significant conclusions cannot be derived as they may not represent the actual field scenario.

Table 8: Spearman's correlations of the original variables with the extracted PC1, PC2 and PC3 scores

Variables	**PC1**	**PC2**	**PC3**
Tree Species Richness	0.911**	-0.163	-0.349*
Tree Species Density	0.911**	-0.146	-0.320*
Shrub Species Richness	0.718**	-0.041	-0.320*
Shrub Species Density	0.673**	0.087	0.539**
Vegetation Tier Index	0.927**	-0.175	0.602**
Canopy Cover Percent	0.872**	0.003	-0.271
Invasive Species Cover	0.099	-0.920**	0.173
Human Disturbance Index	-0.562**	0.578**	0.156

4.4 BUTTERFLY ASSEMBLAGES IN RELATION TO VEGETATION SUCCESSION

When butterfly species richness (OSR), abundance and diversity was correlated to the PC1 scores of the sites, significant positive correlations were obtained (Spearman's correlation r_s = 0.454**, 0.506** and 0.418*respectively, **p < 0.01). No significant negative correlations were obtained when PC2 values were correlated with butterfly species richness and diversity. However, butterfly species abundance was significantly negatively correlated (Butterfly Species Abundance: Spearman's correlation r_s = -0.361336, p < 0.05).

5. DISCUSSION

5.1 BUTTERFLY SPECIES ASSEMBLAGES AND RECOVERY PATTERNS

Despite certain methodological and sampling constraints, my results indicate that butterfly species richness (OSR), abundance and diversity show a general increasing trend with increase in successional age as evidenced by other similar studies investigating butterfly communities across a gradient of disturbance (Bowman, Woinarski, Sands, Wells, & McShane, 1990; Ghazoul, 2002). It is in the later stages of succession where butterfly species or faunal communities in general, positively become more complex as the habitat complexity in the later successional stages is much higher.

The species assemblages were dominated by species from the butterfly family Nymphalidae and also across successional stages. This can be due to Nymphalidae being the most speciose of the butterfly families found in India, with a recorded 563 species (Kunte, 2020) which holds true for the region as a whole, with Garo Hills reportedly having 123 species (Kunte et al., 2012). Nymphalids, also known as the fruit- feeding butterflies, are preferred to other butterfly families in most studies of butterfly communities (Helzer & Jelinski, 1999; Molleman, Kop, Brakefield, De Vries, & Zwaan, 2006; Sáfián, Csontos, & Winkler, 2011; Veddeler & Schulze, 2005) owing to the family having both species that are resilient to high disturbances (generalists) as well as forest specialists. The present study corroborates the above as seen by the presence of open-country species (eg: *Junonia lemonais*, *Neptis hylas*) in addition to forest specialists (eg: *Kallima inachus, Cethosia cyane*) (Appendix 1). Sáfián *et al*. (2011) in his study of fruit- feeding butterfly communities showed that while some species of Nymphalidae like *Charaxes* sp can persist in disturbed sites, other species belonging to the subfamily Limenitidae were restricted to the primary forests. The highest number of Nymphalids were however recorded from the later successional stage, >8 years fallow as it can notionally be inferred that resources are more abundant (larval host plants) in this strata in addition to more niches.

It was also seen that, while Nymphalids seemed to dominate in all the successional stages, lycaenids and pierids seemed to do well in the early successional stages. As seen during field observations also, lycaenids such as the Grass Blues, were seen in higher numbers in the 1-2

years fallows as higher resources such as small nectaring plants and roost sites are available here more than other successional stages. These are however, only field observations.

Trends in butterfly species turnover across vegetation successional classes in this study suggest greater similarity of butterfly species composition between 1-2 years fallows and 3-7 years fallows.

Probably, much clearer results could be obtained if the 3-7 years fallow basket (in addition to a higher sample size) was split into two baskets.

5.2 BUTTERFLY SPECIES ASSEMBLAGES RESPONSE TO HABITAT VARIABLES

All but one (invasive species richness) measured and derived habitat variables were significantly correlated with fallow age. Habitat variables showed strong positive relationships with fallow age while human disturbance had a strong negative relationship with fallow age.

A majority of studies looking at vegetation succession following human disturbance (Toky & Ramakrishnan, 1983; Bowman *et al.*, 1990; Raman *et al.*, 1998; Teegalapalli & Samal, 2009; Yirdaw et al., 2019) reported a similar trend of tree species richness increasing with increase in fallow age. However, it should also be kept in mind that while tree species richness and density increase towards later successional stages, species composition might take several years to recover (Bowman *et al*., 1990; Raman *et al*., 1998; Teegalapalli & Samal, 2009; Toky & Ramakrishnan, 1983; Yirdaw *et al*., 2019).

Butterfly species richness (OSR and ESR), abundance and diversity significantly increased with increase in the forest succession-related variables (PC1). Many studies which have investigated the role of micro-climate (Checa et al., 2014; Dolia et al., 2008), which in turn is influenced by vegetation structure, suggest that intense habitat alterations, for instance, clear-cut patches of Current *Jhum,* have adverse effects on butterfly species assemblages and composition. This is corroborated by the present study as well. Eighty-three per cent of the species recorded in current *jhum* patches were found to be open-country species, while the later successional strata with higher vegetation structure and habitat complexity had a higher proportion of forest-specialists (78.49%).These trends are backed up by previous studies where, tree species density and richness have been found to be the best predictors of butterfly species richness and other faunal groups such as birds (Bobo et al., 2006; Raman et

al., 1998).

Highly “disturbed” Current *Jhum* fallows accounted for lower butterfly species richness and abundance in the studied landscape. Almost all of the species found in the Current *Jhum* fallows has been classified as “generalist” species (Appendix 1) while 73 species of the 93 found in later successional fallows (>8 years fallows) were found to be forest species. This inference corroborates with other similar studies (Hill et al., 1995; Sáfián et al., 2011) suggesting that clear-cut patches are immediately colonised by generalist species while forest species are unlikely to persist in highly disturbed landscapes.

5.3 CONSERVATION SIGNIFICANCE - IMPORTANCE OF SECONDARY FORESTS AND ADEQUACY IN PROTECTION

One of the significant findings of this short-term study is that, in the shifting cultivation landscape of Garo Hills, in general, the inherent butterfly diversity of the landscape is high. Though sampling was inadequate as the results indicate, with only 45 hours of sampling effort distributed across 30 days, a total of 1270 individuals of 124 species were detected in the four successional strata. This shows that the mosaic of secondary successional stages formed due to shifting cultivation does in fact, contribute to heterogeneity in the landscape (Finegan & Nasi, 2004) which in turn provides varied niches for many species to colonise. The increased butterfly species richness and diversity in late successional stages and the high proportion of forest species shows that, these older secondary formations provide refuge to the forest specialists in the face of adverse habitat alterations as in the case of shifting cultivation. The intensity and extent of disturbance in this landscape has to be taken into account. It was observed that the study area was almost devoid of primary patches of forest and that intensification of shifting cultivation has occurred over years as indicated by other studies in the region (Raman et al., 1998; Toky & Ramakrishnan, 1983). It is pertinent to note that the majority of data points of older fallows (>8Y fallows) fall in Community Reserves and thus, increased butterfly species richness and diversity need not necessarily be attributed to only the fallow age but may be a function of protection. However, this has not been tested in this study on account of the low sample size. The study also lacks a control/ reference stage such as a primary forest.

Nevertheless, the importance of secondary successional stages for butterfly and vegetation

recovery after shifting cultivation (Chazdon, 2019; Chazdon *et al*., 2009) has been shown by this study. The results also lay emphasis on the importance of protection of older fallows as they can be of high conservation value (Dunn, 2004) especially for forest-dependent specialist butterfly species, as highlighted in this study.

REFERENCES

Bobo, K. S., Waltert, M., Fermon, H., Njokagbor, J., and Mühlenberg, M. 2006. From forest to farmland: Butterfly diversity and habitat associations along a gradient of forest conversion in Southwestern Cameroon. *Journal of Insect Conservation*, *10*:29–42.

Bonebrake, T. C., Ponisio, L. C., Boggs, C. L., and Ehrlich, P. R. 2010. More than just indicators: A review of tropical butterfly ecology and conservation. *Biological Conservation*, *143*:1831–1841.

Bora, A. 2017. *Final report on Butterflies of Meghalaya*. https://doi.org/10.1007/ BF02473769

Bowman, D. M. J. S., Woinarski, J. C. Z., Sands, D. P. A., Wells, A., and McShane, V. J. 1990. Slash- and-Burn Agriculture in the Wet Coastal Lowlands of Papua New Guinea: Response of Birds, Butterflies and Reptiles. *Journal of Biogeography*, *17*: 227-239

Brown, S. and Lugo, A. E. 1990. Tropical secondary forests. *Journal of Tropical Ecology*, *6*:1–32.

Chazdon, R. L. 2019. Towards more effective integration of tropical forest restoration and conservation. *Biotropica*, 51:463–472

Chazdon, R. L., Peres, C. A., Dent, D., Sheil, D., Lugo, A. E., Lamb, D., and Miller, S. E. 2009. The potential for species conservation in tropical secondary forests. *Conservation Biology*, *23*:1406–1417.

Checa, M. F., Rodriguez, J., Willmott, K. R., and Liger, B. 2014. Microclimate Variability Significantly Affects the Composition, Abundance and Phenology of Butterfly Communities in a Highly Threatened Neotropical Dry Forest. *Florida Entomologist*, *97*:1–13.

Critical Ecosystem Partnership Fund. 2012. *Indo-Burma Biodiversity Hotspot. Ecosystem Profile*. 360 pp.

Dirzo, R. and Raven, P. H. 2003. Global State of Biodiversity and Loss. *Annual Review of Environment and Resources*, *28*:137–167.

Dolia, J., Devy, M. S., Aravind, N. A., and Kumar, A. 2008. Adult butterfly communities in coffee plantations around a protected area in the Western Ghats, India. *Animal Conservation*, *11*:26– 34.

Dunn, R. 2004. Recovery of Faunal Communities During Tropical Forest Regeneration. *Conservation Biology, 18*:302–309.

Finegan, B. and Nasi, R. 2004. The biodiversity and conservation potential of swidden agricultural landscapes. In G. Schroth, H. Vasconcelos, C. A. Harve, C. Gascon, & G. Fonseca (Eds), *Agroforestry and Biological Conservation in Tropical Landscapes*. Island Press. 537 pp.

Forest Survey of India. 2019. In *Indian State of Forest Report*. 173–181 pp.

Ferraz, S. F. B., Ferraz, K. M. P. M. B., Cassiano, C. C., Brancalion, P. H. S., da Luz, D. T. A., Azevedo, T. N., and Metzger, J. P. 2014. How good are tropical forest patches for ecosystem services provisioning? *Landscape Ecology*, *29*:187–200.

Gardner, T. A., Barlow, J., Chazdon, R., Ewers, R. M., Harvey, C. A., Peres, C. A., and Sodhi, N. S. 2009. Prospects for tropical forest biodiversity in a human-modified world. *Ecology Letters*, *12*:561–582.

Gascon, C., Bruce Williamson, G., and da Fonseca, G. A. B. 2000. ECOLOGY: Receding Forest Edges

and Vanishing Reserves. *Science*, *288*:1356–1358.

Geldmann, J., Barnes, M., Coad, L., Craigie, I. D., Hockings, M., and Burgess, N. D. 2013. Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. *Biological Conservation*, *161*:230–238.

Gentry, A. H. 1992. Tropical forest biodiversity: distributional patterns and their conservational significance. *OIKOS*, *63*:19-28

Ghazoul, J. 2002. Impact of logging on the richness and diversity of forest butterflies in a tropical dry forest in Thailand. *Biodiversity and Conservation*, *11*:521–541

Gibson, L., Lee, T. M., Koh, L. P., Brook, B. W., Gardner, T. A., Barlow, J., and Sodhi, N. S. 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature*, *478*:378–381.

Gilbert, L. E., and Singer, M. C. 1975. Butterfly Ecology. *Annual Review of Ecology and Systematics*, *6*:365–395.

Gueratto, P. E., Carreira, J. Y. O., Santos, J. P., Tacioli, A., and Freitas, A. V. L. 2020. Effects of forest trails on the community structure of tropical butterflies. *Journal of Insect Conservation*, *24*:309–319.

Haridasan, K and Rao, R.R. 1985. *Forest Flora of Meghalaya*. Scientific Publishers, Jodhpur. 1381 pp.

Helzer, C. J. and Jelinski, D. E. 1999. The relative importance of patch area and perimeter-area ratio to grassland breeding birds. *Ecological Applications*, *9*:1448–1458.

Hill, J. K., Hamer, K. C., Lace, L. A., and Banham, W. M. T.1995. Effects of Selective Logging on Tropical Forest Butterflies on Buru, Indonesia*, British Ecological Society, 32*:754–760.

KassiN'Dja, J. K. and Decocq, G. 2008. Successional patterns of plant species and community diversity in a semi-deciduous tropical forest under shifting cultivation. *Journal of Vegetation Science*, *19*:809–820.

Kaul, R., Tiwari, S.K., Kyarong, S., Dutta, R. and Menon, V. 2010. *Canopies and Corridors- Conserving the forests of Garo Hills with elephants and gibbons as flagships*, Wildlife Trust of India. 167 pp.

Kehimkar, I. and Gayathri, V.D. 2016. *Butterflies of India.* BNHS Field Guides. Bombay Natural History Society, Mumbai. 528 pp.

Kitahara, M. and Fujii, K. 1994. Biodiversity and community structure of temperate butterfly species within a gradient of human disturbance: An analysis based on the concept of generalist vs. Specialist strategies. *Researches on Population Ecology*, *36*:187–199.

Kleinman, P. J. A., Pimentel, D., and Bryant, R. B. 1995. The ecological sustainability of slash-and-burn agriculture. *Agriculture, Ecosystems and Environment*, *52*:235–249.

Koh, L. P. 2007. Impacts of land use change on South-east Asian forest butterflies: A review. *Journal of Applied Ecology*, *44*:703–713.

Kremen, C. 1992. Assessing the Indicator Properties of Species Assemblages for Natural Areas Monitoring. *Ecological Applications*, *2*:203–217.

Kunte, K., Sondhi, S., Sangma, B. M., Lovalekar, R., Tokekar, K., and Agavekar, G. 2012. Butterflies of the Garo Hills of Meghalaya, northeastern India: their diversity and conservation. *Journal of Threatened Taxa*, *4*:2933–2992.

Kunte, K. 2020. Species checklists, including regional and National Butterflies of S. Asia. In: Kunte, K., S. Sondhi, and P. Roy (Eds.). Butterflies of India, v.3.10. Indian Foundation for Butterflies. 161 pp.

Kurien, A. J., Lele, S., and Nagendra, H. 2019. Farms or Forests? Understanding and mapping shifting cultivation using the case study of West Garo hills, India. *Land*, *8*:1–3.

Lawton, J. H., Bignell, D. E., Bolton, B., Bloemers, G. F., Eggleton, P., Hammond, P. M., and Watt,

A. D. 1998. Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. *Nature*, *391*:72–76.

Lyngdoh, A. W., Kumara, H. N., Karunakaran, P. V. and Babu, S. 2019. A review on status of mammals in Meghalaya, India. *Journal of Threatened Taxa*, *11*:14955–14970.

Magurran, A. E. 2004. *Measuring Biological Diversity*. Blackwell Publishing Company, Oxford, UK. 215 pp.

Mansourian, S. and Dudley, N. 2008. *Public Funds to Protected Areas*. https://doi.org/10.13140/RG.2.1.3869.5286

Martínez-Sánchez, N., Barragán, F., and Gelviz-Gelvez, S. M. 2020. Temporal analysis of butterfly diversity in a succession gradient in a fragmented tropical landscape of Mexico. *Global Ecology and Conservation*, *21*.

McNeely, J. A. and Schroth, G. 2006. Agroforestry and biodiversity conservation - Traditional practices, present dynamics, and lessons for the future. *Biodiversity and Conservation*, *15*:549– 554.

Meghalaya Biodiversity Board. 2017. *The Meghalaya State Biodiversity Strategy and Action Plan*. pp123.

Mohanto, R. K., Kumar, D., Adhikari, B. S., and Bhardwaj, A. 2009. Status and Distribution of Birds at and around wildlife and territorial Division Forest Office premises, New Tura, West Garo Hills, Meghalaya. *Indian Forester*, 1437–1441.

Molleman, F., Kop, A., Brakefield, P. M., De Vries, P. J., and Zwaan, B. J. 2006. Vertical and temporal patterns of biodiversity of fruit-feeding butterflies in a tropical forest in Uganda. *Biodiversity and Conservation*, *15*:107–121.

Nilsson, S. G., Franzén, M., and Pettersson, L. B. 2013. Land-use changes, farm management and the decline of butterflies associated with semi-natural grasslands in southern Sweden. *Nature Conservation*, *48*: 31–48.

Nyafwono, M., Valtonen, A., Nyeko, P., and Roininen, H. 2014. *Butterfly Community Composition Across a Successional Gradient in a Human-disturbed Afro-tropical Rain Forest*. *46*:210–218.

Padoch, C. and Pinedo-vasquez, M. 2010. *Saving Slash-and-Burn to Save Biodiversity*. *42*:550– 552.

Raman, S. T. R. 2001. Effect of slash-and-burn shifting cultivation on rainforest birds in Mizoram, Northeast India. *Conservation Biology*, *15*:685–698.

Raman, S. T. R., Rawat, G. S., and Johnsingh, A. J. T. 1998. Recovery of tropical rainforest avifauna in relation to vegetation succession following shifting cultivation in Mizoram, north-east India. *Journal of Applied Ecology*, *35*:214–231.

Ranjan, R. and Upadhyay, V. P. 1999. Ecological problems due to shifting cultivation. Current *Science*,

77:1246–1250.

Rice, R. E., Sugal, C. A., Ratay, S. M., and da Fonseca, G. A. B. 2001. Sustainable Forest Management: A Review of Conventional Wisdom. *Advances in applied biodiversity science*.pp29

Sáfián, S., Csontos, G., and Winkler, D. 2011. Butterfly community recovery in degraded rainforest habitats in the Upper Guinean Forest Zone (Kakum forest, Ghana). *Journal of Insect Conservation*, *15*:351–359.

Schulze, C. H. and Steffan-Dewenter, I. 2004. *Effects of Land Use on Butterfly Communities at the Rain Forest Margin: A Case Study from Central Sulawesi*. https://doi.org/10.1007/978-3-662- 08237-9

Singh, B., Phukan, S. J., Sinha, B. K., Singh, V. N., and Borthakur, S. K. 2011. Conservation strategies for *Nepenthes khasiana* in the Nokrek biosphere reserve of Garo Hills, North-east India. *International Journal of Conservation Science*, *2*:55–64.

Smetacek, P. 2017. *A Naturualist's Guide to the Butterflies of India*. John Beaufoy Publishing, Oxford, UK. 176 pp.

State of the World's Forests 2020 (In Brief). Food and Agriculture Organization of the United Nations. Rome, Italy. 32 pp.

Teegalapalli, K. and Samal, P. K. 2009. *Forest Recovery Following Shifting Cultivation: An Overview of Existing Review article Forest recovery following shifting cultivation: an overview of existing research*. https://doi.org/10.1177/194008290900200401

Toky, O. P. and Ramakrishnan, P. S. 1983. Secondary Succession Following Slash and Burn Agriculture in North- Eastern India. *Journal of Ecology*, *71*:747–757.

Veddeler, D. and Schulze, C. H. 2005. *The contribution of tropical secondary forest fragments to the conservation of fruit-feeding butterflies: effects of isolation and age*. 3577–3592.

Wright, S. J. 2005. Tropical forests in a changing environment. *Trends in Ecology and Evolution*, 20:553–560.

Wright, S. J. and Muller-Landau, H. C. 2006. The future of tropical forest species. *Biotropica*, *38*:287–301.

Yirdaw, E., Monge, A. M., Austin, D., and Toure, I. 2019. Recovery of floristic diversity, composition and structure of regrowth forests on fallow lands : implications for conservation and restoration of degraded forest lands in Laos for conservation and restoration of degraded forest lands in Laos. *New Forests*, *50*: 1007–1026.

Zar, J.H. 1999. *Biostatistical Analyis*. Pearson Education, Singapore. 661 pp.

APPENDIX

A summary of the 124 species recorded across all the four successional stages sampled in the study area. The relative abundance values are given in the table. The species marked with * denotes the "open-country species" that was taken as the species detected in both the clear cut patches - current *jhum* and the young fallows (1-2Y)

Scientific Name	**Common Name**	**Family**	**Current *Jhum***	**1-2Y fallows**	**3-7Y fallows**	**>8Y fallows**	**Total**
Ariadne ariadne	Angled Castor	Nymphalidae	-	0.01	-	0.002	5
Lethe chandica	Angled Red Forester	Nymphalidae	-	-	-	0.005	2
Lethe confusa	Banded Treebrown	Nymphalidae	-	0.01	0.009	0.012	11
Prosotos bhutea	Bhutea Lineblue	Lycaenidae	-	-	0.002	-	1
Lethe vindhya	Black Forester	Nymphalidae	-	-	-	0.003	1
Rohana parisatis	Black Prince	Nymphalidae	-	-	-	0.005	2
Athyma ranga	Blackvein Sergeant	Nymphalidae	-	-	0.002	0.002	2
Kaniska canace	Blue Admiral	Nymphalidae	-	-	-	0.002	1
Ticherra acte	Blue Imperial	Lycaenidae	-	-	-	0.005	2
Tirumala limniace	Blue Tiger	Nymphalidae	0.03	-	0.009	0.017	14
Sinthusa chandrana	Broad Spark	Lycaenidae	-	-	0.002	0.002	2
Badamia exclamationis	Brown Awl	Hesperiidae	-	-	0.002	-	1
*Mycalesis sp**	Bushbrown sp	Nymphalidae	0.01	0.01	0.025	0.101	58
lambrix salsala	Chestnut Bob	Hesperiidae	-	0.003	0.005	-	3
Appias lyncida	Chocolate Albatross	Pieridae	-	0.72	0.057	0.017	56
Junonia iphita	Chocolate Pansy	Nymphalidae	-	0.015	0.027	0.039	33
Prantica melaneus	Chocolate Tiger	Nymphalidae	-	-	-	0.002	1
N.clinia/nata/soma	Clear/Dirty/Sullied Sailer	Nymphalidae	-	0.009	0.005	0.017	12
Athyma inara	Color Sergeant	Nymphalidae	-	-	0.002	0.002	2
*Surendra quercetorum**	Common Acacia Blue	Lycaenidae	0.01	0.006	0.016	0.002	11
Appias albina	Common Albatross	Pieridae	-	-	0.011	0.01	9
Atrophaneura varuna	Common Batwing	Papilionidae	-	-	-	0.002	1
Graphium sarpedon	Common Bluebotle	Papilionidae	-	-	-	0.002	1
Ariadne merione	Common Castor	Nymphalidae	-	0.003	-	-	1
*Jamides celeno**	Common Cerulean	Lycaenidae	0.01	0.021	0.014	0.007	17
Losaria coon	Common Clubtail	Papilionidae	-	-	-	0.002	1
Euploea core	Common Crow	Nymphalidae	-	0.003	0.02	0.002	11
Oriens gola	Common Dartlet	Hesperiidae	-	-	0.002	0.002	2
*Catopsilia pomona**	Common Emigrant	Pieridae	0.03	0.042	0.009	0.015	27

Melantis leda	Common Evening Brown	Nymphalidae	-	-	0.002	0.054	23
*Ypthima baldus**	Common Five-Ring	Nymphalidae	0.01	0.006	0.036	0.015	25
Ypthima huebneri	Common Four-ring	Nymphalidae	-	0.024	0.018	0.007	19
*Eurema hecabe**	Common Grass Yellow	Pieridae	0.02	0.051	0.05	0.029	53
Cepora nerissa	Common Gull	Pieridae	0.01	0.003	-	-	2
Graphium doson	Common Jay	Papilionidae	-	0.003	-	-	1
Symbrenthia lilaea	Common Jester	Nymphalidae	-	0.003	0.007	0.047	23
Delias eucharis	Common Jezebel	Pieridae	-	-	0.002	-	1
Pantoporia hordonia	Common Lascar	Nymphalidae	-	0.006	0.007	0.007	8
Phalanta phalantha	Common Leopard	Nymphalidae	-	0.009	0.002	-	4
Prosotas nora	Common Line Blue	Lycaenidae	-	0.003	-	-	1
Cyrestis thyodamas	Common Map	Nymphalidae	-	-	-	0.002	1
Chersonesia risa	Common Maplet	Nymphalidae	-	-	-	0.002	1
*Papilio polytes**	Common Mormon	Papilionidae	0.06	0.024	0.032	0.017	34
Elymnias hypermnestra	Common Palmfly	Nymphalidae	-	-	0.005	0.007	5
Papilio bianor	Common Peacock	Papilionidae	-	-	-	0.002	1
Lethe mekara	Common Red Forester	Nymphalidae	-	-	-	0.002	1
Pachliopta aristolochiae	Common Rose	Papilionidae	-	-	-	0.002	1
*Neptis hylas**	Common Sailer	Nymphalidae	0.01	0.057	0.07	0.025	61
Athyma perius	Common Sergeant	Nymphalidae	-	0.009	0.002	0.002	5
Tagiades japetus	Common Snow Flat	Hesperiidae	-	-	0.002	0.007	4
Catapaecilma major	Common Tinsel	Lycaenidae	-	-	-	0.005	2
Hypolycaena erylus	Common Tit	Lycaenidae	-	-	-	0.002	1
Gerosis bhagava	Common Yellow-breasted Flat	Hesperiidae	-	-	-	0.002	1
Baoris farri	Complete Paint-brush Swift	Hesperiidae	-	-	-	0.002	1
Rapala pheretima	Copper Flash	Lycaenidae	-	-	0.002	-	1
Deodorix epijarbas	Cornelian	Lycaenidae	-	0.003	-	-	1
Vindula erota	Cruiser	Nymphalidae	-	0.003	-	-	1
Tirumala septentrionis	Dark Blue Tiger	Nymphalidae	-	0.003	0.002	-	2
Jamides bochus	Dark Cerulean	Lycaenidae	-	-	-	0.005	2
Zizeeria karsandra	Dark Grass Blue	Lycaenidae	-	0.021	0.002	-	8
Telicota bambusae	Dark Palm Dart	Hesperiidae	-	-	-	0.002	1
Mycalesis mineus	Dark-branded Bushbrown	Nymphalidae	-	-	-	0.002	1
Potanthus sp	Dart sp	Hesperiidae	-	-	0.014	0.012	11
Gerosis phisara	Dusky Yellow-breasted Flat	Hesperiidae	-	-	-	0.002	1

Pantoporia sandaka	Extra Lascar	Nymphalidae	-	0.033	0.027	0.027	34
Zeltus amasa	Fluffy Tit	Lycaenidae	-	-	0.002	-	1
Catochrysops strabo	Forget-me-not	Lycaenidae	-	-	-	0.002	1
Pseudocoladenia dan	Fulvous Pied Flat	Hesperiidae	0.01	-	-	0.01	5
Parantica aglea	Glassy Tiger	Nymphalidae	-	0.003	0.002	0.005	4
*Euchrysops cnejus**	Gram Blue	Lycaenidae	0.01	0.003	-	-	2
Papilio memnon	Great Mormon	Papilionidae	-	-	0.002	0.01	5
Junonia alites	Grey Pansy	Nymphalidae	-	0.003	0.014	0.002	8
Aeromachus jhora	Grey Scrub Hopper	Hesperiidae	-	0.003	0.005	0.002	4
Pieris canidia	Indian Cabbage White	Pieridae	-	0.042	0.009	0.005	20
Heliophorus indicus	Indian Sapphire	Lycaenidae	-	-	-	0.002	1
Spialia galba	Indian Skipper	Hesperiidae	-	0.003	-	-	1
Scobura isota	Khasi Forest Bob	Hesperiidae	-	-	-	0.002	1
*Junonia lemonais**	Lemon Pansy	Nymphalidae	0.31	0.096	0.127	0.025	125
Cethosia cyane	Leopard Lacewing	Nymphalidae	-	-	-	0.007	3
Zizina otis	Lesser Grass Blue	Lycaenidae	-	0.003	0.002	-	2
*Papilio demoleus**	Lime Butterfly	Papilionidae	0.01	0.012	0.007	-	8
Mycalesis visala	Long-branded Bushbrown	Nymphalidae	-	-	0.007	0.005	5
Orsotriaena medus	Medus Brown	Nymphalidae	-	-	-	0.005	2
Jamides alecto	Metallic Cerulean	Lycaenidae	-	-	-	0.002	1
Catopsilia pyranthe	Mottled Emigrant	Pieridae	-	0.015	0.005	-	7
*Eurema andersonii**	One-spot Grass Yellow	Pieridae	0.02	0.018	0.005	0.012	15
Nacaduba beroe	Opaque Six-line Blue	Lycaenidae	-	0.003	-	0.002	2
Kallima inachus	Orange Oakleaf	Nymphalidae	-	-	-	0.012	5
Athyma cama	Orange Staff Sergeant	Nymphalidae	-	-	0.002	-	1
*Pseudozizeeria maha**	Pale Grass Blue	Lycaenidae	0.01	0.114	0.014	-	45
Udara dilecta	Pale Hedge Blue	Lycaenidae	-	0.003	-	-	1
Charaxes arja	Pallid Nawab	Nymphalidae	-	-	0.007	0.007	6
Papilio buddha	Paris Peacock	Papilionidae	-	0.003	-	0.005	3
*Lampides boeticus**	Pea Blue	Lycaenidae	0.01	0.012	0.005	-	7
Junonia almana	Peacock Pansy	Nymphalidae	-	0.006	0.002	-	3
Mycalesis malsarida	Plain Bushbrown	Nymphalidae	-	-	-	0.002	1
Euthalia monina	Powdered Baron	Nymphalidae	-	-	-	0.002	1
Leptosia nina	Psyche	Pieridae	-	-	-	0.002	1
*Zemeros flegyas**	Punchinello	Riodinidae	0.14	0.042	0.091	0.069	94
Heliophorus epicles	Purple Sapphire	Lycaenidae	-	-	0.002	0.01	5
*Papilio helenus**	Red Helen	Papilionidae	0.02	0.012	0.014	0.025	22
Delias pasithoe	Red-base Jezebel	Pieridae	0.2	0.006	0.016	0.054	33
*Delias descombesi**	Red-spot Jezebel	Pieridae	0.13	0.036	0.066	0.054	74
Notocrypta curvifascia	Restricted Demon	Hesperiidae	-	-	-	0.005	2
Neptis sappho	Rusty Sailer	Nymphalidae	-	0.003	0.005	-	3

Lethe distans	Scarce Red Forester	Nymphalidae	-	-	-	0.002	1
Zinaspa todara	Silverstreaked-Acacia Blue	Lycaenidae	-	0.003	0.002	0.002	3
Baoris chapmani	Small Paint-brush Swift	Hesperiidae	-	-	-	0.002	1
Symbrenthia hypselis	Spotted Jester	Nymphalidae	-	-	-	0.002	1
Athyma selenophora	Staff Sergeant	Nymphalidae	-	0.003	-	-	1
Appias olferna	Striped Albatross	Pieridae	-	-	0.002	-	1
*Euploea mulciber**	Striped Blue Crow	Nymphalidae	0.02	0.006	0.014	0.01	14
Athyma asura	Studded Sergeant	Nymphalidae	-	0.003	0.002	-	2
Tagiades gana	Suffused Snow Flat	Hesperiidae	-	-	-	0.002	1
Pelopidas sp	Swift sp	Hesperiidae	-	-	0.002	-	1
Abisara neophron	Tailed Judy	Riodinidae	-	-	-	0.007	3
Eurema blanda	Three-spot Grass Yellow	Pieridae	-	0.018	0.016	0.025	23
*Zizula hylax**	Tiny Grass Blue	Lycaenidae	0.02	0.021	0.032	0.002	24
Nacaduba kurava	Transparent Six-line Blue	Lycaenidae	-	-	-	0.002	1
Gandaca harina	Tree Yellow	Pieridae	-	-	-	0.005	2
Mycalesis anaxias	White-bar Bushbrown	Nymphalidae	-	-	0.002	0.002	2
Lestranicus transpectus	White-disc Hedgeblue	Lycaenidae	-	-	-	0.002	1
Loxura atymnus	Yamfly	Lycaenidae	-	-	0.002	-	1
*Junonia heirta**	Yellow Pansy	Nymphalidae	0.05	0.039	0.014	0.005	25

PLATES

Plate 1

A typical shifting cultivation landscape

Plate 2

Successional strata following human disturbance as a result of shifting cultivation

Current *Jhum*

1-2 years fallows

Plate 3

Successional strata following human disturbance as a result of shifting cultivation

3 or 4 years fallows

5 or 6 years fallows

Plate 4

Invasive species characteristic of 3-7 years fallows

Pueraria bracteata

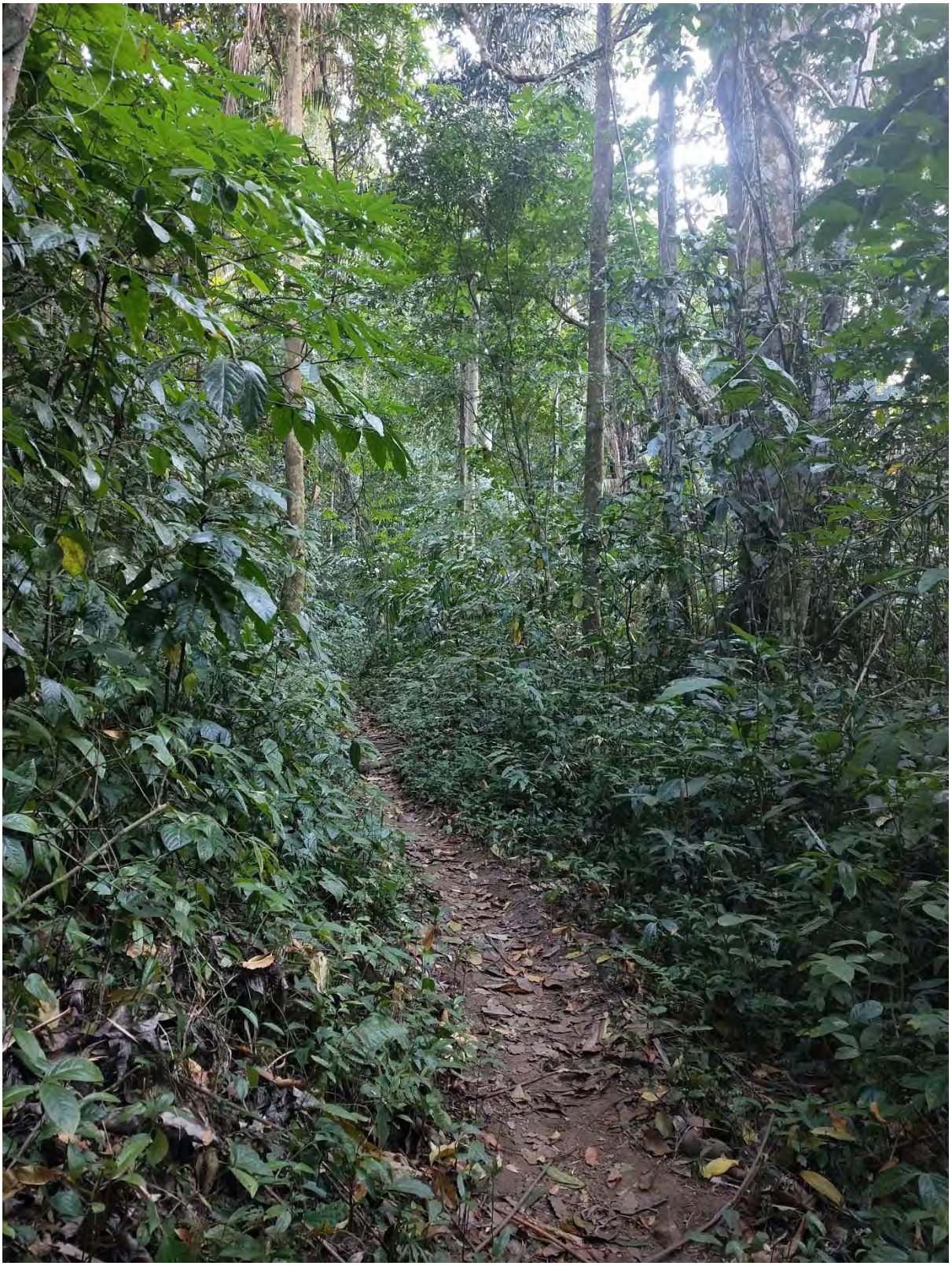
Mikania micrantha

Eupatorium sp

Clerodendrum sp

Plate 5

Successional strata following human disturbance as a result of shifting cultivation



Fallows of 8 years and above

Plate 6

A few representative butterfly species recorded in the successional strata

Family Hesperiidae

Brown Awl *Badamia exclamationis*

Chestnut Bob *lambrix salsala*

Small Paint-brush Swift *Baoris chapmani*

Restricted Demon *Notocrypta curvifascia*

Common Yellow-breasted Flat *Gerosis bhagava*

Fulvous Pied Flat *Pseudocoladenia dan*

Plate 7

Family Lycaenidae

Tiny Grass Blue *Zizula hylax*

Broad Spark *Sinthusa chandrana*
(SCH-II/WPA)

Silver-streak Acacia Blue *Zinaspa todara*
(SCH-II/WPA)

Purple Sapphire *Heliophorus epicles*

Blue Imperial *Ticherra acte*

Fluffy Tit *Zeltus amasa*

Plate 8

Family Nymphalidae

Studded Sergeant Athyma asura (SCH-II/WPA)

Cruiser *Vindula erota*

Medus Brown *Ostrotriaena medus*

Blue Admiral *Kaniska canace*

Orange Oakleaf *Kallima inachus*

Lemon Pansy *Junonia lemonais*

Plate 9

Family Pieridae

Three-spot Grass Yellow *Eurema blanda*

Chocolate Albatross *Appias lyncida*

Indian Jezebel *Delias eucharis*

Tree Yellow *Gandaca harina*

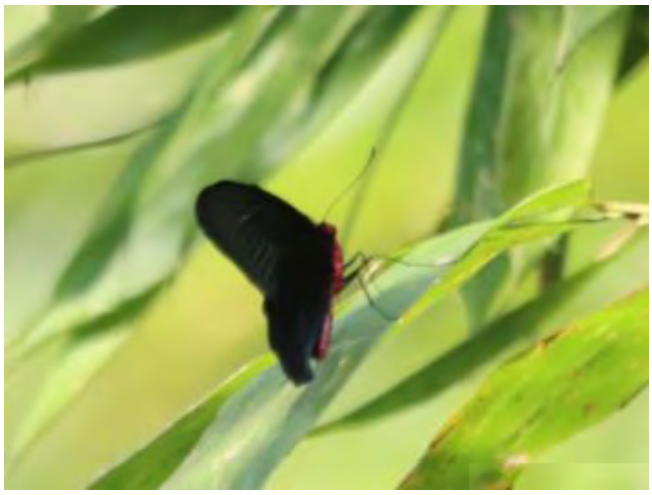
Red-base Jezebel *Delias pasithoe*

Red-spot Jezebel *Delias descombesi*

Plate 10

Family Papilionidae

Red Helen *Papilio helenus* on dead crab meat



Common Mormon *Papilio polytes*

Common Batwing *Atrophaneura varuna*

Great Mormon *Papilio memnon*

Family Riodinidae

Tailed Judy *Abisara neophron*

Punchinello *Zemeros flegyas*