RECOVERY OF FRUIT-FEEDING BUTTERFLY COMMUNITIES IN BUDONGO FOREST RESERVE, UGANDA

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JULY 2018

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JULY 2018

DECLARATION

I, Oloya Joseph, do hereby declare that this dissertation is my original work and that it has never been submitted to any institution of higher learning for any academic award.

Signed.....Date.....18/12/2018.....

Oloya Joseph

APPROVAL

This report has been submitted with the approval of the supervisors.

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DEDICATION

This piece of work is dedicated to my dear parents, Mr Ocira Joseph (RIP) and Ms. Dominica Awor (RIP) for the background they set for me in the academia.

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I am grateful to God who kept me healthy throughout the writing process. I appreciate my supervisors, Dr Geoffrey Maxwell Malinga, Dr Margaret Nyafwono and Dr. Harriet Angwech for guiding me throughout this research process. I thank Budongo Forest Reserve management for their hospitality and for providing a modest working environment during the five months of data collection. I am grateful to my field assistant, Mr Mwesigwa Isaiah, for the help with data collection and butterfly identification. Mr Julius Komakech of Nyabyeya Forestry College-Masindi cannot be forgotten especially for offering accommodation for me and my assistant. I am also thankful to my beloved parents, the late Mr Ocira Joseph and Mrs Dominica Ocira for the foundation they laid for me in academics. I thank all my friends and course mates who assisted me in different ways in the accomplishment of this great academic achievement. Lastly, I appreciate my dear wife, Peace, and my sisters, Beatrice and Pauline, and their entire families for all the support they rendered, which have enabled me complete this study.

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LIST OF ABBREVIATIONS

CFR:	Central Forest Reserve
DSC:	Digital Still Camera
DISTLM:	Distance based linear models
FAO:	Food and Agricultural Organization of the United Nations
IBM:	International Business Machine
NEMA:	Natural Environmental Management Authority
PERMANOVA:	Permutational Multivariate analysis of variance
PRIMER:	Plymouth Routine In Multivariate Ecological Research
SPSS:	Statistical Package for the Social Sciences
UBTFA:	Uganda Biodiversity and Tropical Forest Assessment
USAID:	United States Agency for International Development

ABSTRACT

The effect of anthropogenic activities on the regeneration of forest structure and recovery of animal communities is not well known. This study assessed the recovery pattern of fruit-feeding butterflies as bio-indicators of environmental disturbance, after about 72 years of selective logging and arboricide treatment in the Budongo Forest Reserve, Uganda. Butterflies were sampled in four selectively logged forest habitats and one primary forest using white cylindrical traps baited with fermented smashed bananas. Sampling was conducted for five straight days within a week between 0700-1700 hours, for five months. The study compared the spatial and temporal variation in butterfly species richness, abundance, diversity and community composition in the five forest compartments and also determined specialist butterfly species characterizing each of the five forest compartments. A total of 3,780 individuals, representing 85 species belonging to three families and 28 genera were recorded. There was significant difference in butterfly abundance and diversity between the five compartments and months of study. However, there were no significant differences in the total species richness among the five compartments. This study found no significant directional patterns in the species density, diversity and abundance of butterflies along the successional gradient (gradation of recovery from the youngest to the oldest logged with respect to the primary forest). Communities of all selectively logged compartments differed significantly from each other and from the primary forest. The unlogged primary forest had the highest butterfly indicator species compared to the logged compartments. These results demonstrate that logged forest compartments don't yet provide suitable habitats to fully support butterfly communities like the unlogged primary compartments, highlighting the eminent need to conserve primary forests as a long term conservation strategy for butterfly species.

CHAPTER ONE

INTRODUCTION

1.1. Background

Tropical forests are deteriorating rapidly due to the widespread indiscriminate logging for timber production, wood fuel and human settlements (FAO, 2015; Islam & Sato, 2012), wild fires and clear-cutting for agriculture (Blay, 2012; Hosonuma et al., 2012) and yet they have a significant global biodiversity value (Basset, et al., 2015). The Global Forest Resources Assessment 2015 reports a global decline in forest area of 129 million ha (1%) between 1990 and 2015 (FAO, 2015). The greatest of this decline occurred in poor developing economies of South America and Africa. In Uganda, for instance, during the same period, the forest estate shrunk from 24% (4.9 million ha) of the total forest area cover to 9% (Ministry of Water & Environment [MWE], 2016). These anthropogenic disturbances can modify ecosystem functioning and alter the structure and composition of the entire biodiversity that these tropical forests support (Agea et al., 2010; Green, Cornell, Scharlemann & Balmford, 2005; Sala et al., 2000). In the worst case scenario, they can lead to loss of habitat and biodiversity (Gibson et al., 2011) and species extinction (Laurence, 2007). For instance, government policy on modernization of the economy which promote fast economic growth mainly centered on agriculture are responsible for the destruction and unsustainable use of forest resources (USAID, 2006). This has promoted the giveaway of forest reserves to investors to create opportunity for agricultural production due to the perception that forests yield lower economic value than agriculture for the same land area (NEMA, 2010). For example, Bugala Island forest in Lake Victoria was degazetted where over 6000 hectares of relatively undisturbed natural forest was cleared to give way to oil palm growing (NEMA, 2010).

In the Budongo Forest Reserve, irregular and small-scale logging by pit sawing started in about 1910, from the southern part of the forest (Eggeling, 1947b). It was not until the 1930s that regulated or controlled extraction of timber from this forest began (Paterson 1991. Plumptre, 1996). This was followed by application of arboricide chemicals (2,4-D i.e., Dichlorophenoxyacetic acid and 2,4,5-T i.e., Trichlorophenoxyacetic acid) between 1950s and 1960s to selectively eliminate non-marketable timber species especially the *Cynometra* spp. which had dominated the forest. Through selective logging and arboricide treatment, the tree canopy would open and the regeneration of valuable timber species such as the mahoganies (*Khaya anthotheca, Entandrophragma angolense, E. cylindricum & E. utile*) were promoted and subsequently encouraged the development of mixed forest (Philip, 1965 as cited in Plumptre, 1996). Sixty out of the sixty-eight compartments were logged. Those left unlogged included three compartments in the Kaniyo-Pabidi block (K11, K12 and K13); four in the Waibira block (W17, W30, W31 and W32) and one in the Nyakafunjo block, N15. The compartments N15, W17, W30, W31, and W32 are protected as nature reserve (Plumptre, 1996; Owiunji & Plumptre, 1998). Arboricide treatment was stopped in the 1970s (Synnott, 1985) and the compartments were left to regenerate naturally.

Butterflies are a useful model organism for studying the recovery of tropical forests after disturbance because of their sensitivity to even the slightest change in their environment (Bonebrake, Ponisio, Boggs & Ehrlich, 2010). They also play important roles in ecosystem functioning, such as pollination (Maleque, Hiroaki, & Kaoru, 2006), as prey organisms and keystone primary consumers/herbivores (Larsen, 1996). Besides, their taxonomy and ecology are relatively well known in Uganda (Molleman, 2012).

However, very little is known about the effect of forest disturbance and loss on the fruit-feeding butterfly communities and their recovery pattern in Afrotropical forests. Understanding how disturbance affects forest biodiversity and their recovery patterns would aid the development of better management plans and policies for their conservation (Nyafwono,Valtonen, Nyeko, & Roininen 2014b). In this study, the recovery of fruit-feeding butterflies was assessed after about 72 years of selective logging and arboricide treatment in the Budongo Central Forest Reserve. The study investigated the spatial and temporal variations in the butterfly species richness, abundance, diversity and community composition after forest disturbance. Furthermore, it assessed the butterfly species characterizing each forest successional stage.

1.2. Statement of the problem

Forest disturbances especially through logging and chemical applications are known to affect and upset the ecological balance of the forest by transforming its structure and existing species composition (Bahati, 2005). Predictions from Kibale National Park, Uganda, show that forest structural recovery of heavily logged compartments will take 112 years, and that the recovery of its tree species composition will take even a longer time than this (Bonell, Reyna-Hurtado & Chapman, 2011). The effect of these anthropogenic activities on the recovery of animal communities is not well known.

Previous studies from the Amazon (Barlow, Overal, Araujo, Gardner & Peres, 2007), South East Asia (Cleary, et al., 2009) and the Afro-tropics (Nyafwono, et al., 2014b) have shown that fruit-feeding butterfly community composition in disturbed forest habitats differs significantly from that of primary forests. These disturbances can also cause massive reduction in butterfly species richness & abundance from the undisturbed to disturbed sites (Akite, 2008, Beck & Schulze, 2000) or show the opposite pattern in diversity & abundance

(Fermon, Waltert, Vane-Wright, & Mühlenberg, 2005; Willott, Lim, Compton, & Sutton, 2000). In some studies, there has been no difference in these variables between the disturbed & the undisturbed sites (Luk, Hadi, Ziegler, & Waltert, 2011).

With respect to recovery time after disturbance, there are contradicting results showing that fruit-feeding butterfly communities in Kakum Forest, Ghana, may take 50 to 60 years to recover from disturbance (Sáfián, Csontos, & Winkler, 2011) and 40 years in Kibale National Park, Uganda. (Nyafwono et al., (2014a). Due to the controversies about fruit-feeding butterfly community response to human-induced disturbances and the limited studies done so far from the Afro-tropics, more studies are still needed in this field (Addo-Fordjour, Benjamin, Kpontsu, 2015). In order to develop appropriate forest management plans and policies for conservation of biodiversity in the Budongo Central Forest Reserve, it is important to understand how different insect communities recover after forest disturbance, since some are effective bio-indicators of environmental disturbance. This study assessed the pattern of recovery of fruit-feeding butterfly communities in logged and arboricide-treated Forest compartments of Budongo Central Forest Reserve, Uganda.

1.3. Scope of the study

The study assessed fruit-feeding butterfly communities in four compartments of Budongo forest reserve, N1, N3, N4 and W22, which were logged at different times and intensities and one unlogged compartment, N15 which was preserved as a nature reserve. This unlogged primary forest compartment represents the other primary forests in terms of structure and biodiversity composition. To show whether the butterfly communities have recovered or not, the communities of butterflies in the disturbed forest compartments were compared with those in the unlogged compartment, N15.

1.4. Objectives of the study

1.4.1. General objective

To determine the recovery pattern of fruit-feeding butterfly communities after forest disturbance in the moist Afrotropical lowland rainforest of Budongo Central Forest Reserve in Uganda.

1.4.2. Specific objectives

1) To compare the spatial and temporal variation in butterfly species richness, abundance, diversity and community composition among the five forest compartments at different intensities of disturbance and stages of regeneration.
2) To determine if there is a directional pattern in butterfly species richness, abundance, diversity and community composition from the youngest regenerating logged compartment to the unlogged primary forest.
3) To determine butterfly species characterizing each of the five logged forest compartments, and one primary forest.

1.5. Research questions

1) Are there spatial & temporal variations in butterfly species richness, abundance, diversity and community composition among the logged & unlogged forest compartments?
2) Is there a directional pattern in butterfly species richness, abundance, diversity and community composition from the youngest regenerating logged compartment to the unlogged primary forest?
3) What are the specialist butterfly species characterizing the differently-aged regenerating and primary forests?

1.6. Justification of the study

Forests in Uganda are under pressure and threat of extinction due to uncontrolled human activities (FAO, 2006) such as indiscriminate logging, the need for settlement due to increasing human population, the need for high food production through extensive agricultural practices and other land use developmental activities (Kasangaki, Akol & Basuta, 2012). (Kasangaki et al., 2012). Many forest reserves have been degazetted e.g., Bugala Island forest in Lake Victoria where over 6000 hectares of relatively undisturbed natural forest was cleared to give way to oil palm growing (NEMA, 2010) and many others. Owing to their ecological importance in biodiversity conservation & rainfall formation, there is need to understand the long term impact of such activities on biodiversity and their recovery to guide forest managers and policy makers to formulate appropriate policies for forest management and biodiversity conservation.

CHAPTER TWO

LITERATURE REVIEW

2.1. Status of protected forests in Uganda

In Uganda, natural forest once covered about 10.8 million hectares representing 53% of Ugandan land in the 1980s (FAO, 2001). Ugandan natural forest cover has drastically reduced to about 20% by 1996 and further to about 15% by 2005 with an average deforestation rate of 1.8% (NEMA, 2009). The rate of deforestation was estimated to be about 0.9% per year based on the amount of both bush and woodland changes between 1990 and 1995 (FAO, 2000). According to a report by USAID (2006), the threats imposed on biodiversity in Uganda through human influence have both direct and indirect effects. including (i) habitat loss, degradation and fragmentation, (ii) unsustainable harvesting and over-exploitation of living and non-living resources, (iii) invasion by alien species and (iv) pollution. The quality of Ugandan forests, with respect to fauna and flora has declined over time. The USAID report of 2006 further identified that over 30% of the tropical forests are currently classified as degraded, following uncontrolled human activities. Uganda is at a risk of losing all its forests in 40 years if deforestation continues at its present rate (Musasizi, 2018)

Uganda is home to vast biodiversity (USAID, 2006). There are about 18,783 biodiversity species and of these, there are 1,242 butterfly species representing 6.8% of global butterfly species. Budongo Forest Reserve in particular, is of high global biodiversity importance. ranking third among the protected areas in species richness and overall importance in Uganda (Howard, Davenport, & Kigenyi, 1997).

2.2. History of logging and management of Budongo Forest Reserve

Budongo became a forest reserve between 1932 and 1939 with gazetted land area of 825 km^2. The forest is best known producer of timber in Uganda (Bahati, 2005; Eggeling, 1947a; Howard, 1991). The Forest Reserve was previously managed with the interest to produce high quality timber for export between 1920 and 1930 (Plumptre, 1996). Timber harvesting in Budongo Forest Reserve was manually conducted through pit-sawing technique but by 1925, the first major sawmill was established (Eggeling, 1947b). Between the 1930s and the 1980s, foreign owned saw-milling firms were given exclusive felling rights under a 10-year license and these exposed the forest to extensive logging. Almost all of the compartments (60 out of 68) were logged leaving only eight compartments unlogged, i.e., three in the Kaniyo-Pabidi block (K11, K12 and K13); four compartments in the Waibira block (W17, W30, W31 and W32) and one in the Nyakafunjo block (N15). The compartments (N15, W17, W30, W31, and W32) are protected as nature reserve (Plumptre, 1996; Owiunji & Plumptre, 1998).

Logging was followed by application of arboricide chemicals between 1950's and 1960's to selectively eliminate non-commercial timber producing tree species (Plumptre, 1996). The arboricide suppressed the forest from developing from mixed to climax forest and it also promoted the regeneration of the three light demanding mahogany species (*Enthandrophragma utile*, *E. cylindricum* and *E. angolense*), and one Khaya species (*Khaya anthotheca*). They are known to provide the most priced and valuable timbers. Also, the chemical reduced the abundance of the native tree species, e.g., *Cynometra alexandri* and this created opportunity for a wide variety of tree species such as *Celtis* and *Ficus* without timber value to develop and replace the *Cynometra alexandri* (Owiunji & Plumptre, 1998). Arboricide application occurred in two stages (a) pre-exploitation refining, where overstorey trees that obstructed light needed for the desirable seedlings to establish were poisoned and

destroyed, and (b) post-harvesting liberation of desirable trees, where understorey shrubs that acted as 'weeds' were also poisoned and destroyed (Owiunji & Plumptre, 1998).

Budongo forest underwent a succession of forest developments from colonizing forest, through mixed forest, to climax forest mainly characterized by the iron wood tree (*Cynometra alexandri*), which is the dominant species. The tree composition of the forest varied along an axis from SW to NE, with trees of the earlier successional stages to the SW and trees of the later successional stages to the NE which indicates that the forest is oldest in the NE and youngest in the SW (Plumptre, 1996).

2.3. Characteristics of fruit-feeding butterflies

Fruit-feeding butterflies belong to the Nymphalidae family that use only four legs for walking and not six like in the other butterfly families. This is true except in the family Riodinidae where males use only four legs for walking, while females use six (Molleman, 20012). According to Swachik et al., (2005), butterfly species composition varies with respect to the varying vegetation types. They normally forage in nearly all habitat types in the regions they inhabit and they are found in numerous habitats ranging from sunny, dry open to shaded habitats. They can also inhabit damp forest (such as canopies) open bushy habitats, forest edges with slight disturbance, low lands and others. Territorial behavior exists among the adult males commonly observed at puddling sites. Males establish territories to improve chances of mating and compete for space (Swachik, et al., 2005). Just like other arthropods, butterflies possess exoskeleton impregnated with chitin to prevent desiccation and bacterial entry in the body. They have two pairs of large wings covered with colorful, iridescent scales in overlapping rows which fade and become ragged as they become old (Klass & Dirig 1992).

In relatively high humidity, they have impaired flight especially when temperatures are below 10-16^{0}C and above 38^{0}C. Fruit-feeding butterflies use wing orientation (basking) to raise or lower body temperature. To keep cool, they orient themselves parallel to the sun's rays, with the wings closed over the body to minimize their surface area. To warm up, they employ lateral or dorsal basking. Lateral baskers perch with wings closed and one side of the body perpendicular to the sun. Dorsal baskers (most fruit-feeding butterflies) perch with wings widespread, perpendicular to the sun (Klass & Dirig, 1992). Many of them migrate in order to avoid adverse environmental conditions-like cold weather (Klass & Dirig, 1992). They exhibit significant predator avoidance mechanisms including; aposematism, eyespots, crypsis, flight allometry and mimicry in order to survive the selection pressures. For example, Batesian mimicry, where the palatable fruit-feeding butterflies mimic the unpalatable ones (Meyer, 2006).

Fruit-feeding butterflies may require multiple vegetation types to satisfy their food and habitat needs. Their larvae, feed on a variety of trees, shrubs, herbs and legumes. Though some feed on specific plant species (Nimbalkar, Chandekar, & Khunte, 2011; Vu, 2007;). They are mainly attracted to fermenting sugars and the smell of fruits and can also feed on forest fruits like figs, oozing sap from damaged trees, honey dew produced by aphids and other bugs (Molleman, Van Alphen, Brakefield, & Zwaan, 2005) some also visit flowers to drink nectar (Molleman, 2012). In addition, many fruit-feeding butterflies puddle on mud, dung of predators like civet cats, and carrion to obtain sodium (Boggs & Dau, 2004). In many species, only males puddle and they give the salt obtained to the females during the copulation, but this is not true for all species that puddle (Molleman, 2012).

Fruit-feeding butterflies show annual life cycle transformation from eggs, larvae, pupa and adult on condition that there are favorable environmental conditions yearly for new eggs laid

to mature. The eggs are oval or round/cylindrical and small and laid on leaves of closely related plant species called host plants (Butterfly life cycle, n.d; Oostermeijer & van Swaay, 1998). The larva/caterpillar emerges after about three to five days depending on the species and actively starts feeding on specific host plants on which the eggs where laid. Thus, any alternation of vegetation composition and structure greatly influences their survival (Pinotti, Pagotto, & Pardini, 2012). The caterpillars molts several times and changes into pupa/chrysalis. Here, extensive tissue reorganization and organ formation takes place and the adult emerges from the pupal case. The heart pumps haemolymp fluid through the veins of the weak wings to make them strong and the butterfly flies away (Butterfly life cycle, n.d.). Their life span ranges from as low as seven days in *Euphaedra christyi* species, to a maximum of ninety six days in *Bicyclus golo* (Molleman, Zwaan, Brakefield, & Carey, 2007). Evolution of long life span is favored by selection pressure such as predation, diet and feeding efficiency which depends on morphology of proboscis and feeding behavior among others (Molleman,et al., 2007).

2.4. Fruit-feeding butterflies as indicators of disturbance

Butterflies have long been used as indicator species to assess the response of ecosystems to environmental disturbances and stressful human activities including logging, habitat fragmentation and climatic variations (Bonebrake & Sorto, 2009; McKenzie, Hyatt, & McDonald, 1992). They are also sensitive to changes in vegetation composition and structure (McKenzie et al., 1992; Sawchik et al., 2005). Besides, they play important roles in ecosystem functioning especially in pollination (Maleque et al., 2006) as such, they help in production of fruits hence seeds ecosystem restoration in general (Thomas, 2005). Their taxonomy and ecology are well known in Uganda (Molleman, 2012). They experience short generation times and multiply faster over a relatively short period of time and they are

relatively easy to sample (Blair, 1999; Shahabuddin & Terborgh, 2000). Furthermore, butterflies are important elements of the food chain and are prey for birds, bats and other insectivorous animals.

The fruit-feeding butterfly species characterizing undisturbed forests are usually specialist species some from the genera of Bicyclus, e.g., *B. auricruda, B. campinus;* Charaxes e.g., *Charaxes achaemenes, C. cynthia;* and Euphaedra, e.g., *Euphaedra hollandi, E. harpalyce.* The other genus is the Euriphene, e.g., *Euriphene ribensis* and *E. saphirina.* Butterfly species that are known to characterize old forest regeneration stage are quite similar to those in the undisturbed habitats, e.g., *Bicyclus dentatus, B. auricruda, B. campinus* and *B. safitza.* The intermediate level of regeneration is characterized by *Euphaedra medon, Bicyclus auricruda and Junonia stygia* (Nyafwono et al., 2014b).

2.5. Recovery pattern of fruit-feeding butterflies after disturbances

Habitat disturbance causes negative effects on the butterfly taxon, including, reduction in species abundance and diversity (Ghazoul, 2002), modification of assemblage structure and even extinction (Brook, Sodhi, & Ng, 2003; Hamer, et al., 2003). Each stage of habitat disturbance is characterized by a particular subgroup of species (Rodriguez, Pearson, & Barrera, 1998). In contrast, several previous studies indicate that moderate level of habitat disturbances enhance species abundance and diversity of butterfly communities (Wood & Gillman, 1998) and less species exist in undisturbed habitat. According to Kremen (1994), disturbed forest habitat harbors high species diversity than the undisturbed.

Different species of fruit-feeding butterflies respond differently to forest resurgence. For example, a study in Trinidad showed that butterfly species *Colobura dirce* gain abundance

within five years of habitat disturbance but after a period of thirty years of forest recovery they become less abundant again (Wood, 1999). Similarly, a study in the Kakum forest, Ghana have shown that fruit-feeding butterfly communities may recover after 50 to 60 years following disturbance (Sáfián et al., 2011) and yet still a study in Kibale National Park, Uganda, pointed out that fruit-feeding butterflies may take approximately 40 years to recover from a disturbance on condition that a primary forest is close by (Nyafwono, et al., (2014b). According to Elliot et al., (2013), recovery patterns of formally disturbed butterfly habitat depends on the edaphic factors, distance from a primary forest and the duration and intensity of the disturbance among others. This implies that the recovery process of a disturbed forest is more likely a combination of a number of factors and not only the absence of logging and chemical use. Hence, actual recovery time of butterfly species after habitat disturbance cannot be easily predicted.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study area

This study was conducted in Budongo Forest Reserve (measuring 825 km^2) located in North western Uganda (1°35'–1°55'N, 31°8'–31°42'E), and lies at an average altitude of 1100 meters (Tweheyo & Lye, 2003). The rainy season in the area occurs from March to May and September to November, with monthly average rainfall of between 1200 mm to 2200 mm. It has a relatively constant minimum temperature with a monthly average between 19°C and 32°C (Tweheyo & Lye, 2003). The Forest Reserve is sub-divided into five main blocks, i.e., Nyakafunyo, Siba, Kainyo pabidi, Waibira and Biiso and is bordered by Biso and Butiaba fishing villages in the west along Lake Albert and to the north by the Murchison Falls National Park (Figure. 1). The land slopes from southeast to northwest, and has four main rivers including Waisoke, Sonso, Kamirambwa and Siba, which flow northwestwards towards the Albertine Rift Valley (Eggeling, 1947b; Plumptre, 1996).

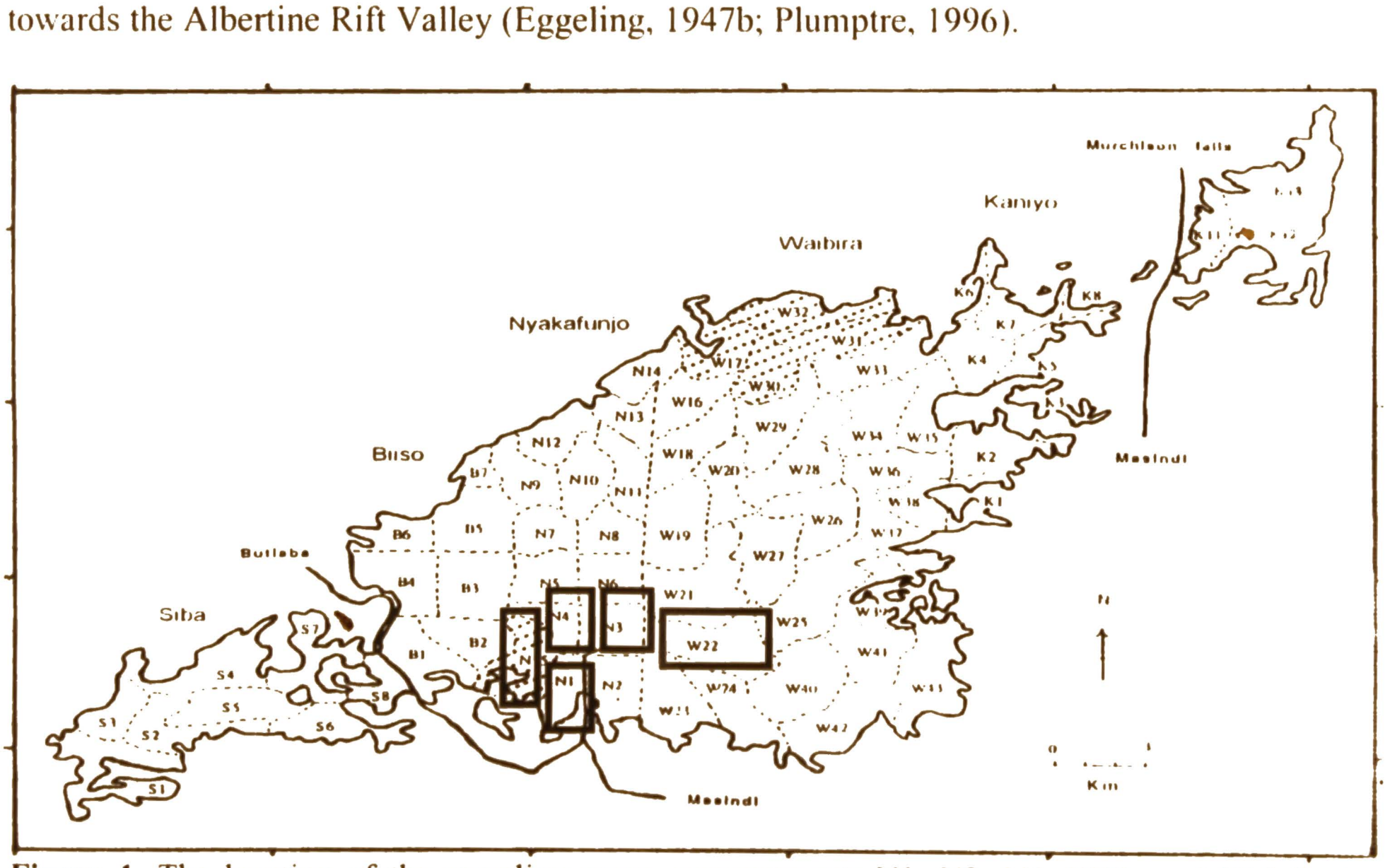


Figure 1. The location of the sampling areas, compartments N1, N3, N4, W22, and N15 in the Budongo Central Forest Reserve (adopted from Owiunji & Plumptre, 1998).

3.2. Study site

To obtain the compartments used for the study, two procedures were followed. First, the management forest map was used to divide the compartments into two strata basing on the history of logging and arboricide treatment i.e. logged and unlogged compartments were identified. Secondly, simple random sampling was conducted from the two strata to obtain the five compartments selected for the study, four from logged and one unlogged compartment. The logged management compartments included; N1, N3, N4, W22 and the unlogged compartment N15, which is a primary forest used as nature reserve (Figure. 1. Table 3.1)

Table 3.1. Description of forest compartments studied in the Budongo Central Forest Reserve.

Compartment	Area/(ha)	Date logged	Date treated with arboricide	Mahogany volume (m^3ha^{-1})	Total volume ($m^3 ha^{-1}$)[1]	Average Elevation (altitude) (m)
N1	412	1945	1962-63	47.1	58.7	1072
N3	620	1947-52	1959-61	39.1	80.0	1077
N4	341	1952-54	1960-62	48.0	94.0	1082
W22	1036	1965-67	1966	23.0	35.9	1096
N15	777					1063

[1]The total volume only shows timber removed by sawmills and does not include timber removed by pit sawyers (Plumptre, 1996)

3.3. Sampling of butterflies

Butterflies were sampled using two transects (measuring 400 meters) in each of the five forest compartments (50 trap points in total). Fruit-feeding butterflies were sampled using white cylindrical butterfly traps (height 65 cm, diameter 25 cm) positioned at 100meters from each other along the transect lines (five traps per transect). Each trap was alternately placed

ten meters away from the transect line and their positions were determined using a Global Positioning System, Garmin GPSmap 60C× (as illustrated in Fig. 2).



Figure 2. Transect lines and location of traps.

The traps were baited with yellow ripe bananas previously smashed and uniformly mixed in a 20 liters plastic bucket and allowed to ferment for four days. Two spoonfuls of the fermented banana fruit was placed in a small plastic plate fixed using glue on to the plywood base of the white cylindrical trap (Appendices 1 a and b). The baited traps were hanged at 40 -50 cm height above the ground (Hughes et al., 1998; Molleman et al., 2005). The traps were baited on the first day of setting and checked on the subsequent five days between 0700-1700 hours. within which butterfly species and abundance were recorded for five months from February to June 2017 (February and June being months without rain and March to May being rainy months). In total, 50 trap points were selected, ten locations in each compartment (a total of 250 trap days of sampling effort per compartment).

The traps were re-baited on the second and fourth day of sampling after recording the catches to maintain the freshness and a fairly uniform odor production of the bait to maintain similar level of fermentation from the same stock. During the final day of the sampling, bait was removed from all the traps, and the traps were either turned upside down or folded and fixed on a tree branch for safety for all the periods of no sampling (DeVries, Walla, & Greeney, 1999). Traps which were damaged by monkeys, baboons, wild rats among others were either replaced with new ones or repaired. The captured butterflies were identified using standard identification field guides (Molleman, 2012; Williams, 1969). Samples of all species captured (three representatives from each species captured on the first day of sampling) were preserved and stored at the Sonso field station. The rest were released (without marking) at approximately one kilometer to one and half kilometers away from the trap location. Only three percent of butterflies are known to fly for more than 100 meters (Molleman, personal communication, 2012 as cited by Nyafwono, 2014a & 2014b). As a result, in her study, butterflies were released without marking at a distance of ≥ 500m from the trapping sites (Nyafwono, 2014a, 2014b). This indicates that there would be absolutely no opportunity for recapture, considering the distance at which trapped butterflies were released in this study. Great care was taken when handling the fragile butterflies to avoid any damage. Photographs of the captured butterfly species were taken using a Digital Still Camera (SONY Corporation, Model number DSC-W270).

3.4 Ethical consideration

Permission to access the forest reserve was granted by the National Forest Authority (see Appendix 4).

3.5 Data analysis

The sample based species accumulation curve, replotted against the x-axis of individual abundance (Gotelli & Colwell, 2011), with 95% confidence intervals. was generated using Estimate S (Colwell, 2013) to determine differences in species richness for each of the five compartments. Shannon diversity index (Magurran, 2004) was calculated with PRIMER-E software (Clarke & Gorley, 2006) to determine butterfly species abundance (number of individuals per trap). Differences among the compartments in species abundance and diversity indices of butterflies were assessed using a one-way analysis of variance (ANOVA) followed by Tukey post-hoc tests with SPSS version 23 (IBM Corporation, Armonk, NY, USA). Prior to the analysis, species richness and abundance data were $\log_{10}$ transformed to improve normality. To test for a directional pattern in the species density, diversity and abundance of butterflies along the successional gradient, Spearman's correlations between the average values of each variable (abundance and diversity) and the 'order' of successional gradient were calculated in IBM SPSS, version 23. The following order of successional analysis was used in correlation analysis and was based on the time since disturbance as well as the intensity of disturbance, Table 1 (W22 = 1, N4 = 2, N3 =3, N1 - 4 and N15 = 5).

Permutational multivariate analysis of variance, PERMANOVA in PRIMER-E, with unrestricted 999 permutations of the raw data (Anderson et al., 2008) with type III sum of squares, based on the Bray-Curtis similarity matrix, was used to test for differences in the community composition of butterflies among the five compartments, months and the interaction between compartment and month. Patterns in communities of butterflies (differences and similarities) among the five compartments and months was visualized using a non-metric multidimensional scaling (NMDS; conducted with restarts set at 50) (Clarke & Gorley, 2006). For this analysis, the data was square root-transformed to reduce the effect of

the most abundant species, with addition of dummy variable 1. To test for a directional pattern in butterfly community composition along the successional gradient a distance-based linear model (DISTLM) was fitted, where the Bray-Curtis similarity matrix was modeled with the 'order' of successional gradient as a continuous predictor. Finally, to identify which species of butterflies characterize (i.e., are indicators of) each of the forest compartments (as indicated by the NMDS plot), a Dufrene Legendre Indicator species values were computed (Dufrene & Legendre 1997). Computations were conducted with package 'labdsv' (Roberts, 2012) in R Foundation for Statistical Computing program using data on total abundance of each species in each trap. Species with index values > 0.25 were regarded as indicator species, following Dufrene and Legendre (1997).

3.6 Study limitations

- First, the tree sap, wild animal dung, decomposing flesh and fermenting fruits that dropped from the fruiting trees adjacent to the sampling plots could have interfered with the efficiency of butterfly trapping.
- The Dufrene-Legendre indicator analysis doesn't differentiate forest-edge from forest-interior species or forest-dependent from non-forest dependent species.
- The traps could not capture all the butterflies in the forest e.g., those from the canopy. The observed species richness in my study is therefore an underestimate of the total species richness within the study area.
- Secondly, financial constraints and time limitation restricted sampling to only five compartments of the forest and five months which could affect interpretation of seasonality effects.

CHAPTER FOUR

RESULTS

4.1. Butterfly species richness, abundance and diversity

A total of 3,780 individuals, representing 85 species belonging to three families and 28 genera were trapped during the five months of study (Appendix 2). The species accumulation curves (Figure 3) nearly reached asymptotes for all compartments. Based on the rarefied species richness values for 120 individuals (the highest shared number of individuals across compartments), and their 95% CIs, there was no differences in the total species richness among the compartments (Figure 3).

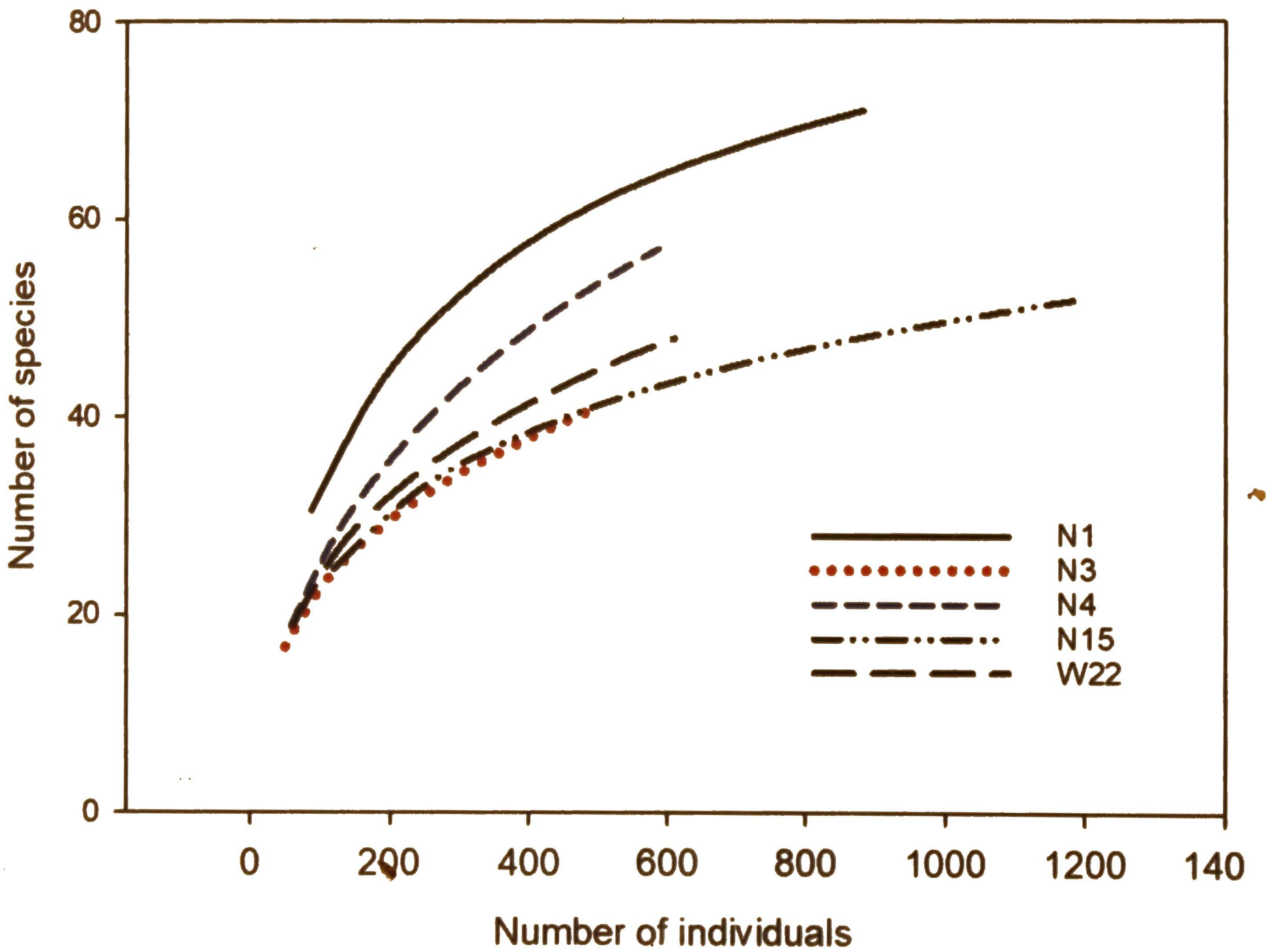


Figure 3. Sample-based species accumulation curves, x-axis scaled to represent numbers of individuals, for the five forest compartments in Budongo Central Forest Reserve, Uganda. N1= heavily logged in 1945, N3= clear cut to almost bare from 1947 to 1952, N4= logged from 1952 to 1954, W22= logged in 1965 to 1967 and N15, is the unlogged compartment/ primary forest.

Compartment N1, presented the highest number of species with 71 species (26.4% of the total species), followed by compartment N4 with 57 species (21.2%), N15 with 52 species (19.3%), W22 with 48 species (17.8%) and the compartment with the least number of species recorded was N3 with 41 species (15.2%) (Figure 4A-C). There was a significant difference in the species density among the five forest compartments (ANOVA: $F_{4, 218} = 39.6$, $p < 0.01$, Figure 4A). The species density was significantly lower in logged compartments (N1, N3, N4 and W22) than in the primary forest (N15). Furthermore, the butterfly species diversity differed significantly among the five forest compartments (Shannon diversity index, $F_{4, 225} = 36.0$, $p < 0.01$, Figure 4B). The abundance of species also differed significantly among the five studied forest compartments ($F_{4, 218} = 44.6$, $p < 0.01$, Figure 4C). The most abundant species in all the compartments was *Bicyclus smithi* which contributed 24% of all individuals caught, followed by *Bicyclus mesogena* with 13%, *Gnophodes new* with 9% and *Gnophodes chelys* with 7%. Singleton species accounted for 0.03% of the total individuals and 0.4% of total species count (Appendix 3).

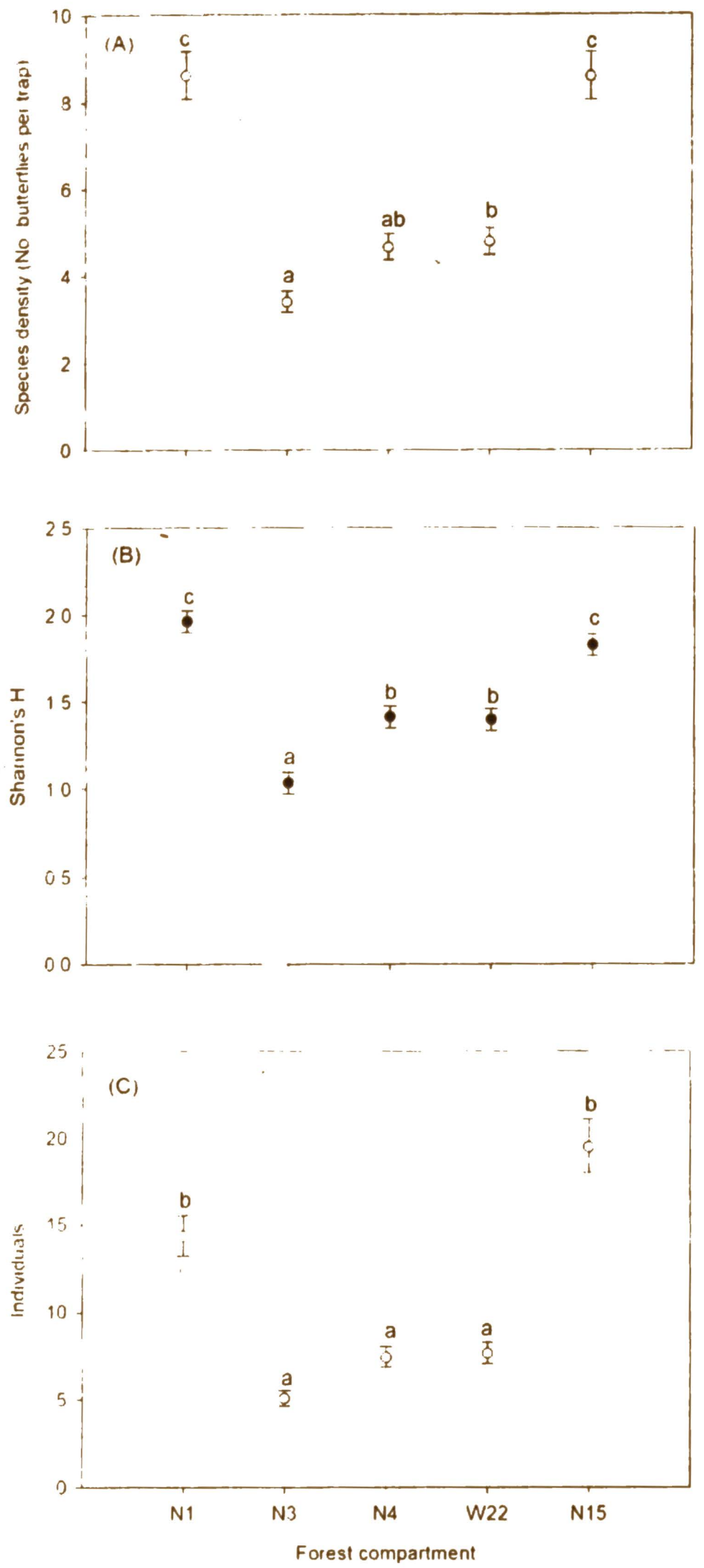


Figure 4. (A) Butterfly species density, (B) diversity (Shannon and (C) abundance (individuals per trap) in the five forest compartments of Budongo Central Forest Reserve, Uganda. Values represent estimated marginal means (±SE) from the one way ANOVA. Forest compartments differing significantly from each other (Tukey post-hoc tests; $P < 0.05$), are indicated by different letters.

The butterfly species density also differed significantly among the months ($F_{4, 218} = 60.7$, $p < 0.01$; Figure 5A). The months of March, April and May had significantly lower species richness per trap than in February and June. There was also a significant difference in diversity among the months ($F_{4, 225} = 43.8$, $p < 0.01$), with months between March and May having a significantly lower diversity than months of February and June (Figure 5B). Also, the butterfly abundance differed among the months ($F_{4, 218} = 97.2$, $p < 0.01$) with months of February, March, April and May having a significantly lower abundance than June (Figure 5C). Finally, the interaction between compartment and month was significant for species density ($F_{16, 218} = 5.2$, $p < 0.01$), diversity ($F_{16, 225} = 5.4$, $p < 0.01$) and abundance ($F_{16, 218} = 5.3$, $p < 0.01$). There were no significant directional patterns in the species density (number of species per trap), species diversity and abundance of butterflies along the successional gradient (Spearman's correlations: species density $r = 0.300$, $p = 0.624$; diversity $r = 0.600$, $p = 0.285$; abundance $r = -0.100$, $p = 0.875$).

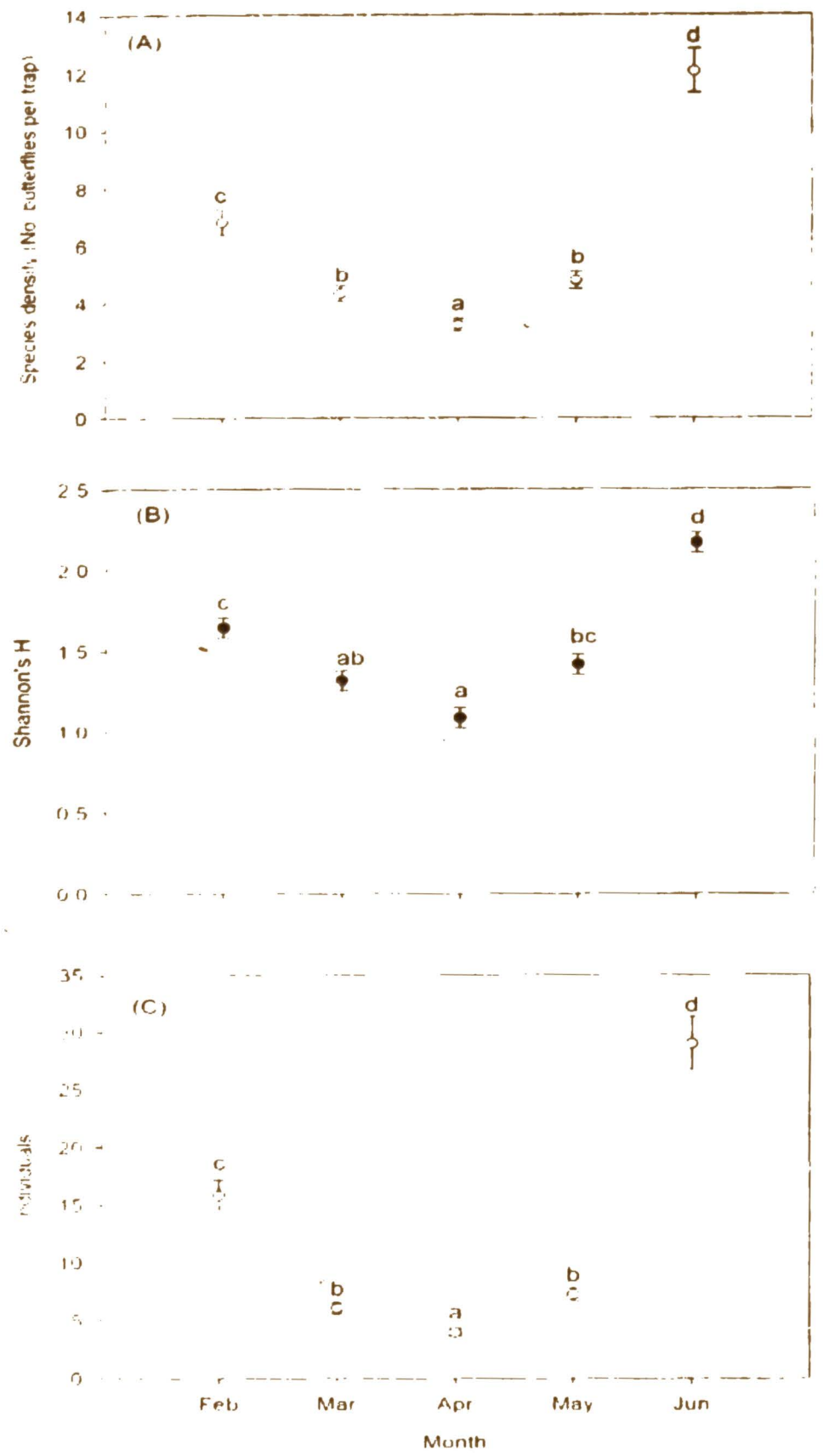


Figure 5. (A) Butterfly species density (species richness per trap), (B) Shannon's D and (C) abundance (number of individuals) during the five study months in Budongo Central Forest Reserve, Uganda. Values represent estimated marginal means from the ANOVA model (abundance and species density values back transformed). Months differing significantly from each other are indicated with a different symbol (Tukey post-hoc tests, $P < 0.05$).

4.2. Butterfly community composition

The butterfly community composition differed significantly between the five compartments, months and there was a significant month-compartment interaction effect (Table 4.2), as illustrated by the NMDS ordination (Figure 6). The largest source of variation in the butterfly community composition was explained by the months (27%), followed by forest

compartments (17%) and the interactions between forest compartment and month (15%) (Table 4. 2). Pairwise tests revealed that communities of all selectively logged compartments differed significantly from each other and from the primary forest (unlogged compartment, $p < 0.05$) except between compartments N4 and W22 ($p > 0.05$). The average similarity in butterfly communities between the regenerating compartments and primary forests varied between 45 and 56 percent. Furthermore, the communities of butterflies differed significantly between different pairs of months ($p = 0.001$). There was a statistically significant directional change in the butterfly communities along the successional gradient (DISTLM model; pseudo-F = 13.5, P = 0.001), but it explained a very small proportion of variation in the data ($R^2 = 0.05$).

Table 4.2. Results of the Permanova analysis showing the partitioning of multivariate variation and tests for the two factors (forest compartment and month) and their two-way interaction. d.f.= degree of freedom; MS= mean-squares, UP = unique permutations, Sq. var = square root of the component of variation. (percentage of the total variation explained in parentheses).

Source of variation	**d.f.**	**MS**	**Pseudo-F**	**P**	**U (perms)**	**Sq.var. (% of variation explained)**
Compartment	4	13547	9.0	0.001	999	15.5 (17%)
Month	4	32000	21.3	0.001	999	24.7 (27%)
Compartment × month	16	3455	2.3	0.001	998	14.0 (15%)
Residual	225	1504	-	-	-	-
Total	249	-	-	-	-	-

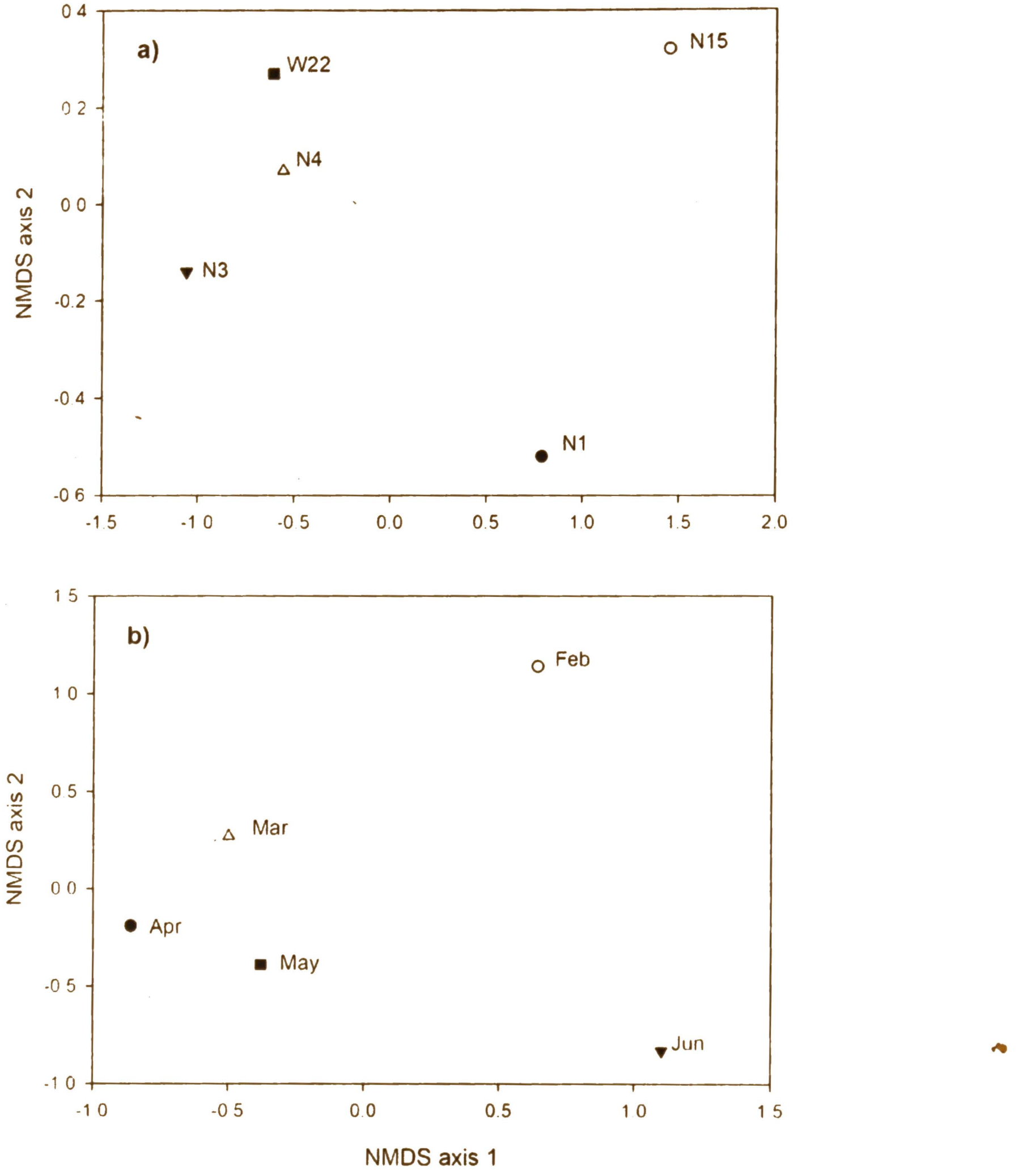


Figure 6. Non-metric multidimensional scaling (NMDS) ordination for; (a) forest compartments and (b) months. Symbols represent centroids of forest areas or months, respectively.

4.3. Indicator species

Dufrene Legendre Indicator species analysis showed that four species, namely; *Charaxes numenes, C. candiope, Gnophodes new,* and *G. chelys* (12% of total Indicator species in all the compartments from the genera Gnophodes and Charaxes having equal representation) characterized the youngest regenerating forest compartment, W22. The three species, *G. chelys, Bicyclus graueri* and *G. new* (9%), with the genus Gnophodes having the highest representation, characterized the mid-regenerating forest compartment, N4, but none of the species characterized the former clear-cut forest compartment, N3. Eleven butterfly species mainly form the genus Charaxes, characterized the oldest regenerating forest compartment, N1, the strongest indicators included *C. fulvescens, C. cynthia* and *C. hipunctatus* (33%). The unlogged primary forest compartment, N_{15} recorded fifteen (15) indicator species most of which from the genus Bicyclus (46% of the total indicator species), which was the highest number in all the forest compartments studied. They included six *Bicyclus species*, three *Bebearia species*, two *Cymothoe* and *Melanitis species*, respectively. The strongest indicator species in primary forest, in descending order, included *Melanitis ansorgei, B. smithi,* and *B. mollitia.* Others included; *B. buea, Heteropsis peitho, B. sambulos, Cymothoe lurida, C. egesta, M. leda, B. safitza, G. betsimena, B. cacolia, B. mesogena, B. absolon,* and *B. sophus* (Appendix 3)

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1. Discussion

The results of this study showed that the species richness, diversity and composition of butterfly communities in the clear cut, selectively logged and arboricide treated compartments in Budongo forest are still significantly different from those of primary forests even after 72 years of natural regeneration. The primary forest here was used as a reference of comparison since there is no data showing species richness, diversity and composition of butterfly communities before the effect of logging and the chemical treatment. The result showed a higher species richness, diversity and abundance in the primary forest than the disturbed forest compartments. This could be attributed to the presence of suitable habitats with numerous host plants and quality diversified fruiting trees compared to the disturbed forests which are constantly exposed to microclimatic extremes (Novotny, et al., 2002; Savilaakso, Koivista, Veteli, & Roininen, 2009b) which may lead to their death. This is consistent with a study in Atewa Range Forest Reserve, Ghana (Addo-Fordjour, et al., 2015). The result showed that the Nymphalidae family had the highest number of species in the five forest compartments. This is so because this family consists of a very diverse group of butterflies with about 440 species recorded in Uganda alone, and they are known to occupy a wide range of habitats (Carder & Tindimubona, 2002; Larsen, 1991) evident of their high level of reproduction and adaptation.

The oldest regenerating compartment N1, showed a similar species density and abundance as that of the primary forest and also having relatively higher diversity compared to the primary forest. This is because of increased resource availability due to the proliferation of pioneer

plant species flora resulting in outstanding impacts on plant's attendants (Filgueiras, et al.,) with numerous fruiting trees e.g., *Ficus sur*.

In this work, no directional gradient in fruit-feeding butterfly species richness, abundance and diversity was found along the natural succession gradient indicating that the disturbed forest compartments have not yet recovered and not convincingly showing gradual recovery towards the primary forest. The directional change only explained a small proportion of the butterfly community composition because of the large difference presented by the primary forest butterfly community. The average similarity in butterfly communities between the regenerating compartments and primary forests varied between 45 and 56% meaning that the disturbed compartments are not yet similar to that of the primary forest.

Similar recovery pattern has also been found in the butterfly communities of clear cut and selectively logged compartments of Kibale National park nearly 40 years after disturbance (Nyafwono et al., 2014b). However, in contrast, a study in the upper Guinean forest in Ghana showed a clear ability of butterfly communities in degraded forest to recover in 40-60 years after clearance (Sáfián et al., 2011). These findings as well as that of the present study demonstrate that the time scale of recovery of butterflies in tropical forests after disturbance is highly variable and cannot be easily predicted and might be location specific.

In addition, remarkable seasonal variations were found in the butterfly species richness, abundance and diversity and community composition, with the highest abundance being found during the months of February and June because maximum vegetation greenness is achieved between two to four months after the two rainfall peaks of March to May and September to November (Tweheyo & Lye, 2003) although this can be highly variable. The

peak of fruiting trees is experienced during the dry season providing sufficient food for the adults (observed by the high variation provided by months, 27%) The finding is consistent with several previous studies conducted in other tropical forests on butterflies (Nyafwono et al., 2014b; Valtonen et al., 2013). The peak in abundance of butterflies during the wet season might be due to seasonality of precipitation (Kasenene & Roininen, 1999) which enhances host plant growth, allowing them to produce new leaves and shoots which are suitable larval foods and oviposition sites for most butterfly species and increasing fruit production (DeVries, 1997).

The results of this study revealed that the unlogged primary forest compartment, N15, had the highest habitat specialist butterfly species followed by the oldest regenerating forest (N1) then the youngest regenerating compartment (W22) followed by the mid-regenerating compartment (N4). This could be explained by their specialization for resources or physiological specialization to different conditions (Koh, 2007; Nyafwono et al., 2014a). Some butterfly species prefer sheltered and cool habitats provided by the high canopies and growth of abundant host plant species in the primary forests which might explain the predominance of *Bicyclus* species, *Bebearia* species, *Cymothoe* species and *Melanitis* species in the unlogged compartments. The highest number of indicator species (46% of the total indicator species) was found in the primary forest, agreeing with the study conducted in Kibale National Park, Uganda (Nyafwono, et al., 2014a) and the majority of them were from the genera *Bicyclus*, *Bebearia*, *Cymothoe* and *Melanitis*. However, a study in Ghana (Sáfián et al., 2011) found the genus *Euphaedra* as the best indicator of undisturbed primary forest. The strongest indicator species in the primary forest included; *Melanitis ansorgei*, *Bicyclus smithi*, and *B. mollitia* among others. Similarly, more indicator species (33% of the total indicator species) characterized the oldest regenerating forest compartment, N1, with the

strongest indicators being *Charaxes fulvescens, C. cynthia* and *C. hipunctatus.* This is in agreement with Larsen (1991) and shows that the forest has not recovered fully from the effects of disturbances as also shown in Kibale National park (Nyafwono et al., 2014a). On the other hand, three species, namely, *Charaxes numenes, C. candiope, Gnophodes new,* and *G. Chelys,* characterized the youngest regenerating forest compartment, W22 and the mid-regenerating forest compartment, N4 was characterized by three species *G. chelys, Bicyclus graueri,* and *G. New.* These compartments are predominantly inhabited by grasslands with sparse vegetation as in the youngest regenerating forest. Also this is attributed to unsuitable breeding sites and probably declining butterfly abundance due to the effect of predators. The identified species could be employed as indicators for forest management in the different compartments in the future.

5.2. Conclusions and recommendations

- This study demonstrates that clear-cut and selectively logged compartments of Budongo Central Forest Reserve do not yet fully support communities of butterflies like those in the unlogged primary compartment even after nearly 72 years of natural regeneration. The results indicate that human induced disturbances (clear-cut, selective logging and aboricide treatment) in the tropical forest can have long term impacts on butterfly communities, highlighting the eminent need to conserve primary forests as a long term conservation strategy for butterfly species.
- The study shows a significant difference in species richness, abundance and diversity among the months
- Butterflies showed high species richness, abundance and diversity in the primary forests compared to the disturbed forest compartments

- Furthermore, the study also shows that different forest compartments in Budongo are characterized by different specialist butterfly species which could be employed in future forest management especially in Afrotropical areas. Additionally, the greatest number of indicators being found in primary forests emphasizes its importance for biodiversity conservation.
- Future studies are required to analyze the direct impact of vegetation cover on fruit feeding butterfly communities

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APPENDICES

Appendix 1a. A cylindrical butterfly trap suspended 40 to 50 cm above the ground.



Appendix 1b. Fermented banana fruit in a plastic plate.



Appendix 2. Butterfly species and total number of individuals trapped in each forest compartment in Budongo Central Forest Reserve, Uganda. Specialist species (Dufrene-Legendre indicator species analysis) in each forest compartment are indicated by asterisks (*) against their name.

	Compartments				
Species	**W22**	**N4**	**N3**	**N1**	**N15**
Ariadne enotrea	3	2	0	4	1
Anthene larydas	2	0	0	0	0
Antanartia delius	2	0	1	7	1
Actinote alciope	0	0	0	1	0
Actinote penelope	1	0	0	1	0
Actinote peneleos	0	0	0	4*	0
Actinote servona	0	1	0	2	1
Aterica galene	0	2	1	2	4
Bicyclus smithi	70	100	122	199	418*
Bicyclus mesogena	61	70	107	97	143*
Bicyclus sambulos	27	20	13	18	41*
Bicyclus graueri	16	23*	9	13	23
Bicyclus amynana	2	0	1	1	6
Bicyclus mollitia	7	15	27	25	62*
Bicyclus golo	1	1	0	0	0
Bicyclus vulgaris/ jefferyi	0	0	1	0	0
Bicyclus istaris	0	0	2	1	0

Bicyclus funebris/ campinus	0	0	0	1	0
Bicyclus mandanes	0	1	0	1	2
Bicyclus safitza	1	3	0	4	9*
Bicyclus auricruda	10	8	6	17*	14
Bicyclus buea	5	2	8	14	21*
Bicyclus campus	0	0	1	3	0
Bicyclus uniformis	2	2	3	12*	8
Bebearia cocalia	5	4	7	4	15*
Bebearia absolon	6	1	12	8	19*
Bebearia sophus	2	2	4	6	11*
Charaxes ameliae	2	4	0	8*	3
Charaxes bipunctatus	1	4	2	11*	3
Charaxes brutus	1	1	1	7	2
Charaxes candiope	21*	5	0	16	9
Charaxes cedreatis	1	2	0	3	0
Charaxes crossleyi	0	0	0	0	1
Charaxes cynthia	28	16	2	38*	15
Charaxes druceanus	1	0	0	0	0
Charaxes etheocles	1	0	0	2	2
Charaxes fulvescens	14	10	1	27*	10
Charaxes tiridates	19	9	3	12	5
Charaxes pollux	1	0	0	1	0

Charaxes pythodoris	0	0	0	1	0
Charaxes protoclea	0	1	0	0	0
Charaxes numenes	12*	3	1	6	2
Charaxes varanes	0	1	0	0	0
Charaxes zingha	2	2	0	4	1
Charaxes zelica	0	0	0	1	0
Cymothoe caenis	0	0	0	1	2
Cymothoe egesta	4	4	1	8	15*
Cymothoe lurida	4	3	4	20*	19*
Cymothoe hobarti	0	0	1	4*	1
Cymothoe herminia	1	0	0	1	3
Euphaedra harpalyce	9	9	4	9	5
Euphaedra edwardsi	0	1	1	1	0
Euphaedra medon	3	4	7	4	4
Euphaedra preussi	2	1	2	2	0
Euphaedra alacris/rattrayi	1	4	0	2	4
Euphaedra eusemoides	0	1	0	2	0
Euphaedra kakamegae	0	0	0	3	1
Euphaedra hollandi	1	1	0	0	0
Eurytela hiarbas	0	0	0	3	0
Euriphene saphirina	0	1	0	0	0
Euriphene ribensis	1	2	2	1	0

Gnophodes betsimena	7	10	10	6	17*
Gnophodes chelys	79*	80*	23	49	31
Gnophodes new	118*	88*	40	60	32
Harma theobene	0	1	0	8	5
Heteropsis peitho	17	10	24	20	41*
Hypolimnas dinarcha	0	0	0	1	1
Hypolimnas salmacis	2	2	0	6	2
Junonia gregorii	0	0	0	1	0
Kallimoides rumia	0	3	1	4	1
Lachnoptera anticlea	0	0	1	10	8
Mesoxantha ethosea	0	1	0	0	0
Melanitis leda	17	15	16	28	36*
Melanitis ansorgei	16	22	26	27	115*
Melanitis libya	0	1	1	3	3
Neptis nemetes	2	0	0	0	0
Neptis metella	0	1	0	1	0
Palla ussheri	0	2	0	2	0
Phalanta phalanta	0	2	0	0	0
Phalanta eurytis	0	0	1	0	0
Pseudacraea clarkia	0	1	0	2	0
Pseudacraea lucreti	0	0	0	0	1
Protogoniomorpha parhassus	0	1	0	4*	0

Protogoniomorpha temora	0	0	0	2	0
Salamis cacta	0	1	0	5*	1
Total individual	**611**	**587**	**500**	**882**	**1200**
Total species	**48**	**57**	**41**	**71**	**52**

ppendix 3. Some habitat specialist butterfly species (*Photos taken by Oloya Joseph*).



Melanitis ansogei



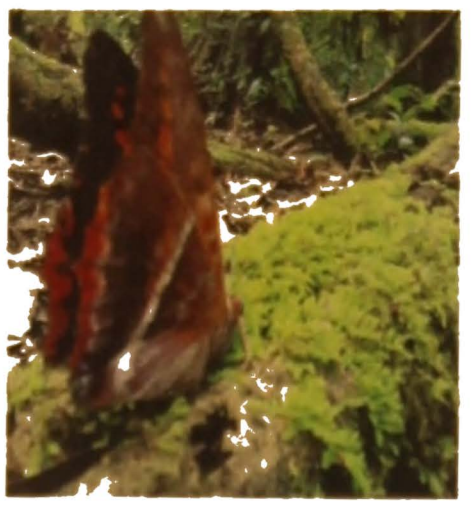
Bicyclus smithi



Cymothoe lurida



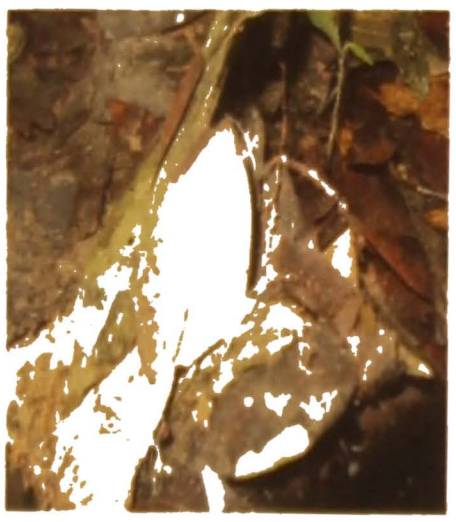
Characxes fulvescens



Characxes cynthia



Characxes hipunctatus



Characxes candiope



Gnophodes new

Appendix 4. National Forestry Authority Permit to undertake study in Budongo.

NFA

National Forestry Authority

The National Forestry and Tree Planting Act, 2003

(Act 8, Section 41-Laws of Uganda)

PROVISIONAL LICENSE TO CARRY OUT RESEARCH IN A CENTRAL FOREST RESERVE (Not Transferable)

License No 238 **Date Prepared** 09-Aug-16 **Forest Management Zone/ Range:** BUDONGO SYSTEM

Subject to the conditions of the National Forestry and Tree Planting Act, 2003 and any Regulations made under the Act and to the terms and conditions stated in this License:

M/s. OLOYA JOSEPH of P. O. BOX 44 LIRA (DOKOLO). 0783924848

is authorised to carry out research in: BUDONGO

Central Forest Reserves for the period 02-Sep-16 to 28-Feb-17

Details of lincensed activities

Sector	Description of activity	Period (Months)	Rate	Amount payable (UGX: / USD):
BUDONGO	Fruit feeding Butterfly community as indicators of recovery in Budongo Central Forest Reserve, Uganda	5.00	20,000	100,000
Application fee for the research:				20,000
TOTAL (Including application fee)				120,000

Amount received (UGX/USD): 120,000

Receipt No 208071

APPROVAL (DIRECTOR NATURAL FORESTS)

Signature: ..... **Name** Levi Etwodu

AUTHORISATION (EXECUTIVE DIRECTOR)

Signature: ..... **Name** Michael Mugisa

Additional special conditions are attached.

** Applicable for all activities except harvesting and land licences*

Copies:Original to Licensee; Finance Department; FORRI; Range Manager

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