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Impact of forest management systems on diversity and abundance of butterflies at Asenanyo forest reserve, Ghana

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ABSTRACT
Objectives: Every forest management practice characteristically affects the structural elements of forests, which eventually influences the habitat conditions of biodiversity living in it. These practices, which may represent various forms of disturbance regimes could influence butterfly species richness, abundance and relationship with their hosts. This study was conducted in the Asenanyo River Forest Reserve in the Ashanti Region of Ghana to determine the impact of forest management systems on the diversity and abundance of butterflies in the forest reserve.
Methodology and Results: The transect method using standard fruit baited traps were employed to capture butterflies in an unlogged, selectively logged and plantation forest management zones. Eight trap net stations spaced at 100 m interval on a 1 km transect were used for the butterfly sampling. This was replicated each other month in all the study areas for a period of six months; each transect was located about 500 m from each other. Shannon-Wiener and Simpson's diversity indexes were used to analyze species richness and diversity of butterflies. The selectively logged forest zone recorded the largest number of butterflies (968) whiles the plantation recorded the least number of butterflies (466). Shannon-Wiener and Simpson's indices for the selectively logged forest and unlogged forest were similar. Shannon-Wiener and Simpson's indexes were however significantly higher in the unlogged than in the plantation forest ($P< 0.05$).
Conclusion and application of findings: The findings of the study indicated that selective logging could be considered as a good alternative to preserve butterflies in production reserves.

INTRODUCTION

Tropical rainforests are well known as centres of biodiversity and much interest has focused on the ecological processes responsible for generating and maintaining this diversity. Recently, some authors have emphasized the importance of natural disturbance and non-equilibrium dynamics, coupled with variations across environmental gradients generated by topographic and edaphic landscape features within forests (Hill *et al*. 2001; Marshall 1992; Whitmore, 1984). Although tropical rainforests vary in species richness, they are among the most threatened of all habitats because of exploitation of forests for timber and economic development (Whitmore, 1984; Wilson, 1988). Forests in West Africa are under increasing threat from logging and agricultural conversion. Among terrestrial ecosystems, forests support the greatest global biodiversity (Battles *et al*. 2001; Lindenmayer *et al.*

2006), and thus the conservation of forest biodiversity is an important goal for forest management (Lindenmayer *et al.* 2000; Kremen, 2005; Junninen *et al.* 2007). Forest management practices, which may represent various forms of disturbance regimes, could influence butterfly species richness, abundance and relationship with their hosts. Although the consequences of logging have been studied for some animals, notably birds and mammals, there is limited information on the response of butterfly species communities to forest disturbance due to management systems. Among insects, butterflies can be considered as one of the best groups to be used to study selective logging and other forest management practices. Selective logging can be defined as carefully planned and controlled harvesting practice that removes certain number and type of tree species in a way that minimizes impacts on forest stands and soils (Putz & Pinard 1993). Butterflies combine a series of characteristics such as their relatively large sizes, high conspicuousness, ease of sampling and a relatively well-known taxonomy (DeVries *et al.* 1999). Butterflies have been used in several studies as good indicator species to predict changes in the environment (Thomson *et al*., 2007). Butterfly species richness may change in response to environmental variables such as plant composition and density, humidity, light intensity and degree of disturbance of vegetation thereby making them good indicators of change (Barlow *et al*. 2007; Bossart *et al*. 2006; Bouyer *et al*. 2007). Several ecological characteristics of fruit-feeding butterflies make them potentially useful tools for monitoring both small and large-scale biodiversity trends (Larson, 2005b). Monitoring butterfly abundance can indicate the presence of semi natural conditions; specifically, flower abundance, understorey cover and vegetation diversity have been found to promote butterfly diversity in an ecosystem (Inoue 2003, Kitahara 2004; Bergman *et al.* 2008; Halder *et al.* 2008). Forests in West Africa are under increasing threat from logging and agricultural Activities. Forest destruction rate in Africa are among the highest in the world. According to IUCN (2006) deforestation rates in Ghana is estimated at around 3% per annum, however, there is limited information about the potential effects of different types of management regimes on diversity patterns for many forest communities (Wood & Gilliam, 1998). Selective logging is known to affect forest structure and the amount of light reaching the ground level through changes in canopy cover (Hamer *et al*. 2003). According to Evans and Turnbull (2004), tree plantations have become increasingly favoured in the tropics. Therefore, the role of plantation forests in maintaining biodiversity cannot be ignored. Gardner *et al.* (2007) also reported that, despite their increased in coverage and potential importance, the biodiversity conservation value of extensive monocultures and areas of native regeneration are poorly understood. Therefore, understanding the ecological consequences of conversion natural forest to mono-specific plantation forests and other types of land use is critical. Habitat specificity and arthropod assemblages can indicate the ecological consequences of forest conversion. The Asenanyo Forest Reserve is an important p forest reserve in the Ashanti Region of Ghana, which has been used for many research works; however, there is limited information on the impact of human activities on butterfly species in the forest. The impacts of management practices on butterfly species richness, abundance and diversity are also not known. The study therefore investigated the impact of forest management systems, mainly selective logging and plantations on the diversity and abundance of butterfly species in the Asenanyo Forest Reserve. Species richness and diversity of butterflies in the three identified management zones in the reserve were determined.

MATERIALS AND METHODS

Study Area: The study was carried out in the Asenanyo Forest Reserve in the Nkawie Forest District of the Ashanti Region of Ghana. The Asenanyo River Forest Reserve lies between latitudes 6° 17' and 6° 36' North and longitudes 1° 50' and 2° 16' West. The Asenanyo River Forest Reserve is a continuous block covering an area of 22792 hectares. The Forest Reserve has a total of 204 compartments (FSC, 2010). Taylor (1960) classified the Asenanyo Forest Reserve as belonging to the *Celtis triplochiton* association, whilst Hall and Swain (1981) put the reserve within Moist Semi-Deciduous North-West subtype (MSNW). There are two well-defined seasons, a rainy season from April to October and a dry season from November to March. The Asenanyo Forest Reserve lies in the two-peak rainfall belt, with the maximum during May/June and the minimum during September/October. The Asenanyo River Forest Reserve lies in the 1250-1500 mm isohyets zone (Forestry Commission, 2010).

Based on the existing management type/system used. Three different forest type/sites namely unlogged, selectively logged and plantation forest were selected for the study. The unlogged forest that served as the referenced site or control has not been logged before whiles the selective logged forest has undergone selective logging for more than fifteen years. Fifteen years old monoculture plantations were also selected as the third site for the study in the forest reserved. These forest type differ significantly in community structure and plant diversity.

Butterfly Sampling: The study was conducted within a period of six months (January to June 2014). Sampling was done in the unlogged, selectively logged (more than fifteen years after logging) and plantation forest (fifteen years old) in the forest reserve using six transects in each study site. The sampling protocol involved the use of line transects and fruit-baiting techniques. A linear, 1-kilometre-long transect was used for the sampling in all the study areas. Transects used were similar to those described by Pollard & Yates (1993). Modified IKEA® standard fruit baited traps (Aduse-Poku, 2006) were used to trap butterflies in the three forest management zones. On each transect, 8 trap net stations spaced at 100 m interval were installed for a quantitative butterfly diversity sampling. This was replicated each other month in all the study areas for a period of six months; each transect was located about 500 m from each other for sampling. Butterfly traps nets were hanged at about 50 cm above the forest floor and baited with different attractants such as overripe pineapples and banana fruits mixed with palm wine for maximum attraction of the butterflies. Baits were replaced with fresh ones after each specimen collection. Trained observers sampled butterflies simultaneously in all the three management zones to avoid sampling bias and they were rotated among the management zones every month. Traps were inspected at the same time in all the study sites during the sampling periods between 10.00 and 15.00 hours GMT. In all 24 standard fruit, baited traps were used for the study. After collection, trapped specimens were transported in glassine envelopes for identification. To avoid a butterfly being identified more than once, permanent markers were used to mark under the wings of the butterfly. Identification was done using Butterflies of West Africa (Larson, 2005) as an identification guide. Butterflies were identified to species-level and grouped into respective taxonomic units (species, genus, and family) using features such as body size, wing shape, wing colour and pattern, flight pattern and behaviour.

Data Analysis: Data on butterflies collected were analysed using student edition of Statistix 9 statistical package. Species Diversity, Evenness and Richness were analysed using Shannon-Wiener (H') and Simpson's indices of diversity (Magurran, 2004). The Shannon-Wiener index (H') is an estimate of species diversity which incorporates richness and evenness into a single measure whilst Simpson's index is a measure of species evenness.

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \qquad D = \sum_{i=1}^{s} p_i^2$$

Where

H' = Shannon index;

D = Simpson index and

S = Number of observed species

the quantity p_i = the proportion of individuals in the *i*th species.

To determine the effects of management systems on butterfly species richness, diversity and abundance, in the forest types, Analysis of variance (ANOVA) was conducted at significance level of 5 % using student edition Statistix 9 statistical package. LSD pair wise comparison test was used to determine differences of means among the management types.

RESULTS

Community characteristics of butterflies at Asenanyo Forest Reserve: A total of 2,314 individual butterflies belonging to 87 species, 41 genera and 5 families were trapped in the three management zones in the forest reserve. The Selectively logged zone recorded the highest number of individual butterflies (968 individuals) and (82 species). Plantation forest management zone had the least individual butterflies (466) and (39 species). All the butterflies recorded in the three management zones belongs to five families as shown in (Table 1)

Table 1: Community characteristics of butterflies at the Asenanyo Forest Reserve

Attributes	Management Systems		
	Unlogged Forest(UF)	Selectively Logged(SL)	Plantation Forest(PF)
Individuals	880	968	466
Species	78	82	59
Genera	37	39	36
Families	5	5	5

Species diversity of butterflies in the management zones: Results of Shannon diversity, Species richness, Simpson diversity, Evenness and Abundance of butterflies calculated for each of the management zones in the forest reserve is presented in table 2. Although Shannon and Simpson's diversity were higher in the selectively logged zone than the unlogged, there was no significant difference ($p>0.05$; CV. 8.01 & 1.51 respectively) between the two; however, there was a significant difference ($p<0.05$) between the unlogged and the plantation management zones. Significant difference ($p<0.05$; CV. 24.14 & 34.99 respectively) existed between the unlogged and the plantation in terms of species richness and abundance, but between the unlogged and the selectively logged zones there was no significant difference ($p>0.05$). Species evenness did not show significant differences ($p>0.05$; CV. 1.03) among all the management zones in the reserve (Table 2).

Table 2: Butterfly diversity, species richness, evenness and abundance in the different management zones in the Asenanyo Forest Reserve (± Standard error of mean)

Parameters	Mean		
	Unlogged Forest	Selectively logged	Plantation
Shannon Diversity index(*H'*)	$3.29^{a} \pm 0.07$	$3.49^{a} \pm 0.09$	$2.93^{b} \pm 0.09$
Shannon Evenness	$0.93^{a} \pm 0.003$	$0.93^{a} \pm 0.005$	$0.92^{a} \pm 0.006$
Species Richness	$34.17^{a} \pm 2.21$	$44.17^{ab} \pm 4.31$	$25.67^{b} \pm 3.22$
Simpson Diversity(1-D)	$0.95^{a} \pm 0.004$	$0.96^{a} \pm 0.004$	$0.92^{b} \pm 0.004$
Species Abundance	$141.83^{a} \pm 13.39$	$162.83^{a} \pm 24.70$	$81.16^{b} \pm 11.37$

Within rows, means with different letters are significantly different ($P < 0.05$)

Distribution and Abundance of captured butterflies among the three management zones in the Forest Reserve: Butterflies species captured in the forest reserve and their distribution across the management types is shown in Table 3. Genus *Euphaedra*, recorded the largest (503) number of individuals; made up of 12 species whilst the least numerous (2) was *Abantis.* In terms of species, *Junonia terea* was the most abundant species trapped in the forest reserve where 131 individuals were recorded followed by *Euphaedra phaethusa* (120) and *Euphaedra harpalyce* (101). The species with fewer individuals were *Pseadacrea eurytus* (1) and *Abantis tanobia* (2). In the selectively - logged management zone, *Euphaedra phaethusa* recorded the largest number (91) of species. *Charaxes cynthia (*55*)* and *Junonia terea (*85*)* were the most abundant species in the plantations and the unlogged zones respectively. Only 1 individual of *Pseadacrea eurytus* was collected; 2 each of *Abantis tanobia* and *Eurytela dryope* were recorded. Thirteen species were found to be unique because they were recorded in only one forest management zone. *Acrea umbra, Abantis tanobia,* *Bicyclus nobiliss, Charaxes petersi and Neptis angusta* were found only in the unlogged forest; the following species were found only in the selectively logged zone; *Bicyclus medetes, Charaxes castor, Euphaedra ceres, Euphaedra thermis, Euphaedra zampa, Eurytela dryope, Pseudacrea eurytus* and *Salamis cacta*. Regardless of the management system, *Junonia tera, Euphaedra phaethusa, Euphaedra harpalyce, Euphaedra medon and Euphaedra janetta* were the most abundant butterfly species in the forest reserve.

Table 3: Distribution and Abundance of butterflies in the different forest management types in the Asenanyo Forest Reserve

Family/Species	**Forest Management Systems**		
	Unlogged	**Selectively Logged**	**Plantation**
PAPILIONIDAE			
Papillio dardanus (Poulton 1924)	15	51	5
Papilio nireus (Linnaeus, 1758)	2	5	0
Graphium Policence (Cramer, 1775)	12	13	9
PIERIDAE			
Pseudopontia paradoxa (Field, 1869)	2	5	3
Eurema hapale (Mabile, 1887)	6	7	0
Eurema hecabe (Buttler, 1875)	12	15	6
Captopsilia florrela (Fabricius, 1793)	13	10	5
Colotis equippe (Linnacus, 1758)	9	11	6
Nepheronia thalasina (Boisduval, 1836)	37	18	12
Leptosia hybrida (Bernardi, 1952)	12	2	6
Leptosia medusa (Cramer, 1777)	9	2	0
Mylothris atewa (Berber, 1980)	11	9	3
Belenois calypso (Drury, 1776)	10	9	5
Appias sabina (Field, 1865)	11	8	3
Leptosia alcesta (Cramer, 1777)	3	5	4
NYMPHALIDAE			
Acraea Pharsalus (Ward, 1871)	5	6	6
Acraea umbra (Drury, 1782)	3	0	0
Ariadne enotrea (Cramer, 1779)	2	5	28
Atrica galena (Brown, 1776)	11	14	6
Bebearia madinga (Felder, 1860)	9	6	3
Bebearia safitza (Westwood, 1850)	3	6	3
Bebearia sophus (Fabriscus, 1793)	6	4	0
Bebearia tentyris (Hewitson, 1869)	9	11	13

Table 3 Cont'd

Family/ Species	**Forest Management Systems**		
	Unlogged	**Selectively Logged**	**Plantation**
NYMPHALIDAE			
Bebearia zonoria (Butler, 1868)	6	16	3
Bicyclus dorothea (Cramer, 1779)	48	12	5
Bicyclus funebris (Meneville, 1884)	13	21	50
Bicyclus Italus (Butler, 1869)	10	8	3
Bicyclus madetes (Condanim, 1986)	0	4	0
Bicyclus nobilis (Aurivillius, 1893)	5	0	0
Bicyclus sandace (Hewitson, 1877)	12	17	9
Bicyclus sangmelinae (Condamin, 1963)	9	10	8
Bicyclus uniformis (Bethune-Baker, 1908)	6	7	4

Bicyclus vulgaris (Butler, 1868)	16	15	27
Catuna crithea (Drury, 1773)	44	18	4
Charaxes boueti (Feisthamel, 1850)	13	14	12
Charaxes brutus (Butler,1869)	12	13	11
Charaxes castor (Cramer,1775)	0	3	0
Charaxes cynthia (Butler, 1869)	14	15	55
Charaxes eupale (Drury, 1782)	12	13	8
Charaxes Petersi (van Someren, 1969)	3	0	0
Charaxes protoclea (Feist, 1850)	9	12	4
Charaxes viola (Butler, 1865)	3	9	0
Cymothea caenis (Drury, 1773)	10	8	0
Cymothoe egesta (Cramer, 1775)	12	11	3
Cymothoe mabilei (Overlect, 1944)	11	6	4
Danus chrysippus (Linnaeus, 1958)	10	14	6
Euphaedra ceres (Fabricius, 1775)	0	3	0
Euphaedra diffusa (Butler, 1866)	4	9	5

Table 3 Cont'd

Family/Species	Forest Management Systems		
	Unlogged	**Selectively Logged**	**Plantation**
NYMPHALIDAE			
Euphaedra harpalyce (Cramer, 1777)	65	23	13
Euphaedra janetta (Butler,1866)	18	61	12
Euphaedra mendon (Linnaeus, 1758)	14	67	11
Euphaedra perseis (Drury, 1773)	4	12	0
Euphaedra edwarsii (Van der Hoven, 1854	8	9	0
Euphaedra phaethusa (Buttler, 1866)	18	91	11
Euphaedra thermis (Hubner, 1806)	0	9	0
Euphaedra velutina	7	9	4
Euphaedra xypete (Hewitson, 1865)	4	7	1
Euphaedra zampa (Westwood, 1850)	0	3	0
Euriphene incerta (Aurivillius, 1912)	4	7	0
Euriphene aridatha (Hewitson, 1868)	8	4	0
Euriphene barombina (Aurivillius, 1894)	17	21	8
Euriphene gambiae (Feisthamel, 1850)	13	15	6
Euryphura chalcis (Felder, 1860)	12	11	3
Eurytela dryope (Cramer, 1775)	0	2	0
Gnophodes betsimena (Dbiday, 1849)	3	9	0
Hallelesis halyma (Fabricus, 1793)	6	3	0
Hypolimnas salmacis (Drury, 1773)	4	8	3
Junonia sophia (Fabricius, 1793)	2	6	0
Junonia terea (Druce, 1773)	85	35	11
Neptis nebrodes (Hewitson, 1874)	3	0	0
Palla ussheri (Hall, 1919)	9	4	3
Pseudacreae lucretia (Cramer,1775)	9	7	5
Salamis cacta (Fabricius, 1793)	0	4	0

Table 3 Cont'd

Family/Species	Forest Management Systems		
	Unlogged	Selectively Logged	Plantation
NYMPHALIDAE			
Pseudacraea eurytus (Linnacus, 1758)	0	1	0
Amaurina hecate (Butler, 1866)	9	4	3
HESPERIIDAE			
Abantis tanobia (Larson, 2005)	2	0	0
Eagris decastigma (Mabille, 1891)	3	1	0
Meza meza (Hewitson,1877)	6	12	8
Melphina malthina (Hewitson, 1876)	4	2	1
LYCAENIDAE			
Pentila hewitsonii (Hewitson, 1876)	9	3	2
Pentila pauli (Staudinger, 1888)	0	1	3
Pentila picena (Hewitson, 1866)	1	5	0
Mimeresia libentina (Hewitson, 1874)	8	7	6
Anthene radiate (Baker, 1910)	8	7	2
Anthene wilson (Taibot, 1935)	6	4	3
Liptena catalina (Smith, and Kirby,1890)	6	3	2

DISCUSSION

Butterfly species differed among the forest management zones in the study area. Most of the butterflies were found in the unlogged and the selectively logged zones. Differences in canopy cover and level of habitat disturbance led to differences in butterfly faunal composition (Hill *et al.* 2001; Schulze *et al.* 2001). A total of 2314 individual butterflies are captured within a period of six months in the forest reserve. Family Nymphalidae recorded the largest number of individuals/species whiles Hesperidae recorded the least number of individuals. This might be because most members of Nymphalidae are fruit feeders with a wide range of adaptations and environmental preferences (Larson, 1997). Addae-Wireko (2008) reported that Nymphalidae are the widely known butterfly species in Ghana. It is estimated that approximately 900 butterfly species occur in Ghana and most of these were identified to belong to the Nymphalidae, which are fruit feeding butterflies (Larson, 1997). Members of the genera *Euphaedra*, *Euriphene*, *Bebearia, Bicyclus* and *Charaxes* predominated in the reserve. The result showed that species richness and diversity of butterflies were similar between the unlogged and selectively logged management zones. Shannon Wiener and Simpson diversity indices in the unlogged forest were similar to that of the selectively logged forest. This implies that the selectively logged forest still harbours resources that favour butterfly success. Ribeiro & Freitas (2012) reported increase in butterfly diversity, which is related to the increase in its host-plant availability caused by reduced impact logging. Addo-Fordjour *et al.* (2015) also found that butterflies diversity depended significantly on vegetation characteristics, indicating that areas with high plant resources supported more butterflies. Thus, selective logging, which usually promotes natural regeneration, could have resulted in an increase in plant diversity and affected butterfly diversity positively. Adult butterflies and their larvae depend on monocotyledonous plants for food resources (Halder *et al.* 2008). The selective logging had also increased the intensity of sunlight, which leads to relatively warmer microclimatic conditions, which also favours butterfly diversity. This result is in agreement with a number of other studies on butterflies showing increases in species diversity in response to selective logging (Pardonnet *et al.* 2013; Ribeiro & Freitas 2012; Halder *et al.* 2008; DeVries *et al.* 1997). However, this research contrasts with other studies where selective logging resulted in a decrease in species diversity of butterflies (Hill *et al.* 1995; Tangah, 2000). Significant differences were recorded between the unlogged and the *Cedrela odorata* plantations management zones for both Shannon Wiener and Simson's diversity index as well as species Richness. Obviously, this was due to the reduced complexity of the vegetation, ground coverage and canopy cover associated with the mixed plantation forest compared with the unlogged natural forest. Monocotyledonous and other herbaceous plant species for which most butterflies depends were not sufficient in the plantation and wider canopy openings in the plantation resulted in the lower diversity of butterflies recorded. Due to the wide canopy openings, butterflies that are specialized in open and agricultural areas were the most common in the plantations. Lower butterfly diversity observed in this study is in agreements with a number of other studies, which found butterfly to be less abundant in plantations than the unlogged forest (Fermon, 2000; Barlow *et al.* 2007). However, this finding also contradicts with other studies, which showed that diversity and richness of butterflies were higher in the plantations than the unlogged forest (Ramos, 2000; Lawton *et al.*, 1998; Bobo *et al.* 2006). Selective logged zone recorded the largest number of individual butterflies in the forest reserve. Selective logging resulted in significant openings in the canopy, which provided favourable microhabitat conditions in terms of food resources and microclimatic conditions for butterflies of good forest, species not strictly limited to forest and those with broad geographical ranges. Butterflies, like most insect groups, adapt well to the mild (intermediate) disturbance principle (Fermon *et al*. 2000). *Euphaedra* species were found to be most abundant in the selectively logged zone. *Euphaedra* species are known to feed exclusively on fruits (Larson, 2005b) and are therefore more likely to visit baited traps. *E. phaethusa, E. medon, E. janetta, Papilio dardanus* and *Junonia terea* were the most abundant species recorded in the selectively logged forest. *E. phaetusa,* which was the most abundant, is known to visit disturbed areas (Larson, 1999) but also prefers the more mature patches inside the secondary forest, which accounted for their large numbers in the selectively logged zone. *Papilio dardanus* can be found is all the forest types of Ghana, known to be generally common, have fairly wide ecological ranges, and can colonise both intact and disturbed forests (Larson, 2005) and therefore their abundance in the selectively logged forest was not surprising. Eight species namely *Bicyclus medetes, Charaxes castor, E. ceres, E. thermis, E. zampa, Eurytela dryope, Pseudacrea eurytus*, *Salamis cacta* were only recorded in the selectively logged zone. These species are species of dry forest (Larson 2005) but they also visit forests with open canopy cover. In the unlogged zone, which served as the control, the most abundant species were *J. terea, E. harpalyce*, *B. dorothea*, *Catuna crithea* and *N. thalasina.* These species are typical forest generalist (Larson *et al*., 2007) and therefore their large in numbers in the unlogged zone was not surprising. *E. harpalyce* is a species occurring in most types of secondary growth as well as intact forest [30]. In the upland evergreen forest in the Atiwa Forest Reserve Addo-Fordjour *et al*. (2015) found *J. terea* and *N. thalasina* to be highly abundant in all the forest types surveyed in the forest reserve. *J. terea* is now known to be much more common in West Africa than they were before due to the widespread destruction and fragmentation of forest cover that has taken place in this part of Africa where as *N. thalasina* is generally a common secondary butterfly with considerable ability to survive intact forest, disturbed areas and transitional zones (Larson, 2005). Nearly one-quarter of Ghana's forest butterfly species are habitat generalists found in all forest subtypes (Larsen *et al.* 2007). The least recorded butterfly species in the unlogged zone were *Papilio nireus, Pseudopontia paradoxa, A. enotrea, Junonia sophus, A. tanobia and P. pecina.* These species are specialized in degraded habitats and open spaces and very few would ever be found within forest of good condition. That is why a few of them were trapped in the unlogged forest. Among the sites surveyed in the forest reserve, plantation forest recorded the least abundance of butterflies. The most abundant species recorded in the plantation were *C. cynthia, B. funebris. A. enotrea, Bicyclus vulgaris,* and *E. harpalyce.* These are species that survive in most types of forest habitats, open habitats and agricultural areas. Therefore, their high abundance in the plantation zone was not surprising and is in conformity with findings from other studies. *Anthene wilsoni, P. hewitsonii, A. radiate, Liptena catalina* and *Euphaedra xypete* were the least abundant species recorded in the plantations. According to Larson, (2005) these species are pure forest butterfly species and this explains why they were the least abundant in the plantations.

CONCLUSION

The selectively logged management zone recorded the largest number of butterflies as well as species richness and diversity. Butterfly diversity and abundance can be attributed to plant species richness, diversity, abundance and canopy cover, which can also be associated with the management system employed. Considering the needs of the growing human population with high requirements of timber resources, selective logging could be considered as a good alternative to preserve butterflies and many other taxa in a production reserve. Although plantations are generally poor substitutes for butterfly habitat compared to intact forest, the study has revealed that they can provide some form of habitats for some forest species, which makes plantation establishment a viable alternative compared to the complete conversion of natural forest for agricultural activities. Monitoring butterflies diversity and abundance is a cost-effective tool for assessing sustainable forest management practices.

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