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Diversity and abundance of butterflies along a land use: Land cover gradient in Eastern Sierra Leone

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Oil palm (*Elaeis guineensis*) is native to West Africa and has been cultivated for thousands of years. It is an essential part of the local cuisine and critical for food security. In Southeast Asia, oil palm plantations have been accused of being the main cause of deforestation and biodiversity loss. However, several recent studies assessing the impact of oil palm plantations have suggested that the conversion of primary forests to oil palm plantations has no negative impact on butterfly diversity or abundance. Permanent transects were established along a gradient of six land-use types (primary forests, secondary forests, farm-bush with few oil palms, farm-bush with a high density of palms, low-intensity oil palm plantations, and high-intensity oil palm plantations) to investigate the richness of butterfly assemblages. Butterfly species were recorded on eight occasions during both the wet and dry seasons over a two-year period using the walk-and-capture method and fruit bait trapping. All sites were within 50 km of each other in the Eastern Province of Sierra Leone. Three species parameters—Margalef's Richness Index, Shannon-Wiener diversity index, and Pielou's Evenness Index—were computed to describe richness, diversity, and evenness at the six sampling areas. A total of 2,502 individuals from 167 species, 60 genera, and 4 families were identified. The family Nymphalidae was the most widespread, accounting for 46.9% of all sampled butterflies. *Eurema senegalensis* (Pieridae), *Junonia oenone* (Nymphalidae), and *Colotis euippe* (Pieridae) were the species with the highest number of individuals. Butterfly species composition and diversity were higher in the forest (primary and secondary) than in any of the other land-use types. The oil palm plantations recorded the lowest number of individuals and species, with only four species restricted to this habitat. This result indicates that converting primary and secondary forests into oil palm plantations has a significant and detrimental effect on butterfly species composition and diversity.

Key words: Butterfly, LULC, oil palm.

INTRODUCTION

Agriculture accounts for 80% of all land-use change globally and is a major cause of habitat destruction (Campbell et al., 2017; Hertzog et al., 2023). As the world population continues to grow, the demand for food

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bioenergy, and fiber will increase (Emmerson et al., 2016). Agricultural intensification reduces the quality and quantity of habitats and has been identified by the IUCN Red List as a threat to 24,000 of the 28,000 species at risk of extinction (Benton et al., 2021).

Originally from West Africa, oil palm (*Elaeis guineensis*) was brought into cultivation sometime between two and five thousand years ago (Sowunmi 1985; Logan and D'Andrea 2012). It is now grown in 43 countries across the tropics, covering a total area of about 19 million hectares, with Malaysia and Indonesia as the top producers (Murphy et al., 2021). Globally, oil palm produces 81 million tons of oil, making it the most productive vegetable oil crop and the leading vegetable oil consumed and traded internationally (Corley and Tinker 2016; Yudea and Santosa 2019; European Oil Palm Alliance 2019). Oil palm is crucial for the economic development of its producing countries and generates over US$ 60 billion, employing over 17 million people (Murphy et al., 2021).

Despite its high economic value, oil palm has been accused of being the leading cause of biodiversity loss in Southeast Asia (Koh and Wilcove 2008; Vijay et al., 2016; Panjaitan et al., 2020; Qaim et al., 2020). Converting natural forest to oil palm plantations results in habitat loss, a reduction in the diversity and abundance of forest-dependent species, and the loss of ecosystem services (Yaap et al., 2010; Mandal and Raman, 2016). According to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, oil palm plantations are a threat to 321 species (Meijaard et al., 2020). The situation in West Africa is more nuanced; as oil palm is a natural part of the flora, it is generally cultivated at a lower intensity and smaller scale than in Southeast Asia. In Sierra Leone, about 60% of the palm oil for human consumption comes from unimproved varieties of oil palms in the "farm bush." Most plantations of improved varieties are only a few hectares, but there is increasing interest from foreign investors in large-scale plantations (tens of thousands of hectares).

As a result of the value of palm oil, the area cultivated has increased tenfold since 1960 (Voora et al., 2023). Concern over the negative environmental impacts of oil palm plantations led to the establishment of the "Roundtable on Sustainable Palm Oil." Producers who follow certain rules developed by the RSPO are encouraged to market their product as "sustainable" (Wangrakdiskul and Yodpijit 2012; Dauvergne 2018; Nor-Ahmad et al., 2022). Insects are important groups of animals and comprise more than half of all animal species described (Aslam 2009; Alarape et al., 2015; Yager et al. 2016; D'Souza et al., 2016; Orimaye et al., 2016; Okrikata and Yusuf 2017). Butterflies are terrestrial diurnal organisms that belong to the order Lepidoptera (Sundufu and Dumbuya 2008; Kemabonta et al., 2015; Sambhu, 2018) and are the second largest and most diverse group within the order "Insecta" (Nuñeza et al., 2016; Khan et al., 2023).

Insects play an important role in the functioning of many ecosystems (Addai and Baidoo 2013; Warren et al., 2021; Nkongolo and Bapeamoni 2018; Chidi and Odo 2020) and are essential for the sustenance of ecosystems through pollination, serving as important components in the food chain (Yager et al., 2016) and maintaining ecological balance. Their short life cycle, narrow niches, and relatively low mobility make them more sensitive to land-cover and land-use changes and are often used as bio-indicators (Wale and Abdella 2021; Koneri et al., 2022). They are also used as "umbrella" species for the protection and conservation of co-occurring species and are among the most studied insects globally (Orimaye et al., 2016; Panjaitan et al., 2020; Miya et al., 2021).

Global estimates of the number of described species of butterflies range from 18,000 (Nidup et al., 2014; Dantas et al. 2021; Koneri et al., 2022) to 28,000 (Aiswarya et al., 2014; Yager et al., 2016), with the West African region harboring about two thousand species (Yager et al., 2016). Sierra Leone is considered a biodiversity hotspot with an exceptional concentration of endemic species. Over 750 species of butterflies are known to exist in the country (Belcastro and Larsen, 2006), with at least 17 endemic species (Kyerematen et al., 2018). Despite the ecological and environmental roles played by butterflies, their populations are undergoing a tremendous decline (Konvicka et al., 2006; Koneri and Maabuat, 2016; Orimaye et al., 2016; Warren et al., 2021) due to land use change. Hamer et al. (2015) reported that converting primary and secondary forests into oil palm plantations lowers butterfly species richness by around 79-83%.

Over the past decade, massive foreign direct investment has taken place in the oil palm sector, with four companies investing in large-scale oil palm plantations. Butterflies are ubiquitous and can be found in various types of habitats, including oil palm plantations, where they are known to serve as agents of pollination. In Sierra Leone, most of the research on butterflies has been carried out in natural areas, particularly forest ecosystems in protected areas (Belcastro and Larsen 2006; Sáfián 2012; Sundufu and Dumbuya, 2008; Kyerematen et al., 2018). There exists no published data describing extensively the richness and diversity of butterflies found in agricultural ecosystems.

Most of the literature on oil palm plantations shows very negative impacts on biodiversity; however, a series of studies from Southeast Asia have reported that the conversion of primary forest, shrubs, and secondary forests to oil palm plantations has a positive impact on biodiversity. Papers by Kwatrina et al. (2018), Mutmainnah and Santosa (2019), Kwatrina and Santosa (2019), Ginoga et al. (2019), Santosa and Purnamasari (2019) all report increases in the number of butterfly

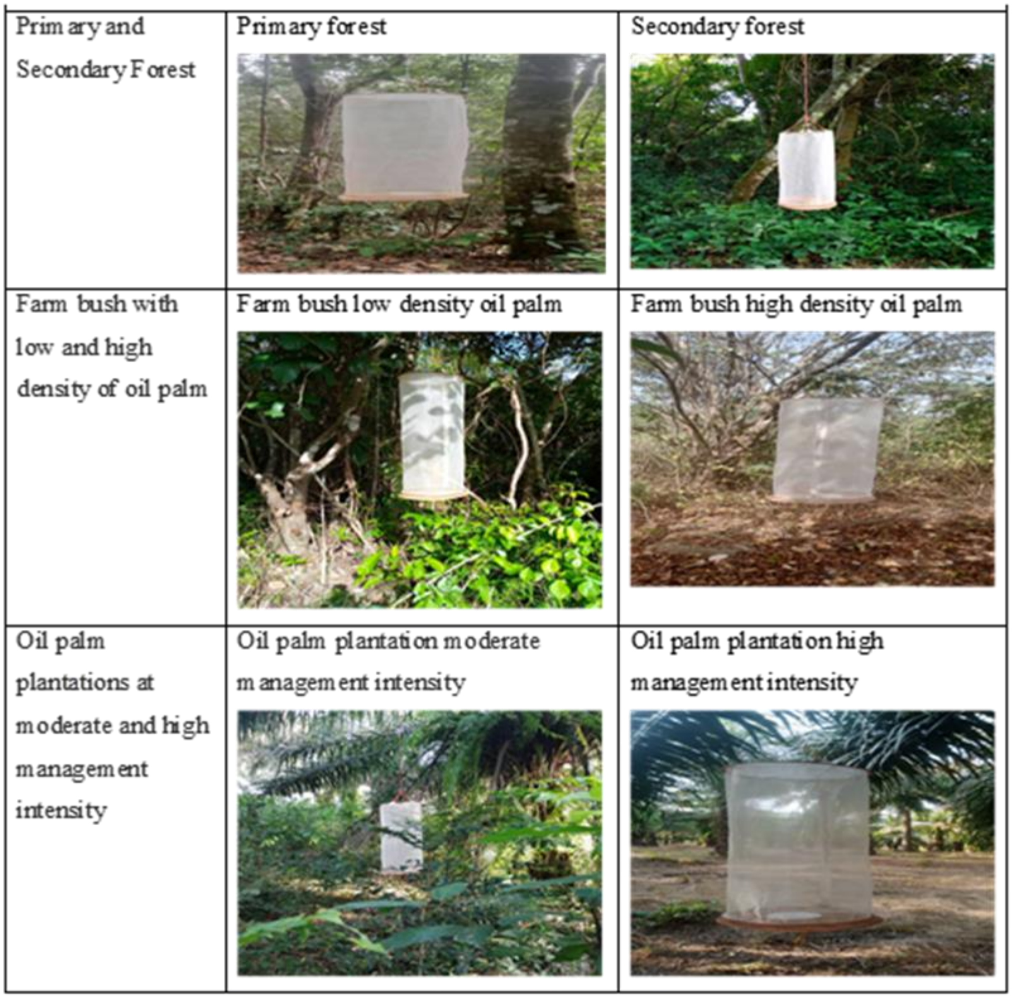

Figure 1. Bait traps in the different habitat types.

species. This study, therefore, sought to investigate the richness of butterfly assemblages in six habitat types typical of eastern Sierra Leone. The six habitats investigated are large and small oil palm plantations, farm-bush with high and low density of unimproved oil palms, and secondary and primary forests.

MATERIALS AND METHODS

Study area

The study took place in six land-use types covering a gradient based on palm plant density from very low (primary forest) through to near monoculture. The six land-use types are: “primary” forests (no oil palm and no disturbance for >50 years), secondary forests (less than 1 oil palm per ha, no disturbance for >20 years), farm-bush with few oil palms (20 palms/ha), and farm-bush with a high density of palms (>200 palms/ha). In Sierra Leone, many plantations were planted about 7 meters apart in an equilateral triangular pattern (~190 palms per ha), which is closer than modern recommendations of a 9-meter spacing (~150 per ha). The difference between low or medium intensity and high-intensity plantations in our study is that in low or medium intensity, the ground cover is native species cut once per year, while in high-intensity plantations, the ground cover is often planted and cut three or four times per year. Photographs of some of the survey plots with butterfly traps in these land covers are illustrated in Figure 1.

The six study sites are in Kenema and Kailahun Districts in the Eastern Province of Sierra Leone (Figure 2). The two districts contain the Gola Rainforest National Park and the Kamboi Hills Forest Reserve, but most of the land is under traditional swidden agriculture (bush-fallow) with fallow periods of between 5 and 10 years; there are scattered small plantations of cocoa, coffee, and oil palm.

Sampling methods

Butterflies were sampled in the study area using a combination of two methods:

(a) walk and capture along a pre-defined 100-meter-long transect, and
(b) fruit bait trapping at specific locations along the transects.

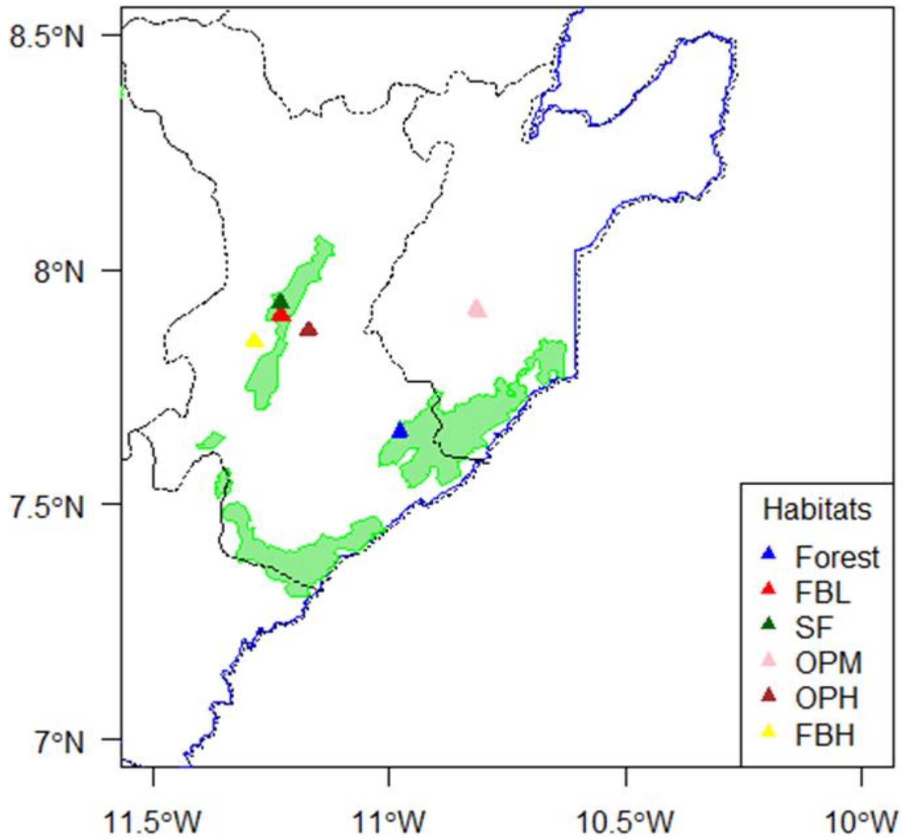

Figure 2. Location of the six study sites. Protected Areas are shown in green. Key, Forest – primary forest, FBL farm-bush with low density of oil palm, SF=secondary forest, OPM = oil palm plantation low intensity, OPH = oil palm plantation high intensity, FBH = farm bush with many oil palm.

Each of the sampling sites was visited eight times over a period of two years. The transect walk and capture method is based on that used by Pollard (1977) and Efenakpo et al. (2021). Each transect was 100 m long, and three transects were placed in each of the six habitats, giving a total of 18 transects, each recorded by GPS coordinates and marked with flagging tape. Transects were walked between 09:00 and 12:00 in the morning under sunny weather conditions for a duration of 15 minutes. All butterflies encountered within 2.5 meters of the transect centerline and 5 meters in front and above were trapped with a sweep net, counted, photographed, and released. Those that were not identified in the field were captured and saved for later identification (Sundufu and Dumbuya, 2008; Chinaru and Joseph, 2011; Kemabonta et al., 2015).

To sample butterflies that are frugivorous, three cylindrical traps of at least 90 cm in height were placed in each sampling plot (Barlow et al., 2007). Each trap was set by hanging the nets on a support within 0.1 m and 1 m from the ground level, separated by at least 50 m from other traps (Bossart et al., 2006). The traps were baited with fermenting banana and alcohol and left in the plot for one day.

Identification of butterfly samples

The identification and naming of butterflies was done with the help of the field guide ‘‘Butterflies of West Africa’’ (Larsen, 2005).

Data analysis

All the data from the sampling plots were pooled and analyzed using Microsoft Excel and the R package (R Core Team 2024). Butterfly local status was determined based on the number of individual species counted during the survey and categorized into four categories: Very Rare (less than 2), Rare (2 to 15), Fairly Common (15 to 50), Common (50 to 100), and Very Common (more than 100), based on the classification of Miya et al. (2021). Three species parameters were computed to describe richness, diversity, and evenness at the six sampling areas. They were calculated using the following:

1. Margalef’s Richness Index R (Magurran, 1988): this is a measure of the number of species present making some allowance for the number of individuals (Equation 1).

$$R = (S - 1) / \ln (N) \qquad (1)$$

where, S = total number of species, Ln (N) = natural logarithm of the total number of individuals in the sample.

2. Shannon-Wiener diversity index (Shannon and Weaver 1949, 1949): this is the diversity within a community or habitat (Equation 2).

$$H = -\sum P_i \ln (P_i) \quad (2)$$

where, $P_i = S_i / N$, S_i = number of individuals of species number "I", N = total number of all individuals in the sample.

3. Pielou's Evenness Index (Pielou, 1969): this is a measure of equitability, a measure of how evenly the individuals are distributed among the different species (Equation 3).

$$e = H / \ln (S) \quad (3)$$

where, H = Shannon – Wiener diversity index (from equation 2), ln (S) = natural logarithm of the total number of species in the sample.

RESULTS AND DISCUSSION

Butterfly composition in the study area

A total of 2,502 individuals of butterflies from 167 species, 60 genera and four families were identified during the study (Table 1). This account for about 22.26% of the total butterfly species (750) identified in the country. *Eurema senegalensis* (Pieridae), *Junonia oenone* (Nymphalidae) and *Colotis euippe* (Pieridae) were species with the highest number of individuals (310, 251 and 160, respectively). Recording about one quarter of butterfly species known in the country from the study implies that more butterfly species could have been encountered if the sampling period would have been extended.

Family-wise composition of butterflies

Four butterfly families were identified in this study*:* *Nymphalidae, Pieridae, Lycaenidae* and *Papilionidae* (Figure 3). These families appear to be common in other reports from the tropics, for example, Ginoga et al. (2019) who studied butterflies in oil palm plantations in West Kalimantan Province in Indonesia and found *Nymphalidae* made up 63.3% of the sample**.** Some studies (Acharya and Vijayan 2015; Suhaimi et al., 2017; Kwatrina and Santosa, 2019; Mutmainnah and Santosa, 2019; Santosa and Pumamasari, 2019; Panjaitan et al., 2020; Miya et al., 2021) found *Nymphalidae* to be the most common family. *Nymphalidae* is the largest family of butterflies and has been estimated to contain around 6000 species and has been an important taxon used in developing hypotheses explaining the evolutionary relationship between plants and insects (Peña and Espeland, 2015; Khyade et al., 2018). The high dominance of *Nymphalidae* in the study area could be associated to their polyphagous nature which enables them to live in all kinds of the habitats (Suhaimi et al., 2017).

Butterfly community composition in different land-use types

The butterflies showed a monotonic decline in richness along the six habitat types as density of oil palm increases, even though Pielou's index was 0.787 and above (Figure 4). The forests (primary and secondary-PF and SF) recorded the highest number of butterflies with 95 species, 492 individuals and 88 species, 373 individuals, respectively. They also had the highest Shannon index (3.8316 and 3.8711) and Margalef index (15.165 and 14.692), respectively. The abundance and diversity of butterflies has also been reported in similar studies to be higher in forests areas than other habitats (Rembold et al. 2017, Panjaitan et al., 2020, Wale and Abdella 2021). The high diversity of butterflies in the forest (primary and secondary) could be associated to its more heterogeneous structure and a higher plant diversity (Miya et al., 2021). There is high correlation between the presence of butterflies and the presence of the host plants which are used by butterflies for laying eggs and serving as feed for larvae. Species like *Cymothoe caenis* (Figure 4) were only found in the forest habitats where the fruit trees they feed on were available.

The farm bush (low-density and high-density oil palm) were richer in butterfly species than the oil palm plantations recording 85 species, 418 individuals and 60 species, 407 individuals, respectively. This corresponds with their Shannon index (3.5403 and 3.2241) and Margalef index (13.917 and 9.985), respectively. Recording more species in the farm bush than the oil palm plantations indicates that the farm bushes have more plant diversity which can be used as food and host plants to help with forest recovery.

The oil palm plantations (medium and high intensity) had the lowest number of butterflies with 53 species, 414 individuals and 43 species, 398 individuals, respectively. They also had the lowest Shannon index (3.1282 * 3.0700) and Margalef index of (8.629 and 7.016), respectively. This contradicts the findings of Kwatrina et al. (2018); Mutmainnah and Santosa (2018); Kwatrina and Satonsa (2019); Ginoga et al. (2019); and Santosa and Purnamasari (2019), which stated that butterfly species diversity and abundance increases following the conversion of primary forests, secondary forest, and shrubs into oil palm plantations. The reasons for the difference in the findings from those of Kwatrina et al. (2018); Mutmainnah and Santosa (2018); Kwatrina and Santosa (2019); Ginoga et al. (2019); and Santosa and Purnamasari (2029) may be a result of the sampling efforts, as the sampling was conducted 8 times over 2 years and in both the wet and dry seasons. In their studies, butterflies were sampled for between one and two months with at most 3 visits.

Some species are rarely encountered in transect walks as they are too high in the canopy. Baited traps were

Table 1. Diversity and distribution of butterflies in the study area.

FAMILY	SPECIES	Habitat						Abundance
		PF	SF	FBL	FBH	OPM	OPH	
	Acraea abdera	4		2				R
	Acraea bonasia			1	1			R
	Acraea caecilian			1	3		2	R
	Acraea camaena		2	4	3		2	R
	Acraea egina	1	5	6	3		7	FC
	Acraea encedon			1			5	R
	Acraea endoscota	3	7	3	1		1	R
	Acraea epae	1						VR
	Acraea neobule	2	3		5	1	4	R
	Acraea Pharsalus			1				VR
	Acraea pseudegina	2	5	7	12	15	17	C
	Acraea serena			2	3	3	18	FC
	Acraea tellus		3					R
	Acraea translucida				1			VR
	Acraea umbra		2					R
	Acraea zetes			2	3	4	4	R
	Amauris niavius	4			1			R
	Ariandne pagenstecheri	1		1				R
	Aterica galena	1						VR
	Bebearia absolon	1						VR
	Bebearia mardania	1	1			1		R
	Bebearia phatasina	1						VR
	Bicyclus abnormis		1				1	R
Nymphalidae	*Bicyclus dorothea*	21	12	13	21	31	16	VC
	Bicyclus evadne elionas	3				4		R
	Bicyclus iccius	1						VR
	Bicyclus madetes	1	6					R
	Bicyclus maesseni	1						VR
	Bicyclus martius	2				6		R
	Bicyclus taenias			1		3	1	R
	Byblia anvatara crameri	1	1	2	4	1	2	R
	Byblia ilithyia				1			VR
	Catacroptera cloanthe ligata			1				VR
	Catuna oberthueri	9						R
	Charaxes ameliae doumeti	1						VR
	Charaxes anticlea anticlea	2		1		2		R
	Charaxes bipunctatus			1	1			R
	Charaxes boueti	1						VR
	Charaxes brutus	3	2	1	3	3		R
	Charaxes castor		2					R
	Charaxes cedreatis		1	1		1		R
	Charaxes Cynthia	2	1			1		R
	Charaxes etesipe			2				R
	Charaxes eupale eupale	1		1				R
	Charaxes eupale latimargo		2	2		1	1	R
	Charaxes Lucretius	2		1				R
	Charaxes numenes	1		1				R
	Charaxes plantroui		1	1				R

Table 1. Contd

	Charaxes pollux	1		1				R
	Charaxes protoclea	2	2					R
	Charaxes smaragdalis butleri		2					R
	Charaxes tridates	1	1					R
	Charaxes varanes vologeses				2			R
	Charaxes zingha	2						R
	Cymothoe adela						1	VR
	Cymothoe caenis	3	1					R
	Cymothoe coccinata		1					VR
	Cymothoe egesta	1						VR
	Cymothoe fumana	4	8	1				R
	Cymothoe jodutta	13	7					FC
	Cymothoe lurida hesione		1					VR
	Danaus chrysippus	1	2	6	5	10	11	FC
	Elymniopsis bammakoo			1	2			R
	Euphaedra ceres	3	7	2		1		R
	Euphaedra controversa		1					VR
	Euphaedra crockeri crockeri	2	2					R
	Euphaedra cyparissa cyparissa	3	8	9	1			FC
	Euphaedra eleus					1		VR
	Euphaedra gausape	2	2					R
	Euphaedra hebes	5	2					R
	Euphaedra Judith	7	1					R
	Euphaedra laboureana		3					R
	Euphaedra sarcoptera	1						VR
Nymphalidae	*Euphaedra themis*	12	1		1	3		FC
	Euriphene doricles		2					R
	Euriphene veronica	1						VR
	Euryhpura chalcis	2		1	2			R
	Hallelesis halyma	1						VR
	Hamanumida Daedalus			3				R
	Hypolimnas anthedon	7	4	2	4	3	1	FC
	Hypolimnas dinarcha				2			R
	Hypolimnas misippus			1			1	R
	Hypolimnas salmacis	8	1	7		2	2	FC
	Junonia oenone		1	56	70	67	57	VC
	Junonia Sophia			2	6		8	FC
	Junonia stygia	3		1				R
	Junonia terea	5		16	19	11	17	C
	Lachnoptera anticlia	3						R
	Melanitis leda				1	4	2	R
	Melanitis Libya		1					VR
	Neptidopsis ophione	6	4	4	5			FC
	Neptis agouale	4	2	2				R
	Neptis alta	1			1			R
	Neptis melicerta	1	2	1	1			R
	Neptis metella			1	2	2		R
	Neptis nemetes	1	1	3	1			R
	Phalanta eurytis		2	2	3	1		R
	Phalanta phalanta aethiopica	2	1	2	2	1	1	R

Table 1. Contd.

	Precis ceryne			1	4	1		R
	Precis pelarga				3	1		R
	Protogoniomorpha parhassus	6	5	1		1		R
	Pseudacraea eurytus	6	3	4	2	2		FC
	Pseudacraea lucretia		1	1				R
	Pseudathyma sibylline	1						VR
	Pseudoneptis bugandensis ianthe	1	1					R
	Tagiades flesus	1						VR
	Ypthima doleta	8	9	12	11	16	9	C
	Appias epaphia	1		2		1	5	R
	Appias phaola			1				VR
	Appias Sabina	1		3	2	4	6	FC
	Appias slyvia	6	4	4	5	5	4	FC
	Belenois calypso	7	2	10	8	11	12	C
	Belenois theora		2					R
	Catopsilia florella	1		2	12	6	4	FC
	Colotis euippe	6	5	37	41	37	34	VC
	Eurema floricola leonis	5	1					R
	Eurema hapale	1						VR
Pieridae	*Eurema hecabe solifera*	10	7				1	FC
	Eurema senegalensis	28	43	53	59	67	60	VC
	Leptosia alcesta	17	16	11	7	8	11	C
	Leptosia hybrid		2					R
	Leptosia medusa	26	5					FC
	Mylothris chloris		1					VR
	Mylothris spica	1						VR
	Nepheronia argia			1				VR
	Nepheronia buqueti		2					R
	Nepheronia thalassina	1	3	2	7	5	4	FC
	Pseudopontia paradoxa	69	28					C
	Graphium angolanus	1	1	5	1	4	9	FC
	Graphium antheus			1				VR
	Graphium latreillianus					3		R
	Graphium Leonidas		1	2	3			R
	Graphium liponesco			2				R
	Graphium policenes	25	21	14	5	7	5	C
	Papilio chrapkowskoides	18	13	3	2	4	3	FC
Papilionidae	*Papilio cynorta*		1	2				R
	Papilio cyproeofila		2	1				R
	Papilio dardanus	14	8	3	2	5	2	FC
	Papilio demodocus	1	5	17	21	23	33	C
	Papilio gallienus		1					VR
	Papilio nireus	3	4	1				R
	Papilio phorcas			5		5		FC
	Anthene amarah		3					R
Lycaenidae	*Anthene lachares*	5						R
	Anthene levis			1	1		1	R

Table 1. Contd

Axiocerses harpax			1			1	R
Azanus isis	1	5	20	14	6	13	C
Cupidesthes leonine		1					VR
Deudorix antalus				1		1	R
Eresina rougeoti				1			VR
Hypolycaena atifaunus					1		VR
Hypolycaena nigra	5	5					R
Hypolycaena philipus			1				VR
Iolaus eurisus			2				R
Lachnocnema vuattouxi			1				VR
Larinopoda eurema	1						VR
Liptena albicans	2						R
Liptena septistrigata	1						VR
Megalopalpus zymna	3	5					R
Mimeresia libentina	6	1	1				R
Oxylides faunus	3	1					R
Stempfferia subtumescens				1			VR
Telipna sanguinea				1			VR
Telipna semirufa			1				VR
Tetrarhanis baralingam	3			1	1		R
Triclema coerulea					3		R
Zizeeria knysna			1				VR

FBH-Farm bush High Density oil palm, FBL-Farm bush low density, OPH-Oil Palm High density, OPM-Oil palm density, PF-Primary Forest, SF-Secondary Forest, Abundance-Local status.

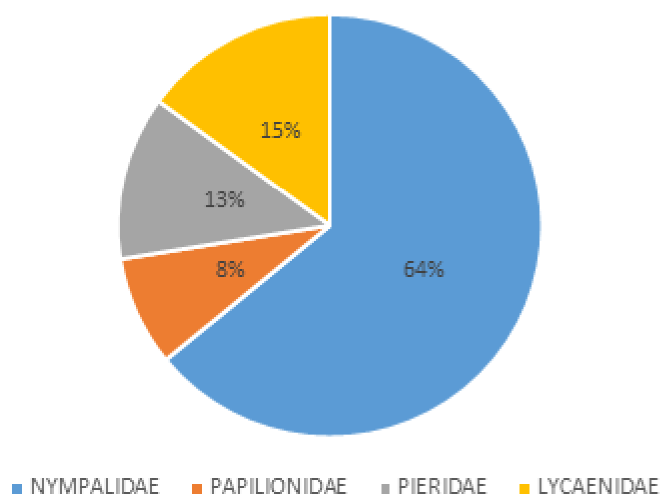

Figure 3. Family-wise composition of butterflies in the study area.

employed to catch species attracted to rotting fruit. The plantations, especially the high-intensity plantations, have very limited ground flora; it is speculated that nectar-producing plants could be used as a ground cover in plantations to encourage insects, although no reference to this can be found. The butterfly species found in the oil palm plantations are the ones that are commonly found in degraded areas. The low diversity of butterflies in the oil

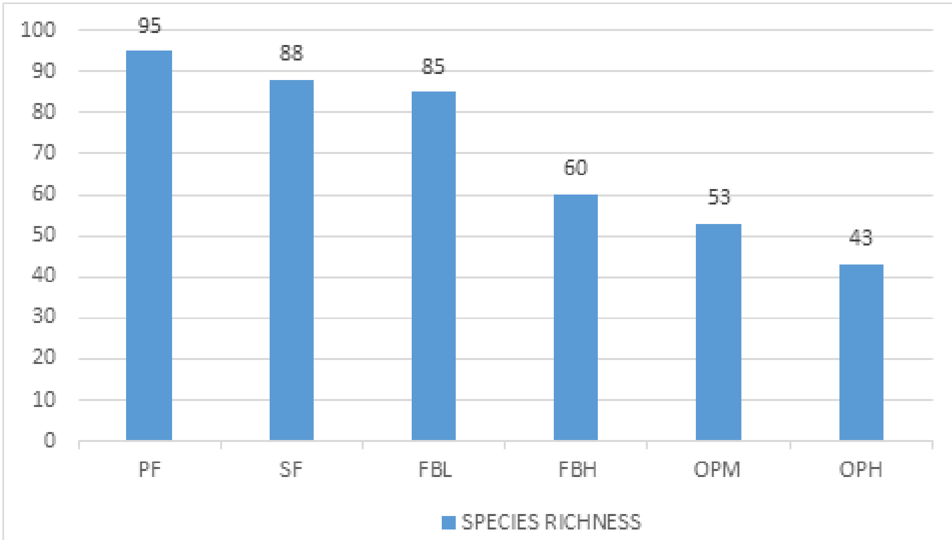

Figure 4. Species richness of butterflies in study area.

palm plantations in this study can be attributed to the fact that oil palm plantations are homogenous in structure with only a few plant diversities. Plants in the plantations do not support butterflies that depend on plants for laying their eggs and as feed for their larvae. Butterflies are highly sensitive to changes in habitat condition, and this affects their distribution. While the number of individuals in each habitat is not significantly different, the number of species does vary by a factor of two, from 95 species in primary forest to 43 species in the higher intensity oil palm plantations.

Habitat specific species

From the 167 species identified in the study, 55 species were restricted to only one type of habitat. The primary forest had the highest number of these species (18) followed by the secondary forest (14), farm bush low density oil palm (12) and farm bush high density (7). The oil palm plantations had only 4 species restricted to that habitats and these were all recorded in the oil palm medium intensity plantations. The oil palm plantation managed at a high intensity recorded no unique species. The diversity of butterflies appears to follow the diversity of plants found in the primary forest, secondary forest, and farm bush. This finding is corroborated with the findings of Curtis et al. (2015) who reported that the abundance of butterfly is determined by the availability of food resources like nectar and the quality of the habitats. Butterflies are short live organisms and can react rapidly to changes in the habitat. They have limited dispersal ability, larval food plant specialization and close-reliance on the weather and climate.

Local status of butterflies

From the butterflies identified, 91 (54.49%) are rare species, followed by very rare 42 species (25.14%), fairly-common 21 species (12.57%), common 9 species (5.38%) and very common 4 species (2.39%). This study corroborates the findings of Belcastro and Larsen (2006) who collected several rare and interesting butterfly species at the Gola forest. Figure 5 shows *cymothoe caenis* encounter along the transects in the secondary forest feeding of fruits of *parinaria excelsa*.

Sampling effort

All sites were visited eight times over the two years. The Primary Forest site was visited 3 times in the rainy season and 5 times in the dry season, while all the other sites were visited 4 times in the rainy season and 4 times in the dry season. For the three less diverse habitats (the farm bush with a high density of oil palm and the two types of plantations), the number of new species encountered appears to have almost leveled off. From this data, it would not be expected to encounter many more species with more samples (Figure 6). For the secondary forest and farm-bush with a low density of oil palm, the encounter rate for new species has slowed but was still increasing, so it might be expected that there were still species in these habitats that had not yet been encountered. The slope of the line for the primary forest

Figure 5. *Cymothoe caenis* feeding on the fruit of *Parinaria excelsa* in secondary forest.

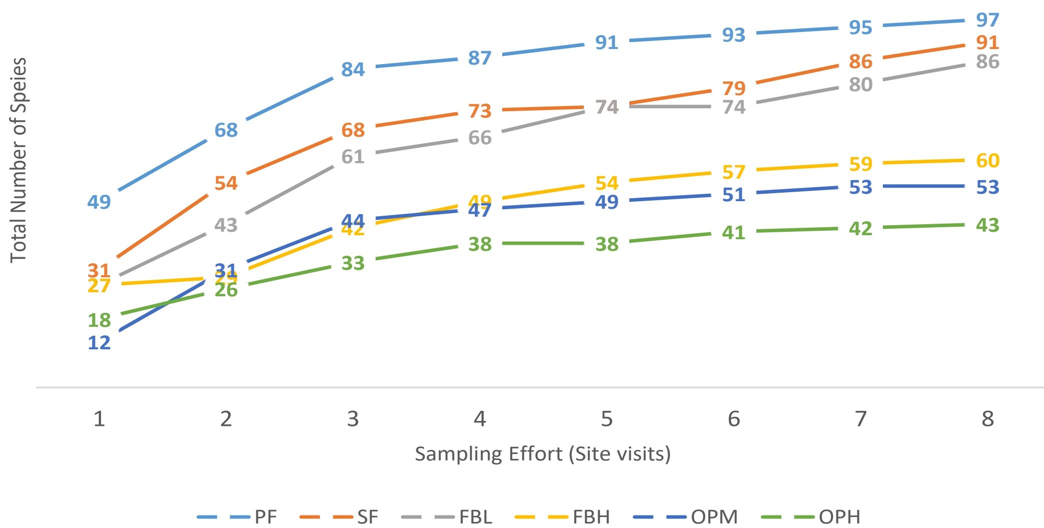

Figure 6. Total number of species plotted against sampling effort.

site is still upwards but less steeply than for the secondary forest. There might still be a few species that had yet to be encountered. This is interpreted as a reflection of greater diversity in the canopy in the "forest" habitats, particularly of fruits, and the lack of diversity in the canopy and the ground flora in the plantations and the "degraded" farm bush (that is, farm-bush with a very high density of palms).

CONCLUSION

Two main conclusions are drawn from this study: firstly, that one-off surveys may significantly underestimate the diversity of a habitat; and secondly, that in order to increase the diversity of butterflies and presumably other insects, oil palm plantations need to consider the diversity and management of the ground flora. The results from the study indicate that oil palm plantations are not very suitable for butterflies, as only a few species were recorded in the oil palm plantations compared to the other land-use types. The findings of this study are not consistent with those of Kwatrina et al. and others (Kwatrina et al., 2018; Mutmainnah and Santosa, 2018; Kwatrina and Santosa, 2019; Ginoga et al., 2019; Santosa and Purnamasari, 2019) who all assert that butterfly species composition increases following the conversion of primary forests, secondary forest, and shrubs into oil palm plantations.

Most of the species recorded in the oil palm plantations were species that are found in almost every type of habitat. Oil palm plantations are monocultures that are homogeneous in nature with only a few plant diversities. Their homogeneity affects the distribution of biodiversity such as butterflies, which rely on the presence of plants for their distribution. Butterflies are sensitive to environmental change, and their distribution can be influenced by the quality of the habitat. They are dependent on host plants as habitat and feed for the caterpillars.

Butterflies are important in both natural and agricultural landscapes like oil palm plantations, as they provide key ecosystem services like nutrient cycling, pollination, and serve as food for animals, and must be protected. Oil palm is a crucial economic good for the development of Sierra Leone and must be grown sustainably with minimal impact on biodiversity. To ensure the presence of butterflies in oil palm plantations, oil palm plantation developers should be encouraged to promote the growth of understory vegetation in their plantations so that understory butterflies can thrive. They should also be encouraged to create wildlife corridors in the plantation site, which facilitate the movement of forest butterflies. Plantation owners should also be encouraged to grow islands of native trees within their plantations to boost butterfly diversity and ecosystem functioning.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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