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Land use type affects butterfly diversity: a case study of the university of ghana, main campus, Legon

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Abstract

Butterflies are known to be well distributed worldwide, however, the different species and their occurrence in an area depend on various factors such as the extent of ecological damage and the availability of suitable food plants. The main campus of the University of Ghana, the largest University in Ghana, which covers an area of 11.4 km^2 was divided according to land use type into four areas and butterflies were sampled from these areas. Species diversity, composition and abundance were compared. A total of 1316 specimens representing 54 species from 9 families were recorded. The Botanical Garden (BG) with the highest diversity of plants and the least amount of human disturbance recorded the highest numbers (N=586) as well as diversity (S=53) while the Academic Areas (AA) with the highest amount of human activity recorded the lowest numbers (N=60) as well as diversity (S=16).

Introduction

Global biodiversity loss has become a cause for concern in recent years. Land use is a main driver of global biodiversity loss and its environmental relevance is widely recognized in research on life cycle assessment (LCA) (de Bann *et al.,* 2012). Although the environmental relevance of assessing land use impacts on biodiversity in life cycle impact assessment (LCIA) is widely recognized, the task remains difficult. Biodiversity is a complex and multifaceted concept, involving several hierarchical levels (i.e., genes, species, and ecosystems), biological attributes i.e., composition, structure, function, (Noss, 1990) and a multitude of temporal and spatial dynamics (Rosenzweig, 1995).

Finding a measure to quantify impacts of concurrent multiple drivers of biodiversity loss in a globally applicable and spatially differentiated way will be a challenge for future LCA research (de Bann *et al.,* 2012). Geyer *et al.* (2010), Michelsen (2008) and De Schryver *et al.* (2010) are among the many scientists that have tried to propose ways of quantifying the impacts of land use on biodiversity.

The order Lepidoptera is one of the most species-rich groups of insects, with an estimated number of species close to 146,000 (Bakowoski & Doku-Marfo, 2009). Butterflies occur in all parts of the world, but they are primarily tropical. The number of known butterfly species worldwide is between 18,000 and 20,000 and about a fifth of these are African butterflies (Larsen, 2005a). Butterflies are relatively easy to study, most being recognizable by their varied colour patterns, and they have a positive connotation in most cultures (Larsen, 2005a).

Although very mobile, many species are restricted to particular habitats through their dependence on special food plants, and by the range of their preferred climatic environment. Butterflies are good model organisms used in biological research (Butterfly Conservation Europe, 1998) and are also recognised as valuable environmental indicators, both for their rapid and sensitive responses to subtle habitat or climatic changes and as representatives for the diversity and responses of other wildlife (UKBMS, 2006).

The butterflies of West Africa, especially Ghana, are well studied (Kuhne, 1999; Kuhne, 2001; Larsen, 2005a; Larsen, 2005b; Emmel & Larsen, 1997; Nganso *et al*., 2012; Kyerematen *et al.,* 2014a; Kyerematen *et al.,* 2014b) with about 915 butterfly species recorded in Ghana (Larsen 2005a). Families of West African butterflies include Papilionidae, Pieridae, Danaidae, Satyridae, Nymphalidae, Acraeidae, Libytheidae, Lycaenidae, Hesperiidae, Riodinidae and Charaxidae (Larsen, 2005a).

The University of Ghana, Legon, Main campus lies within the Accra Plains, a geographical region in southern Ghana that has undergone one of the highest urban expansions from growing human populations and migration in the country (Ofori *et al.,* 2014). The university is one of the few areas that still harbour vegetation types that fairly reflect the original vegetation cover of the Accra Plains (Ofori *et al.,* 2014).

With the rapid urbanization of Accra in recent years and the urgent need for land for real estate development and other modern developments such as ultra modern shopping malls, it has become imperative to maintain and conserve the few 'green' areas that remain in the capital. According to Hart & Horwitz (1991), the habitat heterogeneity hypothesis simply predicts that more arthropod species will occur where different forms and species of plants provide greater structural heterogeneity in the vegetation.

The main objective of this study was to identify the different species of butterflies found in demarcated areas of the university campus according to land use, compare their occurrence in these areas and recommend management and monitoring strategies aimed at conserving this very important group of animals across a landscape matrix that is fast becoming devoid of vegetation.

Materials and methods

Study Area

The university of Ghana Legon campus (05°39'03"N 00°11'13"W) lies about 13 kilometres north-east of Accra, the capital city of Ghana, at an altitude of between 91m and 122m and covers an area of about 13km². The climate is characterized by a pronounced gradient of mean annual rainfall ranging from 733 mm to 1118 mm (Decher & Bahian, 1999). It has representative habitat types such as thicket, swamp, grassland and forest.

The campus was divided according to land use types into four areas: Residential Area (RA), Academic Area (AA), Botanical Garden (BG) and University Farm (UF). The Residential Area (RA) covers an area of about 5.5 square kilometres, and includes areas around the students' halls and hostels, and chalets and bungalows housing staff. The Academic Area (AA) covers an area of about 1.8 square kilometres and includes the central administration, lecture halls, offices for faculty, academic departments, libraries restaurants and canteens. The Botanical Garden (BG), located north of the campus, covers an area of about 2.0 square kilometres, and is characterized by a large variety of plants including grasses, shrubs and trees.

Examples of flowering plants found in this area are *Delonix regia*, *Bougainvillea glabra*, *Nerium oleander* and *Cassia sp*. It has a dam, the Vaughan dam, an arboretum for teaching, research and biodiversity conservation and a recreational area. The University Farm (UF), located adjacent to the Botanical Garden, covers an area of about 0.3 square kilometres, and has mainly mango and cashew trees, as well as food crops such as maize and vegetables and a constructed pool for irrigation.

Data Collection

Butterflies were identified in flight and during feeding by patterns and markings on their wings, and by their mode of flight. Direct counts of individuals were recorded along transects and by random walk sampling by two individuals in the study areas, carefully to ensure there was no double counting. Five charaxes traps, meant to attract alcohol-loving species, or those attracted to fermenting fruits were set randomly at different locations (about 30m apart) in each location. The traps were baited with fermenting banana mixed with beer, and were left hanging for up to three days. The bait was recharged each morning. Trapped butterflies were killed in a killing jar containing ethyl acetate and kept in labeled envelopes for later identification. Aerial nets were also used to capture some butterflies, especially those which were not easily identifiable in flight. The net was swung swiftly around butterflies in flight and trapped butterflies where necessary, were killed by pinching the thorax gently, but firmly, and placed in labelled envelopes. Butterflies were identified with reference to the collection in the Museum of the Department of Animal Biology and Conservation Science, University of Ghana, (Carcasson, 1981; Carter, 1998; Chinery, 1995; Larsen, 2005a; Belcastro & Larsen, 2006; Gullan & Cranston, 2005; Gullan & Cranston, 2010; Scholtz & Holm, 1985).

Field sampling was carried out between January and February of 2012.

Data Analysis

Three diversity indices were computed (Magurran, 2004) to compare data from the four sampling areas:

1. Species richness (Margalef): $d = (S-1)/Log(N)$ - This is a measure of the number of species present, making some allowance for the number of individuals.

2. Pielou's evenness: $J= H'/\ln(S)$ - this is a measure of equitability, a measure of how evenly the individuals are distributed among the different species

3. Shannon-Wiener index: $H = -\Sigma p_i \ln(p_i)$ – incorporates both species richness and equitability components.

n_i = the number of individuals of species i in the sample, $\Sigma n_i = N$. p_i = the proportion of individuals of species i in the sample, $p_i = n_i/N$. S=the number of species in the sample, N= the total number of individuals in the sample.

Results

1316 individuals from 54 species of butterflies were counted throughout the study period (Table 2). These species belonged to the families Nymphalidae, Acraeidae, Satyridae, Papilionidae, Danaidae, Pieridae, Charaxidae, Lycaenidae and Hesperiidae (Table 2). The highest number of species and individuals were from the family Pieridae (23 species, 619 individuals).The families Satyridae, Danaidae, and Charaxidae were represented by one species each (Fig. 1). *Papilio demodocus* (Papilionidae) and *Danaus chrysippus* (Danaidae) had the highest numbers of individuals (232 and 207 respectively). *Neptis metella*, *Gnophodes chelys* (Nymphalidae); *Bicyclus safitza* (Satyridae); *Graphium policenes* (Papilionidae); *Belinois gidica* (Pieridae); and *Castalius carana* (Lycaenidae) recorded the lowest numbers of one specimen each. The Botanical Garden (BG) recorded the highest diversity and abundance, followed by the Residential Area (RA), the University Farm (UF) and the Academic Area (AA) (Fig. 2).

The botanical garden (BG) was the most important site for butterflies, with the highest numbers (N = 586) and the highest species numbers (S = 53), which was corroborated by the highest Margalef index (d) of 8.159 as well as Shanon Weiner index (H') of 3.175. The academic area (AA) had the lowest species numbers (*S* = 16) as well as abundance (N= 60) corroborated by the lowest Margalef index (d) of 3.664. Butterflies were fairly evenly distributed in all the sampling areas with each area having a Pielou's evenness (J) of 7.5 or higher (Table 1.) Two species *Danaus Chryssipus* and *Papilio demodocus*, alone accounted for 33% of all the butterflies recorded.

Table 1. Diversity indices calculated for the four sampling areas.

Sample	S	N	d	J'	H'(loge)
RA	35	509	5.455	0.7993	2.842
AA	16	60	3.664	0.8503	2.358
BG	53	586	8.159	0.7998	3.175
UF	22	161	4.133	0.749	2.315

N – abundance, S – species richness, d- Margalef's index, j' – Pielou's index, H' – Shannon- Wiener

Table 2. List of species recorded in the four study areas.

FAMILY	SPECIES	RA	AA	BG	UF
Nymphalidae	*Euriphene barombina*	1	0	6	0
	Euriphene sp.	0	0	2	0
	Melanitis leda	0	0	3	1
	Pseudoacraea sp.	1	0	2	0
	Neptis melicerta	1	0	4	0
	Neptis metella	0	0	1	0
	Neptis merosa	0	0	2	0
	Salamis anacardii	0	0	2	0
	Junonia terea	1	0	11	0
	Junonia westermanni	2	0	0	0
	Junonia oenone	13	0	19	5
	Precis octavia	1	0	5	0
	Gnophodes chelys	0	0	1	0
	Phalanta phalanta	1	0	1	0
Acraeidae	*Acraea epaea*	0	0	2	0
	Acraea zetes	35	1	5	0

FAMILY	SPECIES	RA	AA	BG	UF
	Acraea eponina	3	0	3	2
Satyridae	*Bicyclus safitza*	0	0	1	0
Papilionidae	*Papilio demodocus*	100	12	97	23
	Papilio dardanus	0	1	18	0
	Papilio nireus	2	0	2	0
	Papilio menesthus	1	1	3	0
	Graphium policenes	0	0	1	0
Danaidae	*Danaus chrysippus*	63	9	78	57
Pieridae	*Eurema brigitta*	8	1	12	5
	Eurema senegalensis	2	0	1	0
	Eurema hecabe	3	3	3	0
	Nepheronia thalassina	11	2	38	1
	Nepheronia argia	5	1	29	2
	Leptosia alcesta	0	0	8	0
	Leptosia medusa	0	0	3	0
	Colotis ione	38	0	23	12
	Colotis eucharis	16	1	17	9
	Colotis evenina	18	0	13	7
	Colotis danae	21	0	9	2
	Colotis euippe	13	3	11	3
	Colotis antevippe	40	6	31	14
	Cototis eunoma	27	0	14	6
	Belenois calypso	18	2	7	0
	Belenois creona	0	0	4	2
	Belenois theora	0	0	2	0
	Belenois gidica	0	0	1	0
	Belenois aurota	6	0	2	0
	Catopsilia florella	5	12	43	4
	Mylothris chloris	6	0	3	0
	Mylothris poppea	2	0	2	1
	Mylothris rhodope	0	0	5	0
Charaxidae	*Charaxes varanes*	0	0	2	1
Lycaenidae	*Castalius carana*	0	0	1	0
	Hypolycaena liana	12	2	19	2
	Euchrysops albistriata	30	3	6	0
Hesperiidae	*Pyrrhiades lucagus*	0	0	4	1
	Tagiades flesus	2	0	3	1
	Osmodes adon	1	0	1	0

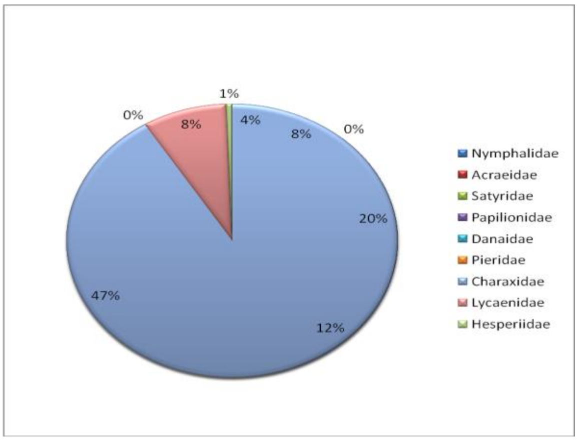

Fig. 1. Relative abundance of butterfly families.

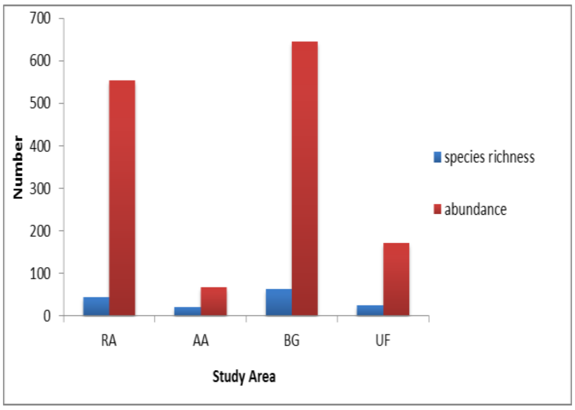

Fig. 2. Species richness and abundance of butterflies in the four study areas.

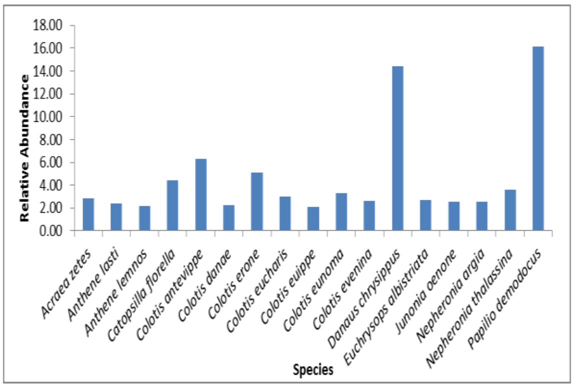

Fig. 3. Relative abundance of butterfly species across the entire study area. Species that had more than 2% of the total counts were used.

Discussion

Butterfly distribution and ecology

The families Pieridae, Papilionidae and Danaidae recorded the highest relative abundance of butterflies, and this could probably be because butterflies belonging to these families usually dwell in open areas (Scholtz & Holm, 1985) such is typical of the general University of Ghana area. They are brightly-coloured, feeding on fruits and flowers, and are thus easily spotted in flight. The families Satyridae and Charaxidae on the other hand, recorded the lowest relative abundance of butterflies. This could be because species from these families are mostly high-dwellers, shade-loving and occur more commonly in forest areas (Scholtz & Holm, 1985).

Pyrrhiades lucagus the Western Blue Policeman, is common in the coastal dry forest patches of Cape Coast, but can also be numerous in dense savannah on the Accra Plains (Larsen, 2005a). It was observed in the BG and UF and is a representative of one of the two genera that are strictly West African (Larsen, 2005a).

Mylothris poppea, a widely distributed species endemic to the forest area west of the Dahomey Gap was also observed (Larsen, 2005a).

Papilio demodocus and *Danaus chrysippus*, which were the most abundant butterflies on the University of Ghana main campus, are probably the best known butterflies in West Africa (Larsen, 2005a). *P. demodocus* was the most common butterfly, and this could be because it is specialized in degraded habitats and open spaces- which characterises most areas of the main campus. The main host-plant for *P. demodocus*, *Citrus sp.* is also common and widely distributed (Larsen, 2005a). The citrus plant was found in all the study areas, and this could account for the high abundance of *P. demodocus* on the campus.

The most abundant butterfly species in the family Pieridae were *Colotis antevippe*, *Catopsilia florella*, and *Nepheronia thalassina*. *C. florella* is a migratory species, and is commonly known as the African Emigrant. It usually occupies savannah country habitat, but can effectively colonize disturbed areas. It prefers imported shrubs and so is more likely seen in man-made resorts and gardens than anywhere else (Coombes, 2010), and as such could explain why the highest counts of the species were made in the BG. It is also abundant in most places where the larvae feed on the ornamental *Cassia sp.* (Larsen, 2005a), which is present in the BG.

In the family Papilionidae, other species observed besides *Papilio demodocus* were *P. dardanus*, *P. nireus*, *P. menesthus*, and *Graphium policenes*. *P. dardanus*, also called the Mocker Swallowtail or Flying Handkerchief, is a large, beautiful, mimetic butterfly which shows sexual dimorphism- the male is tailed, whilst the female is tail-less (Larsen, 2005a). Although it is broadly distributed throughout sub-Saharan Africa (Nijhout, 2003), it is more frequent in drier forests and probably most common in garden suburbs of major towns (Larsen, 2005a). This could explain why 18 out of the 19 observed specimens were from the BG.

Danaus chrysippus, the Plain Tiger, was the only specimen observed in the family Danaidae throughout the study period. It was originally a butterfly of the savannahs, but has successfully colonized disturbed habitats in the forest zone

(Larsen, 2005a). The presence of large portions of disturbed forest habitats in BG, RA and UF could explain why most of the individuals of this species were observed in these areas.

Junonia oenone, the Dark Blue Pansy, a nymphalid, is originally a savannah butterfly, but is now common in cleared areas of forest zones (Larsen, 2005a),and could thus explain why the highest counts were made in the BG (19) and RA (13) which are both characterized by cleared forest areas.

A. zetes, the Large Spotted Acraea, has been recorded in habitats that are well-developed savannah and open deciduous forest, but does not extend into the Sudan Savannah or the Sahel (Larsen, 2005a). Since the four study areas had either savannah or open forest habitats, or both, its distribution may have been due to a combination of both land area and available food sources.

Euchrysops albistriata (family, Lycinidae) also known as Capronnier's Cupid is widely distributed in the Guinea Savannah, slightly penetrating the Sudan Savannah, and in disturbed areas in the forest zone (Larsen, 2005a). The highest number of individuals was observed in the RA, and this could be due to the disturbance of a once existing forest area to make way for the construction of bungalows to house university staff.

Bicyclus safitza and *Charaxes varanes* were the only butterfly species observed from the families Satyridae and Charaxidae, respectively. *Bicyclus safitza*, the Common Savannah Bush Brown, is a savannah butterfly that can be common in the Guinea Savannah, but sometimes extends patchily into degraded parts of the forest (Larsen, 2005a). It was observed only in the BG.

Charaxes varanes, the Pearl Charaxes, has colonized degraded parts of the forest zone, although it was originally a species of dry forest and dense savannah (Larsen, 2005a). Two of these were observed in the BG, whilst one individual was observed in the UF, and this could be because the BG has both dry forest and dense savannah habitats, whilst the farming activities in the UF may have destroyed once existing dry forest areas.

Land use type and butterfly diversity

Botanical Garden (BG)

The BG had the highest number and species of butterflies, and was the most diverse area because it has the highest diversity of plants and thus provides more microhabitats and food resources for the different species of butterflies. There was also the least frequency of human activity in this area, compared to the other three study areas. Apart from a relatively small area at its northern end demarcated for recreational activities the botanical garden is mostly a restricted area reserved for teaching and research.

Residential Area (RA)

The residential area (RA) had the second highest diversity and abundance. This area of the University campus (05°38'96"N 0°11'23"W) is characterized by only grassland vegetation and avenue trees consisting mainly of Mahogany along the major roads. Within the residential area of the university campus can also be found, halls of residence, lecture theatres, game fields, and staff bungalows as well as fountains for beautification of the campus landscape (Acquah-Lamptey *et al.*, 2013). Many of the staff bungalows in the RA have gardens that have ornamental plants which serve as food sources for these butterflies. Human activity here is minimal during the day when most of the staff move to the academic area (AA) to work with their children going to school. This allows the butterflies the freedom they need to move around and feed without much interference and disturbance from humans during the day when they are most active.

Academic Area (AA)

The AA recorded the lowest number of butterflies, species numbers and diversity because this area experiences the highest rate of disturbance and interference (compared to the other three areas) from human activities such as moving vehicles, human movement, mowing of lawns, and construction works. With the increasing student population in recent years at the University of Ghana, many of the green areas in this part of the University have been cleared for the construction of newer and larger lecture facilities and car parks for the increasing number of vehicles. This obviously has had a very negative impact on butterfly diversity, evident from the results of this study.

University Farm (UF)

Even though the University farm (UF) is the area adjacent to and closest to the botanical garden, it recorded low numbers and diversity of butterflies because most of the vegetation had been cleared for farming as well as the construction of the Accra Sewage Improvement Project (ASIP). The UF due to its proximity to the BG (facilitating the movement of butterflies between the two areas), should have recorded higher numbers of butterflies but this was not the case. Trees here are regularly pruned, adding to the disturbance of the life processes of these insects. According to (Kyerematen *et al*., 2014b), the presence of pockets of farmlands in a forested area creates a wider range of habitat types and adequate food resources as well as pockets of open areas for easy flight allowing for the colonization of more butterfly species. This though was not the case for the UF since although there was a lot of open space for butterflies to move around, the farm does not have a wide variety of plants that serve as food resources for butterflies. At the initial stages of habitat loss, new habitats occur as gaps within the original habitat; however, as the proportion of new habitats increases in the landscape, the remaining areas of original habitat will be smaller and more isolated from one another (Harden, 1997).

Conclusions and recommendations

The University of Ghana, Legon campus exhibits a clear case of how land use type affects biodiversity. The Botanical Garden (BG) recorded the highest number of butterfly species and individuals, followed by the Residential Area (RA), University Farms (UF) and Academic Area (AA). These differences indicate a fine grained response by the butterfly communities to habitat changes and confirm the suggestion by Gordon & Cobblah (2000) that butterfly monitoring would provide useful ecological indicator data to compliment those of mammals, birds, and plant species monitoring. Species such as *Junonia oenone*, *J. terea*, *Papillio nireus,* and *P. demodocus* are specialized in degraded habitats and open spaces and very few would ever be met within forest of good condition (Kyerematen *et al*., 2014b) Their presence at the University of Ghana, is thus a is a clear indication of forest degradation (the result of the conversion of parts of the open deciduous forest typically of this part of Ghana, into farmlands, residential areas and academic areas).

It is recommended that a similar study be carried out during the Wet and Dry seasons to obtain a detailed catalogue of all the different species that are found on the campus and to observe any differences in butterfly diversity during the seasons. Another study of the distribution of the butterflies on the campus could also be carried out taking note of areas that may be described as transition zones between any two areas on the campus.

References

Acquah–Lamptey D, Kyerematen R, Owusu EO. 2013. Dragonflies (Odonata: Anisoptera) as tools for habitat quality assessment and monitoring. Journal of Agriculture and Biodiversity Research. **2 (8),**178- 182

Bakowski M, Doku-Marfo E. 2009. A Rapid Biodiversity Assessment of the Ajenjua Bepo and Mamang River Forest Reserves. Conservation International.

Belcastro C, Larsen TB. 2006. Butterflies as an indicator group for the conservation value of the Gola forests in Sierra Leone. Report to the Gola Forest Conservation Concession Project.

Butterfly Conservation Europe. 1998. Why Butterflies and Moths Are Important. Available at: http://www.bc-europe.org (Assessed April 20, 2012).

Carcasson RH. 1981. Collins Handguide to the Butterflies of Africa. William Collins Sons & Co. Ltd.

Carter D. 1998. Butterflies and Moths, Stoddart Publishing.

Chinery M. 1995. Butterflies and Moths, *Photoguide*, Harper Collins Publishers.

Coombes S. 2010. The African Migrant-Catopsilia florella. Captain's European Butterflies. Available at: http://www.butterfly-guide.co.uk/species/whites/t3.htm (Assessed May 31, 2012).

De Baan L, Alkemade R, Koellner T. 2013. Land use impacts on biodiversity in LCA: a global approach. International Journal of Life Cycle Assess. **18**, 1216–1230

Decher J, Bahian LK. 1999. Diversity and structure of terrestrial small mammal communities in different vegetation types on the Accra Plains of Ghana. Zoological Society of London. **247**, 395–408

De Schryver AM, Goedkoop MJ, Leuven RSEW, Huijbregts MAJ. 2010. Uncertainties in the application of the species area relationship for characterisation factors of land occupation in life cycle assessment. International Journal of Life Cycle Assess **15 (7),** 682–691

Emmel T, Larsen TB. 1997. Butterfly Diversity in Ghana, West Africa. Tropical Lepidoptera **8(3),**1-13.

Geyer R, Lindner JP, Stoms DM, Davis FW, Wittstock B. 2010. Coupling GIS and LCA for biodiversity assessments of land use: Part 2: impact assessment. International Journal of Life Cycle Assess **15 (7)**,692–703

Gordon I, Cobblah M. 2000. Insects of the Muni-Pomadze Ramsar site" Biodiversity and Conservation, **9 (4),** 479–486.

Gullan PJ, Cranston PS. 2005. Insects. An Outline of Entomology. 3rd edition. . Blackwell Publishing Ltd, p. 505

Gullan PJ, Cranston PS. 2010. Insects. An Outline of Entomology. Chapman and Hall – Publishers.

Harden J. 1997. A survey of vertebrate pests in the service estate.' NSW National Parks and Wildlife Service, Armidale, NSW.

Hart DD, Horwitz RJ. 1991. "Habitat diversity and the species area relationship: alternative models and tests," In *Habitat Structure: The Physical Arrangement of Objects in Space*, SS Bell, ED McCoy, & HR Mushinsky, Eds., Chapman and Hall, London, UK. p. 47–68

Kühne L. 1999. Contribution to the Lepidoptera-Fauna of Ghana – Part I. Results of the Expeditions 1992-1997 (Lepidoptera, Papilionoidea, Hesperioidea). Esperiana **7**, 399- 424.

Kühne L. 2001. Contribution to the Lepidoptera-Fauna of Ghana – Part II. The Butterfly Collection of the Department of Zoology in Legon, University of Ghana. Esperiana **8**, 637-648.

Kyerematen R, Acquah-Lamptey D, Owusu EH, Anderson RS, Ntiamoa-Baidu Y. 2014a. Insect Diversity of the Muni-Pomadze Ramsar Site: An Important Site for Biodiversity Conservation in Ghana. Journal of Insects. **2014**, 11

Kyerematen R, Owusu EH, Acquah-Lamptey D, Anderson RS, Ntiamoa-Baidu Y. (Accepted, Sept. 2014b). Species composition and diversity of insects of the Kogyae Strict Nature Reserve in Ghana. Open Journal of Ecology

Larsen TB. 2005a. Butterflies of West Africa. Apollo Books, Svendborg, Denmark.

Larsen TB. 2005b. Rapid assessment of Butterflies of Draw River, Boi-Tano and Krokosua Hills. In: McCullough J, J Decher, D Guba Kpelle (eds). *A Biological Assessment of the Terrestrial Ecosystems of the Draw River Boi-Tano and Krokusa Hills Forest Reserves, Southern Ghana*. RAP Bulletin of Biological Assessment 36. Conservation International, Washington, DC.

Magurran AE. 2004. Measuring Biological Diversity, Blackwell Publishing, Oxford, UK.

Michelsen O. 2008. Assessment of land use impact on biodiversity. International Journal of Life Cycle Assess **13(1),**22–31

Nganso BT, Kyerematen R, Obeng-Ofori D. 2012. Diversity and Abundance of Butterfly Species in the Abiriw and Odumante Sacred Groves in the Eastern Region of Ghana. Research in Zoology, **2 (5),** 38-46.

Nijhout HF. 2003. Polymorphic Mimicry in *Papilio dardanus: Mosaic Dominance, Big Effects and Origins*. Evolution & Development. **5(6),** 579-592.

Noss RF. 1990. Indicators for monitoring biodiversity: A hierarchical approach. Conservation Biology **4,** 355-364.

Ofori BY, Garshon RA, Quartey JK, Attuquayefio DK. 2014. Preliminary checklist and aspects of the ecology of small mammals at the University of Ghana Botanical Garden, Accra Plains, Ghana. Journal of Biodiversity and Environmental Sciences. **4 (3),** 323-333.

Rosenzweig ML. 1995. Species Diversity in Space and Time. Cambridge: Cambridge University Press.

Scholtz CH, Holm E. 1989. Insects of Southern Africa. Butterworths Professional Publishers Ltd.

United Kingdom Butterfly Monitoring Scheme (UKBMS). 2006. Butterflies as Indicators. Available at: http://www.ukbms.org/butterflies_as_indicators.htm (Assessed April 20, 2012).

Weidema B, Lindeijer EW. 2001. Physical impacts of land use in product life cycle assessment, final report of the EURENVIRON-LCAGAPS sub-project on land use, DPU Technical University of Denmark, Lyngby, DK.