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Butterfly Assemblages of Two Wetlands: Response of Biodiversity to Different Environmental Stressors in Sierra Leone

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Abstract

In a bid to enhance the integrity and health of selected network of ecosystems and effectively manage them in Sierra Leone, a baseline assessment of butterfly diversity of two wetland ecosystems Mamunta Mayosso Wildlife Santuary (MMWS) and Sierra Leone River Estuary (SLRE) affected by different environmental stressors was undertaken as part of the Sierra Leone Wetland Conservation Project (SLWCP). We hypothesised that different environmental stressors affect butterfly communities in wetlands in Sierra Leone and the higher the stress the lower the butterfly diversity in an area. Sampling was conducted via field identification by wing patterns, flight mode, direct counts along transects and charaxes trapping. A total of 2300 individuals representing 95 species of butterflies were recorded. Though butterflies were evenly distributed at both sites, MMWS recorded the highest richness and abundance of butterflies during both seasons. This observation is reported to be because of high environmental stressors such as mining, agriculture and pollution from factories in the SLRE. The results further show that MMWS is made up of a mosaic of different vegetation patches that support higher diversity of butterfly species. This study also reveals that anthropogenic activities have a negative impact on butterfly diversity.

Keywords

Biodiversity, Butterflies, Environment, Sierra Leone, Wetlands

1. Introduction

The on-going biodiversity crisis in the world is partly due to the transformation of natural systems through human-induced anthropogenic activities [1] [2]. This phenomenon is even more pronounced in the South of the Sahara which is believed to have lost a substantial amount of its natural habitats and resources through anthropogenic activities [3]. Direct human activities such as agricultural expansion and intensification, commercial logging, infrastructural development and settlement expansion also play a role in habitat loss as key environmental stressor [4] [5]. Among the most important natural resources that are affected through anthropogenic activities are diversity of animals and their habitats (e.g. wetlands and their associated fauna and flora) [6] [7]. In 2005, the Millennium Ecosystem Assessment reported that 10% - 30% of mammals, birds, and amphibians were threatened with extinction because of human activities. The most important of these anthropogenic impacts on biodiversity is land use change [8] [9]. Other environmental stressors such as habitat loss and degradation, pollution, overexploitation, and invasive species also play significant roles in accelerating biodiversity declines. Many of such habitats that have suffered degradation through anthropogenic impacts over the years are wetlands.

According to the Ramsar Convention [10], a wetland is defined as an area of marsh or fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty. Wetlands are believed to be among the earth's most productive ecosystems [11] [12]. It also includes areas of marine water, with less than six metres in depths and of low tides. Other than supplying local communities with resources for subsistence, wetlands support distant communities with ecological services. Some of these ecological services are flood impact control, and drought alleviation, ground-water recharge, water quality protection and purification. Other important functions of wetlands are providing alternative sources of drinking water and storage, erosion and sediment control, wastewater treatment, carbon retention and climate modification [13] [14].

The New Partnership for Africa's Development (NEPAD) identified six sectorial priorities, including the Environmental Initiative of which wetland conservation was highlighted as one of eight sub-themes demanding priority intervention [15]. Streams and their associated wetlands are recognised as valuable mainly due to their environmentally sensitive habitats and microclimate modification. These ecosystems are dominated by complex biotic communities of animals mostly invertebrates [16]. Wetlands have always been thought of as "wastelands" [17] [18] and therefore subjected to degradation through dredging. The attraction and value of wetlands as important wildlife habitats, among other uses such as provision of fin and shell fish, salt, thatch and wood [18] have increasingly been identified. Coastal wetlands are especially important as nutrient-rich habitats for fish spawning and nursery [19]. Equally important in wetland ecosystem is the insect community.

Insects are critical natural resources in ecosystems, particularly those of forests [20]. Additionally, insects play key roles as efficient pollinators and important biological control agents that ensure proper functioning of various ecosystems. Other insects act as important indicators in ecosystems and their management practices [21]. Some of these important insect indicators are, grasshoppers [22] [23] [24], dragonflies [25] [26] and butterflies [4] [27].

This study was conducted as a baseline study to document biodiversity in different wetlands that have been impacted by human activities. Butterfly bionomics has been exploited in the study of various aspects of forest ecology in natural, managed and degraded ecosystems [28] [29] [30] [31]. This is largely because they are known to be very sensitive to environmental changes and tightly coupled with various ecological processes as primary consumers (nectarivorous), pollinators and food items [32]. Wetlands host unique populations of butterflies, some of which have narrow habitat requirements and hence cannot migrate far from pockets of suitable habitats. The most important resource degradation that can affect butterflies and other nectarivorous insects directly is degradation of their floral resources. Floral diversity is a key component of butterfly diversity within a wetland [33]. Forest areas serve as refuges for displaced butterfly species from areas where farming and other human activities have affected insect diversity and their habitats [31]. The overview of African butterfly biogeography is given by Larsen [34], of which 750 species are known to occur in Sierra Leone. This region has been fairly studied compared to other regions with at least 17 endemic butterfly species known to occur in the whole of Sierra Leone or localities in the country [35].

Our hypothesis for this study is that different environmental stressors such as land use affect butterfly communities in wetlands in Sierra Leone. We also hypothesised that there are significant differences in butterfly diversity between SLRE and MMWS, and that the more exploited a forest is or the higher the environmental stress, the less the butterfly diversity. From this hypothesis we investigated butterfly communities on different wetland patches in different areas in Sierra Leone that have been impacted by different environmental stressors such as mining, agriculture and logging. More specifically, we measured butterfly alpha and beta diversity between pristine natural wetlands and compared these with more impacted neighbouring wetland areas of the above-mentioned wetland reserves (SLRE and MMWS).

2. Methods

2.1. Sampling Areas

The Mamunta Mayosso Wildlife Sanctuary (MMWS) 8˚35'N 12˚10'W is a game reserve in Tonkolili District, Northern Province, Sierra Leone about 180 km east of Freetown. It is one of the few areas in the country that protects the threatened Dwarf Crocodile. Although relatively small, MMWS is home to more than 252 bird species [36]. It is situated between Magburaka (30 km to the Northeast) and

Yonibana (35 km to the Southwest) of Sierra Leone. This wetland is a 20 km^2 Nature Reserve which was first protected in 1972. It is made up of a series of inland lakes amidst savannah grasslands [36]. Located almost at the centre of the country, this sanctuary encompasses a wide range of vegetation types. Predominant among these vegetation types is bolilands (seasonally flooded grassland) with occasional occurrence of swamps, savannah and secondary forests. Water depths in swamps in this wetland could rise to 1.5 m during flooding events. The dominant natural vegetation of this sanctuary has been transformed mainly by agricultural activities.

The Sierra Leone River Estuary (SLRE) (8˚37'N 13˚03'W) is a drowned estuary of the Seli and Rokel Rivers covering an area of 295,000 ha. It is located on the western coast of Sierra Leone and stretches across the coastal regions of the Koya, Maforki, Loko Massama and Kafu Bullom chiefdoms, Northern Province and the northern coast of the Freetown Peninsula. The estuary, near Freetown Peninsula, is dominated by mangrove systems, with lowland coastal plains to the north. The estuary extends about 11 km towards the Atlantic Ocean and naturally forms an important shipping harbour. It is the largest natural harbour on the African continent and the third largest in the world [37] and covers 19% of Sierra Leone's total mangrove area [38]. Several islands, including Tasso (the largest), Tombo, and the historically important Bunce Islands, are in this estuary. Vegetation in this wetland is predominantly mangrove swamp of *Avicennia africana*, *Laguncularia* sp. and *Conocarpus* sp. [38]. The SLRE was designated the 1008th Ramsar site in the world by the Ramsar Convention. The site was also designated an important Bird Area in 1994 by BirdLife International [39]. Vegetation clearance and unsustainable fishing threaten the Estuary, but efforts are being made strictly to conserve certain core areas within the site [39]. Vast areas of untouched mangrove forests still exist, however, and traditional fishing and agro-forestry for fuel wood can be managed sustainably in collaboration with an existing EU-funded Artisanal Fishing Community Development Programme. Tourism development for the area is promising with its fine beaches and the historic slave castle on Bunce Island. This estuary is important due to its high avian diversity, as a significant component to regional and global wetland ecology. There is currently no national legislation protecting the estuary, but some interventions by the Pilot project for Sustainable Coastal Management (PRCM) project could result in the designation of the site as a marine protected area (**Figure 1**).

2.2. Survey

Surveys were conducted in six locations along the coastal zones of Koya and Maforki chiefdoms and six locations in MMWS. These sampling sites covered shorelines, riverine vegetation, mud and sand flats, and associated terrestrial vegetation. Sampling was conducted on sunny days with low wind speed and an average temperature between 20˚C - 30˚C. Butterflies were identified by sight

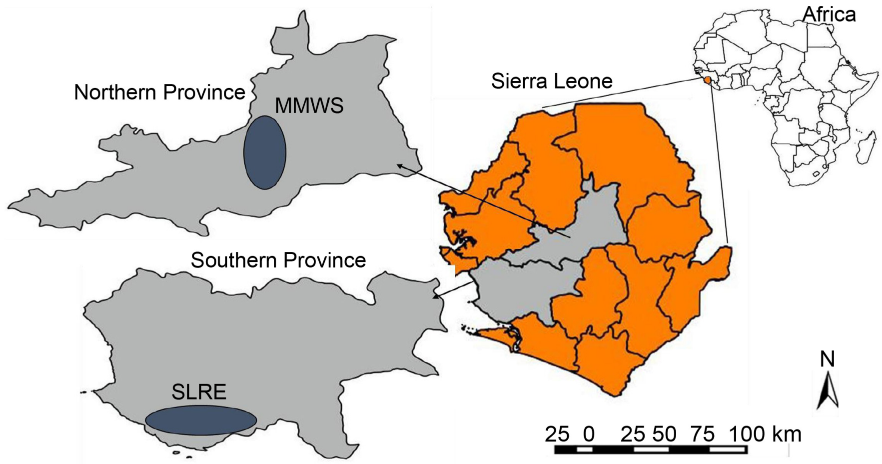

Figure 1. A picture showing the locations of Mamunta Mayosso Wildlife Sanctuary and Sierra Leone river estuary in Sierra Leone.

(sometimes using binoculars) via wing patterns and flight mode as done in previous studies [40] [41]. Individuals were recorded through direct counts along transects and by random walk by three collectors. Five charaxes traps were set randomly at least 100-metre intervals from each other in each of our selected study sites in each study location. One charaxes trap was set up per each sampling site. Sampling was conducted on 30 sites in total (*i.e.* 5 sites ×6 study locations) in each reserve. The traps were baited with a mixture of fermented banana and beer and left hanging for approximately three days. Each bait was restocked every morning. Aerial nets were used alongside baited traps to capture other species, especially those which were not attracted to bait or not easily identifiable in flight for closer examination. Trapped butterflies were killed when necessary in a killing jar containing ethyl acetate. The necessary condition here refers to a situation where we were unable to identify the species on the field and hence needs to send it for identification in the laboratory. We kill such butterfly species so as to keep them in good condition during the transportation period. If the butterflies are kept alive for a long period before identification, we risk losing important features on their wings such as scale that are very important in the identification process through struggle in their storage containers. A minimum of three hours was used for each sampling period twice each day for seven days in each of the four months in the dry season (December-March) and wet season (May-August) using random walk sampling by three persons for each site. Fifty-six sampling events per season were realised on each of the two reserves. Butterfly specimens were kept in labelled envelopes for safe transportation and for later identification to species level. Butterflies were identified with reference to [34] [42] [43].

3. Statistical Analyses

Alpha species diversity indices (Pielou's evenness, Shannon-Wiener, Simpson's) were computed [44], ranked and treated as surrogates for biodiversity [45]. For indices on shared species, the classic Jaccard and Sorensen indices were computed [44] as well as the adjusted Jaccard and the adjusted Sorensen indices [46] which were abundance based rather than just presence or absence of species. These analyses were computed using EstimateS [47]. Rank abundance curves (Whitaker plots) were constructed in Excel to compare total butterfly diversity within the two wetlands. Furthermore, a t-test was conducted in Statistica 13.2 [48] [49] to find out if there were any significant differences in butterfly populations between the two study areas (*i.e.* MMWS vs SLRE) in terms of richness and abundance.

4. Results

A total of 2300 individuals classified into 95 species were recorded for this study (**Table 1**). Eighty-nine species were recorded within the Mamunta Mayosso Wildlife Sanctuary (MMWS) while 66 species were recorded in the Sierra Leone River Estuary (SLRE). The number of species varied over different seasons; at SLRE, 44 species were recorded in the wet season while 36 species were recorded in the dry season. At MMWS, 64 species were recorded during the wet season, whiles 75 species were recorded in the dry season (**Figure 2(a)**). The highest Shannon and Simpson's diversity indices were recorded in MMWS (**Figure 2(b)** and **Figure 2(c)**). In the wet season, MMWS recorded a higher butterfly abundance (**Figure 2(d)**) but recorded a relatively lower species richness compared to the dry season (see **Figure 2(a)**). SLRE recorded the lowest abundances and species numbers for both wet and dry seasons respectively (see **Figure 2**). Butterflies were relatively more evenly distributed at both sites during the dry season than in the wet season (see **Figure 2(c)**). Of the 95 species of butterflies recorded during this survey, 38 species were common to both SRLE and MMWS during the wet season. In the dry season, 21 species were common to both study areas. The least number of shared species (9) was recorded in SRLE between the dry and wet seasons (**Table 2**). The species rank abundance curve of individuals sampled within the SLRE ranked 62 species while 77 species were ranked in MMWS. In addition, the slope of the rank abundance curve showed that MMWS had the highest evenness compared to SLRE (**Figure 3**). Four species *Junonia terea*, *Mylothris chloris*, *Catopsilia florella* and *Hypolimnas misippus* dominated the entire collection. In the dry season, *Elymniopsis bammakoo*, *J. terea* and *Azanus jesous* were the most abundant species whiles *J. terea*, *M. chloris* and *C. florella* were the most abundant species collected during the wet season. Results from t-test conducted on butterfly communities in MMWS and SLRE showed significant differences in diversity (t-value = 2.43, $p < 0.05$). Arrow signs in **Figure 4** show that butterfly diversity in SLRE is in decline because of high environmental stressors especially anthropogenic activities in Sierra Leone.

5. Discussion

The total number of butterflies recorded in this study account for about 20% of

Table 1. Abundance of butterfly species in Mamunta Mayosso Wildlife Sanctuary (MMWS) and Sierra Leone River Estuary (SLRE).

Butterflies species	Families	MMWS	SLRE
Acraea egina	Acraeidae	27	36
Acraea epaea	Acraeidae	16	24
Acraea pseudegina	Acraeidae	12	30
Amauris tartarea	Danidae	2	14
Amauris niavius	Danidae	16	6
Appias epaphia	Pieridae	10	10
Appias sabina	Pieridae	16	2
Aterica galene	Nymphalidae	5	3
Bebearia mandinga	Nymphalidae	5	0
Bebearia mardania	Nymphalidae	2	0
Bebearia tentyris	Nymphalidae	2	0
Belenois calypso	Pieridae	2	2
Belenois calypso	Pieridae	10	10
Belenois hedyle	Pieridae	20	10
Belenois neduleianthe	Nymphalidae	0	2
Bicyclus dorothea	Satyridae	16	10
Bicyclus funebris	Satyridae	14	15
Bicyclus martius	Satyridae	10	10
Bicyclus milyas	Satyridae	14	17
Bicyclus sofitza	Satyridae	5	16
Bicyclus taenias	Satyridae	5	0
Bicyclus taenias	Satyridae	20	15
Bicyclus technatis	Satyridae	32	16
Bicycus dorothea	Satyridae	50	12
Catopsilia florella	Pieridae	45	46
Celaenorrhinus proxima maesseni	Hesperiidae	1	0
Ceratrichia semilutea	Hesperiidae	0	1
Charaxes boueti	Charaxidae	5	0
Charaxes brutus	Charaxidae	2	0
Charaxes eupale	Charaxidae	1	1
Charaxes obudoensis	Charaxidae	0	1
Charaxes petersi	Charaxidae	1	0
Charaxes pollox	Charaxidae	6	0
Charaxes protoclea	Charaxidae	1	0
Charaxes zingha	Charaxidae	1	0
Citrinophila erastus	Lycaenidae	10	15
Citrinophila marginalis	Lycaenidae	1	2
Colotis euippe	Pieridae	50	30

Continued

Cymothoe egesta	Nymphalidae	5	0
Danaus chrysippus	Danidae	27	11
Euphaedra crockeri	Nymphalidae	1	0
Euphaedra francina	Nymphalidae	1	0
Euphaedra harpalyce	Nymphalidae	5	5
Euphaedra janetta	Nymphalidae	1	0
Euphaedra luperca	Nymphalidae	1	0
Euphaedra melpomene	Nymphalidae	10	0
Euphaedra themis	Nymphalidae	0	4
Euphaedra etusta	Nymphalidae	1	0
Eurema hecabe	Pieridae	1	0
Eurema senegalensis	Pieridae	20	30
Gnophodes betsimena	Nymphalidae	26	0
Gnophodes chelys	Nymphalidae	30	10
Graphium leonidas	Papilionidae	6	16
Graphium angolanus	Papilionidae	25	10
Graphium policenes	Papilionidae	10	15
Hamanimida daedalus	Nymphalidae	2	0
Hamanumida daedalus	Nymphalidae	16	6
Hypolimnas dinarcha	Nymphalidae	15	9
Hypolimnas misippus	Nymphalidae	39	40
Hypolimnas salmacis	Nymphalidae	16	29
Iolaus aethria	Lycaenidae	9	9
Junonia oenone	Nymphalidae	21	15
Junonia stygia	Nymphalidae	6	10
Junonia terea	Nymphalidae	150	20
Leptosia alcesta	Pieridae	20	0
Leptosia medusa	Pieridae	45	40
Liptena xanthostola	Lycaenidae	10	10
Melanitis libya	Nymphalidae	0	5
Mylothris chloris	Pieridae	80	22
Mylothris poppea	Pieridae	50	10
Mylothris rhodope	Pieridae	23	10
Nepheronia pharis	Pieridae	15	10
Neptis alta	Nymphalidae	10	5
Neptisme licerta	Nymphalidae	2	0
Neptisme talla	Nymphalidae	16	15
Neptis morose	Nymphalidae	20	10
Neptis nemetes	Nymphalidae	20	25
Neptis nicoteles	Nymphalidae	5	1
Oborona pseudopunctatus	Lycaenidae	16	0

Continued

Papilio dardanus	Papilionidae	5	5
Papilio demodocus	Papilionidae	3	13
Papilio nireus	Papilionidae	13	31
Phalanta phalantha	Nymphalidae	25	13
Phalanta eurytis	Nymphalidae	0	2
Precis octavia	Nymphalidae	39	16
Precis ceryne	Nymphalidae	2	4
Precis octavia	Nymphalidae	20	0
Precis sinuate	Nymphalidae	50	22
Pseudacraea eurytus	Nymphalidae	20	10
Pseudacraea semire	Nymphalidae	4	0
Pseudargynnis hegemone	Nymphalidae	5	0
Sarangesa brigida	Hesperiidae	1	1
Vanessa cardui	Nymphalidae	20	0
Ypthima antennata cornesi	Nymphalidae	2	0
Ypthima doleta	Nymphalidae	3	3

Table 2. Seasonal suite of beta diversity indices of butterflies for Mamunta Mayosso Wildlife Sanctuary (MMWS) and Sierra Leone River Estuary (SLRE).

1^{st} Sample	2^{nd} Sample	Shared S	SJ	SS	Adjusted SJ	Adjusted SS
MMWS WS	SRLE WS	38	0.644	0.784	0.886	0.94
MMWS WS	MMWS DS	16	0.252	0.402	0.290	0.45
MMWS WS	SRLE DS	10	0.252	0.402	0.290	0.45
SRLE WS	MMWS DS	10	0.273	0.429	0.376	0.546
SRLE WS	SRLE DS	9	0.290	0.450	0.319	0.484
MMWS DS	SRLE DS	21	0.373	0.543	0.414	0.586

S-Total species numbers; SJ-Jaccard's index: SS-Sorensen similarity coefficient: Adjusted; SJ-Chao-Jaccard-Raw Abundance-based; Adjusted SS-Chao-Sorensen-Raw Abundance-based; DS-dry season; WS-wet season.

known butterfly fauna of Sierra Leone. It also accounts for 42% and 26% of the recorded and estimated butterfly fauna of the Gola Forest respectively [34] [35]. This study documents diurnal butterfly species occurring within MMWS and SLRE during wet and dry seasons. MMWS recorded less species during the rainy season, whereas SLRE recorded less species in the dry season. A similar distribution of species was recorded by Kyerematen *et al.* [50] in a transitional vegetation zone, where more butterflies were recorded during the dry season within a riparian forest mosaic in Ghana. The reverse diversity was the case for butterfly records in neighbouring savanna woodlands in the wet season in Ghana. In general, MMWS recorded a higher diversity of butterflies in relations to the diversity in SLRE. This is because there were different vegetation structures that included secondary forest at MMWS that is believed to affect diversity as opposed

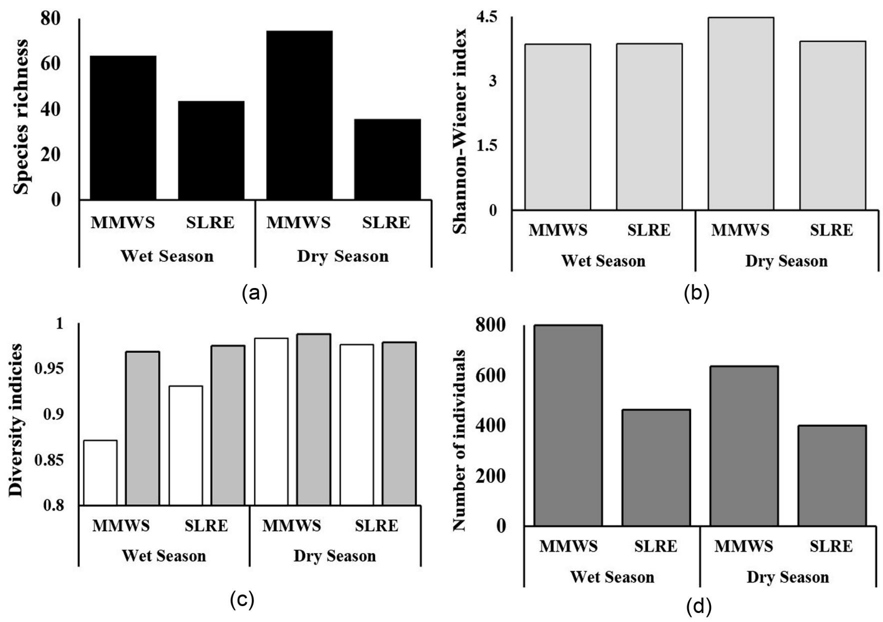

Figure 2. Seasonal diversity indices of butterflies for Mamunta Mayosso Wildlife Sanctuary (MMWS) and Sierra Leone River Estuary (SLRE). Grey coloured series in C = Simpson's index while the black and white spots series also represent Pielou's evenness index.

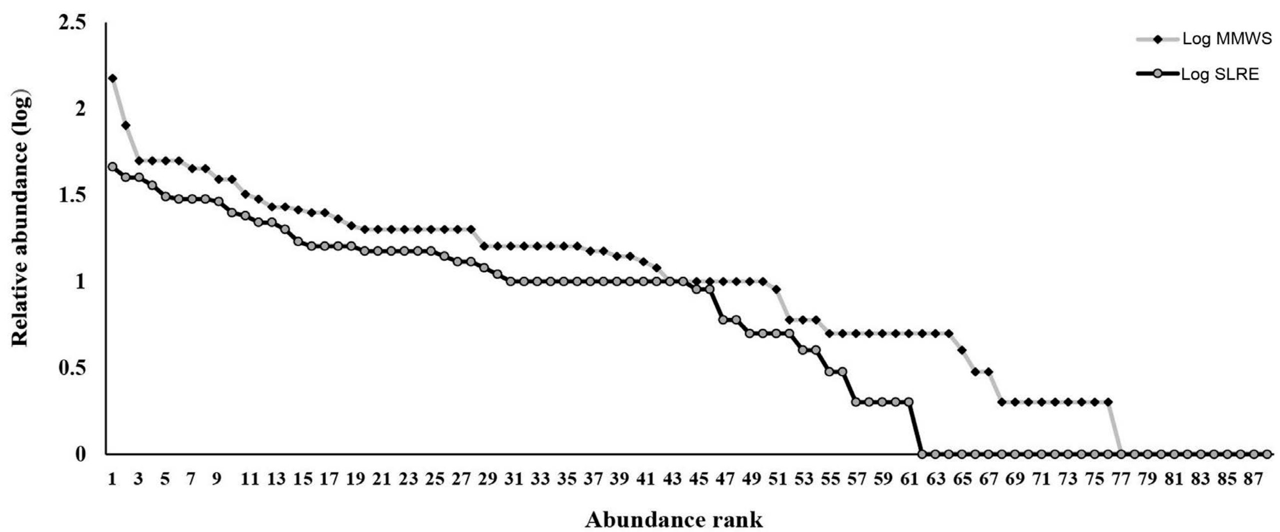

Figure 3. Species rank abundance curves for total butterfly individuals recorded in Mamunta Mayosso Wildlife Sanctuary (MMWS) and Sierra Leone River Estuary (SLRE).

to the dominant mangrove swamp vegetation in SLRE. This conforms to studies by Kyerematen *et al.* [33] who found more butterflies in high-forested areas compared to less forested ones. Furthermore, more butterflies were recorded during the dry season at MMWS than in the wet season. This finding contradicts studies by Kyerematen *et al.* [33] and Castro and Espinosa [51] who recorded more butterflies in forested areas during the rainy season as compared to the dry season. SLRE, with less dense vegetation cover, recorded more species during the rainy season compared to the dry season. This seems to suggest an optimum

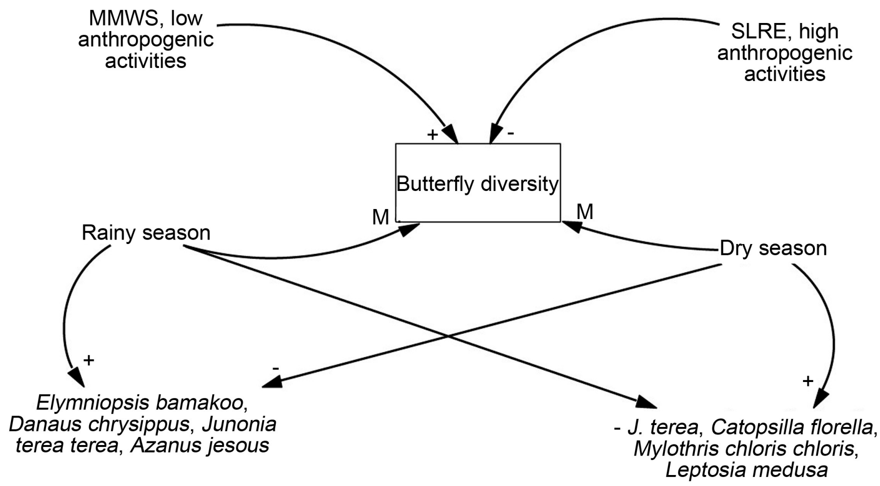

Figure 4. A summary of butterfly diversity studies in MMWS and SLRE in Sierra Leone. Positive influence or response = +, negative influence or response = − and mixed response = M.

preferred vegetation density by butterflies, a phenomenon that requires further studies.

In this study, most of the species from the genera Acraea, *Eurema*, *Cymothoe* and all species from Anthene and Euretela were recorded in the dry season only. In contrast, most species of the genera Precis, Charaxes and Colotis were recorded in the wet season. Because of these differences, the use of periodic flight variation in butterflies was justifiably used as surrogates for seasonal variations in species compositions between the two study areas. The high abundance of grass-feeding Satyrine species in both MMWS and SLRE could be an indication of high environmental stress [52]. The close association between grasses and Satyrine species in this study could signal a higher potential for use as indicators of forest condition. Such an attribute can be beneficially exploited to help direct limited conservation resources in economically disadvantaged areas and for prioritising conservation efforts such as identifying priority sites for formal protection or steering restoration efforts [27]. Another reason that could account for these variations in species compositions between the two study areas is the extent and impact of human activities or environmental stressors such as agricultural expansion and intensification, infrastructure development, settlement expansion and pollution which according to Bonebrake *et al.* [4] and Gardner *et al.* [5] play significant roles in biodiversity decline.

For instance, in the SLRE, woodcutting from the dominant mangrove vegetation is extremely high in many areas compared to MMWS. The intensity is particularly high along the Bunce River and the Aberdeen Creek because of their proximity to Freetown where the demand for wood fuel is high (personal observation). According to Dumbrell and Hill [53], extensive woodcutting destroys forest canopies and gradually turns a forest into an open habitat that eventually results in the reduction of species richness of many animal species including butterflies. In addition, agricultural production and high human settlement in the SLRE has further reduced the mangrove vegetation mainly through rice cultivation in and around Pepel and Robere. This situation is believed to have caused a reduction in floral resources and their diversity in SLRE but such is not the case in MMWS. Under such a situation, several generalist species could be recorded because they can thrive under a more degraded environment compared to specialist species [54] [55]. Such degradations could also increase the incidence of flooding events along the estuary. Increased disturbance and degradation of natural landscapes has the potential of accelerating declines in butterfly assemblages [28]. Many industries in and around Freetown also use the SLRE as a dumping site for their untreated wastes and hence add more stress to various habitats within the wetland. MMWS was the richest in butterfly fauna mainly because it had very little environmental disturbance or stress at the periphery of the sanctuary. One of such environmental less stressful activity on the environment was cattle grazing which is known to help accommodate more butterfly species because of its partial disturbance [56] [57] [58]. This is further substantiated in a study by Bennet [59] that areas with moderate disturbance in forest cover can relatively have higher butterfly abundance and richness. This is evident in the high abundance of open area species like *J. terea* and *M. chloris*. Pressure from hunting (although low to moderate and probably because of control exerted by game guards) can increase the pressure exerted on birds and such higher trophic animals (e.g. spur-winged geese and other large ducks that feed on butterflies) causing their reduction and hence less pressure on butterfly due to less predation impact.

The most commonly encountered butterfly species in this study were *Graphium policenes*, *Mylothris poppea*, *Catopsilia florella* and *Nepheronia thalassina*, which are typically grassland/open country species. These species are commonly encountered in African woodlands. *Papilio demodocus*, *P. nireus*, *Bicyclus dorothea*, *Junonia oenone* and *J. terea* are known over the last decade to be much more common in West Africa than they ever were. This could be because of the ongoing and widespread destruction and fragmentation of forest cover [34] and the ability of these mentioned species to colonise both pristine and disturbed forests. These are all characteristics, which according to Bossart *et al.* [27] facilitate persistence of forest butterfly species in highly transformed landscapes. Larsen [34] found that certain butterfly species are vulnerable to habitat degradation. Many of such species belonging to the genera Papilio, Cymothoe and Charaxes-known to be highly sensitive to forest fragmentation-were encountered at MMWS. Although MMWS is a wetland, it had patches of primary forests at Mayosso and Mabobo villages. These primary forests may be part of sacred grooves in these communities and may form refugia for butterfly species escaping from degraded areas. The relatively low butterfly abundance and diversity recorded at SLRE can be attributed to high anthropogenic activities and other environmental stressors such as mangrove harvesting, sand winning, fishing and infrastructural development.

On the other hand, the relatively high butterfly diversity at MMWS can be attributed to different types of vegetation mosaics that characterises this site, which also has very little environmental stress. This provides a variety of different vegetation patches which also supply butterflies with large varieties of floral resources. According to Hart and Horwitz [60], the habitat heterogeneity hypothesis simply predicts that more arthropod species will occur where different forms (type and structure) and species of plants provide greater structural heterogeneity in vegetation. Factors such as resource availability for adults and larval host-plants, behavioural traits and interaction with other species [61] may explain the higher butterfly richness and diversity as well as abundance at MMWS.

6. Conclusion

The two studied wetlands (MMWS and SLRE) combined had a high butterfly diversity with 95 species. Butterfly species were evenly distributed although the numbers varied significantly depending on the type of vegetation and the amount of vegetation cover as well as the type and extent of anthropogenic activities within each site. This study also shows that high environmental stressors have a negative influence on butterfly diversity, and that the relatively high activities at SRLE corresponded to a relatively low butterfly richness and abundance while the reverse was the case at MMWS. *Elymniopsis bammakoo*, *Danaus chrysippus*, *Junonia terea* and *Azanus jesous* were the most abundant or dominant species of butterflies during the dry season while *J. terea*, *Catopsilia florella*, *Mylothris chloris* and *Leptosia medusa* were the most abundant or dominant species of butterflies encountered during the wet season. This reiterates the use of butterflies as bioindicators for quality assessment of vegetation, ecosystems health, and/or show onset of seasonal changes. Furthermore, this study also shows that, protected wetlands are vital for maintaining the total complement of diversity of butterflies in Sierra Leone (see **Figure 4**).

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