Original Research Article
Papilionoideae Species Abundance and Diversity in Forest and Outside a Forest Reserve in Taraba State, Nigeria

ABSTRACT

Aims: To assess the abundance and diversity of Papilionoideae species in Ngel-Nyaki forest reserve and its surrounding landscape.
Study design: The study area was divided into two habitat types; Protected (Ngel-Nyaki forest reserve) and unprotected habitat (surrounding landscape). We identified all species of Papilionoideae in the study area, and we used general linear models to compare the abundance and diversity of Papilionoideae species between the protected habitat and unprotected habitat.
Place and Duration of Study: The study was conducted in Ngel-Nyaki forest reserve and surrounding landscape, in Taraba State, South-eastern Nigeria from April to August 2019.
Methodology: Thirteen line transects, each measuring 1000m was laid across the study sites, and on each of the 13 line transects, sixteen 10 x 10 m quadrats were established and spaced at an interval of 50m. All Papilionoideae species in our established 10 x 10 m quadrats were identified and recorded. All unidentified Papilionoideae species were collected and transferred to Ngel-Nyaki forest reserve herbarium for identification.
Results: We recorded 560 individual species, consisting of 42 species from 6 genera. The protected habitat had the highest abundance and diversity of Papilionoideae species.
Conclusion: Overall, we have shown that the Ngel-Nyaki forest reserve and surrounding landscape host many individual Papilionoideae species, suggesting the need for conservation to ensure that these habitats continue to support these species.

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Keywords: Papilionoideae species, forest, abundance, diversity, surrounding landscape

1. INTRODUCTION

Increasing human pressures and corresponding land-use changes are among the greatest threats to tropical biodiversity [1, 2]. It is therefore important to preserve biodiversity in habitats that are impacted by human activities, because these habitats make up an increasingly large portion of the earth [3].

Over the years, government across the globe have invested in establishing protected areas as a fundamental strategy towards biodiversity conservation [4]. The protected areas create habitats for threatened species, support healthy ecosystems and provides ecosystem services to humans (e.g., climate regulation, food security, and clean water) [5]. However, the ability to solely conserve biodiversity within a network of strictly protected areas has become limited by lack of funding, political will, and conservation opportunity [6]. As a result, the protected areas have not totally slowed rates of biodiversity loss. There are numerous gaps in the protected areas networks, especially because these areas do not cover the distribution of many threatened species [5]. Therefore, to develop effective conservation strategies, it may be important to assess biodiversity values both within and outside the protected areas [6, 7]. Moreover, Primack [8] have shown that unique ecosystems and several endangered species are comparatively or solely found within unprotected areas.

In Nigeria, protected areas were originally established around the country in recognition of the significance of many flora and fauna species [9]. However, many of these species are currently threatened or endangered due to lack of proper management and missing data on the status of biodiversity e.g., *Eugenia gilgie* [9-11]. Importantly, some plant species recorded in lowland rainforest outside protected areas in Nigeria are vulnerable, facing a high risk of extinction in the wild, e.g., timber trees *Entandrophragma angolense and Khaya grandifoliola* [11]. Therefore, to conserve biodiversity in a longtime, it is important to understand the distribution of plant species in and outside protected areas boundaries [12], particularly in Nigeria where there is increasing biodiversity loss [13].

Our study tries to improve the current knowledge on the distribution of a plant species inside and outside Ngel-Nyaki forest reserve, in Taraba State, Nigeria. To this end, we focused on the Fabaceae: Papilionoideae species; a good proxy for understanding plant species distribution patterns in many habitats [14]. Papilionoideae species exhibit wonderful variation in their distribution patterns; from trees, shrubs, lianas, vines [15, 16], and are key stone species in many tropical rain forests because of their ability to provide food and shelter for other animals [17]. However, some species of Papilionoideae are endangered, for example, *Dalbergia melanoxylum* [18]. Therefore, understanding the distribution pattern of these species is a crucial step in management and conservation of plant communities as well as ecosystems.

We compared the abundance and diversity of Papilionoideae species between habitats (protected and unprotected). We predict that Papilionoideae species abundance and diversity will be higher in the Ngel-Nyaki forest reserve as compared to outside the reserve since the reserve is protected against anthropogenic disturbance (e.g., livestock grazing, farming, and cutting of trees for fuelwood).

2. MATERIAL AND METHODS

2.1 Study area and location of sampling sites

Our study took place in forest and outside the Ngel Nyaki Forest Reserve in Taraba State Nigeria (7.0876°N, 11.0534°E), South Eastern Nigeria [11]. There is a distinct wet and dry season with a mean annual rainfall of around 1700mm. The minimum average monthly temperature is between 15.5-18.5 ^{0} C and the maximum ranges from 27.5-30.5 ^{0} C [19]. The forest, with an average elevation of ~1650 m asl is characterized by gently undulating hills covered in overgrazed *Sporobilis* grassland. This forest is well known for its rich flora and

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fauna, containing several Nigeria's endangered plant species, notable among which are the large forest tree species such as *Entandrophragma angolense, Lovoa trichilioides, Millettia conraui* and *Pouteria altissima*.
The Ngel Nyaki forest reserve is a vulnerable site of conservation concern because it has been negatively affected by annual bushfires that are usually ignited by Fulani pastoralists [20]. These fires have led to the creation of wide-open grasslands principally consisting of *Sporobolus pyramidalis* and *Hyparrhnenia rufa* within the reserve [21]. Outside the reserve, habitat degradation is evident from anthropogenic activities (e.g., livestock grazing, farming and fuelwood), giving way to degraded grazing land and farmlands.

2.2 Sampling plots

We sampled Papilionoideae species between April and August 2019 when species can be easily identified. Two hundred and eight study plots, each measuring 10 x 10 m quadrats and spaced at an internal of at least 50 m were established in the forest reserve and those of the surrounding landscapes. We selected areas sampled outside the reserve using the methodology of Abiem, et al [9], with modification. All unidentified Papilionoideae species were collected and transferred to Ngel-Nyaki forest reserve herbarium for identification.

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2.3 Data analyses

All statistical analyses were carried out using the R statistical package version 3.5.6 (R Core Team 2018). We used general linear models (GLMs) to compare the abundance of Papilionoideae species between the reserve and its surrounding areas. Plant species diversity was calculated using Shannon Wiener's diversity index and GLMs was used to compare species diversity between the reserve and surrounding area. In all cases, statistical test was performed at the significance level of $p < 0.05$.

3. RESULTS

A total of 560 individual plants of Papilionoideae species consisting of 42 species from 6 genera were recorded during the survey: forest reserve 316 (56%), and surrounding area 244 (44%). See Appendix 1 for checklist of species.

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As shown in Table 1, the abundance of Papilionoideae species was higher inside the protected area. General linear model with a Poisson error structure (count data) showed a significant difference between Papilionoideae species abundance ($p<0.001$) of the protected area and the unprotected area.
The results from the general linear model in Table 2, showed the diversity of Papilionoideae species differed significantly between the protected and unprotected areas, with the protected area having the highest diversity of Papilionoideae species ($p<0.001$).

Table 1: Abundance of Papilionoideae species between forest reserve (protected) and surrounding areas (unprotected)

Parameters	Estimate	SE	T value	P value
Protected habitat	0.75	0.056	13.25	**<0.001**
Unprotected habitat	0.11	0.085	1.26	0.206

Note: Protected habitat was set as the intercept based on alphabetical order. P values in bold show significant difference. Model; abundance = habitat, family = Poisson. Null deviance: 492.17 on 253 degrees of freedom.

Table 2: Diversity of Papilionoideae species between protected and unprotected habitats.

Parameters	Estimate	SE	T value	P value

Protected habitat	1.63	0.032	50.69	**<0.001**
Unprotected habitat	0.11	0.050	2.28	**0.024**

Note: Protected habitat was set as the intercept based on alphabetical order. P values in bold show significant difference. Model; diversity = habitat. Null deviance: 40.090 on 253 degrees of freedom.

4. DISCUSSION

The Ngel-Nyaki forest reserve and its surrounding landscape host many individual Papilionoideae species, including *Dalbergia melanoxylo~~u~~m*, an endangered species in the IUCN red list [18]. This suggests the need to ensure that these habitats continue to support the diversity of these species.

The protection effect was evidenced by high abundance and diversity of Papilionoideae species in the protected habitat compared to the unprotected habitat, indicating that protected area plays important role in guaranteeing the conservation of biodiversity. On the other hand, the unprotected areas may have experienced anthropogenic interference from livestock grazing, farming, cutting of trees for firewood, and access road, making the soil unsuitable for the growth of the plants. Another possible explanation for the lower diversity in the surrounding landscape could be the extensive collection of seeds, fruits, and roots by the locals from some of the Papilionoideae species may have possibly affect the distribution, and natural regeneration of the plant species in the surrounding areas, especially for species that could not adapt to the change in the environmental condition [22]. Therefore, there is need for a broad spectrum conservation [9].

The soil composition within protected areas is rich in humus because of the minimal anthropogenic activities, when compared to surrounding areas [23]. This may support the growth of vigorous plants species, an indication of ecological healthy ecosystem. Perhaps, this is true because we recorded a good number of the Papilionoideae family in the protected areas only. E.g., *Abrus cicimanga, Adenocarpus celerata, Alysicarpus rugosus, Calopogonium muconoides, Crotalaria retusa, Dalbergia afzeliana, Dalbergia melanoxylo~~u~~m, Dalbergia nitoduna, and Dalbergia vogelii.* However, it is important to note that, at the time of this study, even within the protected habitat, anthropogenic activities e.g., illegal forest fire still occurs, although at a minimal level compared to the surrounding areas. If this persists, it could lead to habitat degradation of the protected habitat, which may result to loss of the Papilionoideae species as well as other plant species. Hence, the need for humans, policy makers and the management of the forest reserve to ensure the protection of this habitat.

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CONCLUSION

Overall, the results of this study have direct implications for conservation. The high abundance and diversity of Papilionoideae species in the reserve when compared to the surrounding landscape can be attributed to the differences in environmental conditions and the ability of the species to adapt to these conditions [24]. However, conservation of the surrounding landscape is as important as the protected reserve because we also recorded some Papilionoideae species outside the reserve. This surrounding landscape could act as either population sinks for some fauna and/or valuable corridors increasing connectivity [25-27].

ETHICAL APPROVAL

Not applicable. This research does not require an ethics approval.

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APPENDIX

Appendix 1: Checklist of Papilionoideae species identified in forest and outside Ngel-Nyaki Forest Reserve**.**

S/N	Common name	Species name
1	Rosary pea	*Abrus precatorius*
2	Cosedo	*Adenocarpus celerata*
3	Americanjointvetch	*Aeschynomene aAmericana*
4	Budda pea	*Aeschynomene indica*
5	Red moneywort	*Alysicarpus rugosus*
6	Pigeon pea	*Cajanus cajan*
7	Calopo	*Calopogonium muconoides*
8	Showy pea	*Campylotropis speciosa*
9	Devil bean	*Crotalaria goreensis*
10	Rattle weed	*Crotalaria retusa*
11	Smooth rattlebox	*Crotalaria striata*
12	Rose wood	*Dalbergia afzeliana*
13	African blackwood	*Dalbergia melanoxylum*
14	indian rosewood	*Dalbergia nitoduna*
15	Diola flup	*Dalbergia rufa*

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16	North indian rosewood	*Dalbergia sisso*
17	rose wood	*Dalbergia spp*
18	Sarivan	*Desmodium cordifolia*
19	Salparni	*Desmodium gangeticum*
20	Roundhead tickclover	*Desmodium rotundufolia*
21	scorpion tick trefoil	*Desmodium scorpiorus*
22	Creepingtick trefoil	*Desmodium triflorum*
23	Silverleaf desmodium	*Desmodium uncinatum*
24	Tick clover	*Desmodium velutinum*
25	Gallito	*Erythrina vogelii*
26	Silky indigo	*Indigofera astragalina*
27	Hairy indigo	*Indigofera hirta*
28	Indigo	*Indigofera microphylla*
29	Western indigo	*Indigofera miniata*
30	True indigo	*Indigofera pseudotinctoria*
31	Three leaf indigo	*Indigofera trifoliata*
32	Valvet bean	*Mucuna puggie*
34	Caribbean stylo	*Stylosanthes hamata*
35	Hoarypea	*Tephrosia cajanus*
36	Poison pea	*Tephrosia vicicoides*
37	Fishpoison bean	*Tephrosia vogelii*
38	Hairypod cowpea	*Vegna luteola*
39	Zombi pea	*Vigna vexillata*
40	Banmoong	*Vigna wightii*
41	Two-leaf zornia	*Zornia latifolia*
42	Dogon	*Zornia spp*