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Floral Resources of key Afromontane Tree Species Predict Sunbird Distribution and Abundance in Ngel Nyaki Forest, Taraba State-Nigeria.

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ABSTRACT

Background: Species diversity is a community attribute that is directly related to ecosystem productivity and trophic structure. Bird's choice of habitat and by extension their distribution depends largely on the availability of critical resources. Abundance and diversity assessment of sunbird species at Ngel Nyaki forest reserve was conducted during and after peak periods of flowering of key bird visited tree species.
Methods: Line transects method was used to assess sunbird species abundance and distribution. Mist-nets placed strategically in places of high abundances and diversity of floral resources was used to capture and identify sunbird species that eluded observers during focal observations. Nineteen (19) transects cutting across two distinct habitat classes were used to record the abundance and diversity of sunbird species.
Results: A total of 3,035 individuals from 11 species, drawn from 8 genera in the Nectrinidae family were sighted and recorded during 1680 minutes (28 hrs) of focal observation. Sixteen (16) Afro-tropical tree species were sampled for interactions between sunbird species and their floral resources. Ninety nine (99) individuals of 8 sunbird species were captured after about 209hrs 4mins of trapping. Bird traps revealed three species that were not seen during focal observations. Results indicated that the reserve accounts for about 46.2 % of the total species of sunbirds in Nigeria and about 36.4% in the West African sub-region.
Conclusion: Although more individuals in total of the various sunbird species were sighted in the Core forest than in the riparian fragments, sunbird species diversity did not differ significantly between the two habitat classes. Floral resources and flowering phenology appear to be major drivers in the distribution and abundance of sunbird species at Ngel Nyaki Forest Reserve.

INTRODUCTION

Birds are among the most mobile organisms on earth, occurring in all habitats known to man. (Mann and Cheke, 2001); the ubiquitous nature of birds makes them a very important component of biodiversity, and as such; birds are often used as good indicators of the state of health of the environment (Pearce and Ferrier, 2001; Gregory *et al.*, 2003). Birds mirror changes in other biodiversity (example other animals and plants) and are highly responsive and sensitive to environmental change; making them very useful in studies designed to address the effects of human and other environmental disturbances on community stability and productivity. Birds contribute substantially to the overall species richness of West African forests, currently recognized as biodiversity hotspots of global importance (Orme *et al*., 2005).

Species diversity is a community attribute that is directly related to ecosystem productivity and trophic structure (Tilman, 1996). Research has shown that community productivity is directly linked with species composition and diversity as well as patterns of distribution and interactions among species (Pringle *et al*., 2010).

In the past, ecosystem-function research such as pollination and dispersal, overlooked the relevance of species abundance /diversity and how this two attributes of a community can be used to improve understanding of ecosystem multi-functions and community productivity (Tilman, 1996). However, recent studies have shown the overarching importance of these parameters of ecological communities in predicting species extinction probabilities (Saavedra *et al*., 2011); evaluating network structure and species composition across various ecological islands, community productivity and stability (Bascompte *et al.*, 2003, Memmott *et al*., 2004; Bastolla *et al*., 2009; Pringle *et al*., 2010).

For instance, Pringle *et al*. (2010) showed that the regular (even spacing) spatial pattern of termite mounds found in a homogeneous African savannah provided a guide for parallel spatial patterning in tree-dwelling, termite-dependent animal communities. Their findings, which also confirm that the uniformity of these patterns at small spatial scales enhanced productivity of the whole landscape; provide support for models linking spatial patterns with ecosystem processes and functioning (Memmott *et al*, 2004).

In the same manner, this study explored the predictive power of floral resources in determining the spatial structure of sunbird species at Ngel Nyaki. This was possible because floral resources form the main dietary component of sunbirds and are utilized by all sunbird species. Furthermore, studies have shown that vegetation structure is the most proximate factor that determines the spatial distribution of species; in addition bird diversity in any habitat is mainly determined by vegetation structure which is further enhanced by the plant species composition (Nsor and Chapman, 2013; Tela et al, 2021).

The main goal of this study was to underscore the importance of resource availability and sunbird abundance and diversity. The study had the following objectives; (1) Develop a comprehensive check-list of sunbird species at Ngel Nyaki forest. (2) Determine the relative contribution of focal tree species in the distribution of sunbird species in the two habitat types. (3) Determine the local distribution and abundance status of sunbird species at Ngel Nyaki forest relative to their regional or national distribution status.

MATERIALS AND METHODS

Study Site

The study was conducted at Ngel Nyaki Forest Reserve (7.16˚N, 11.66˚E) located at the eastern edge of the Mambilla Plateau in Taraba state Nigeria (Fig. i) at an elevation of approximately 1550 m above sea level (Chapman and Chapman, 2001). Ngel Nyaki Forest Reserve is 45 km^2 in extent, of which approximately 7.5 km^2 comprises montane/submontane forest (Chapman and Chapman 2001). The forest is surrounded by overgrazed grassland and savannah as well as associated riparian forests (Dowsett-Lemaire 1989).

At Ngel Nyaki, rain peaks during the months of June/July and September. Mean annual rainfall is approximately 1800 mm occurring between mid-April and mid-October (Chapman and Chapman, 2001). Mean maximum and minimum temperature for the wet and dry seasons are 26.1^o C and 13.1^o.C, and 23.1^o C and 16. 1^o C, respectively (Ezealor, 2002). Daily mean temperature has never exceeded 30 ^{o} C (Chapman and Chapman, 2001).

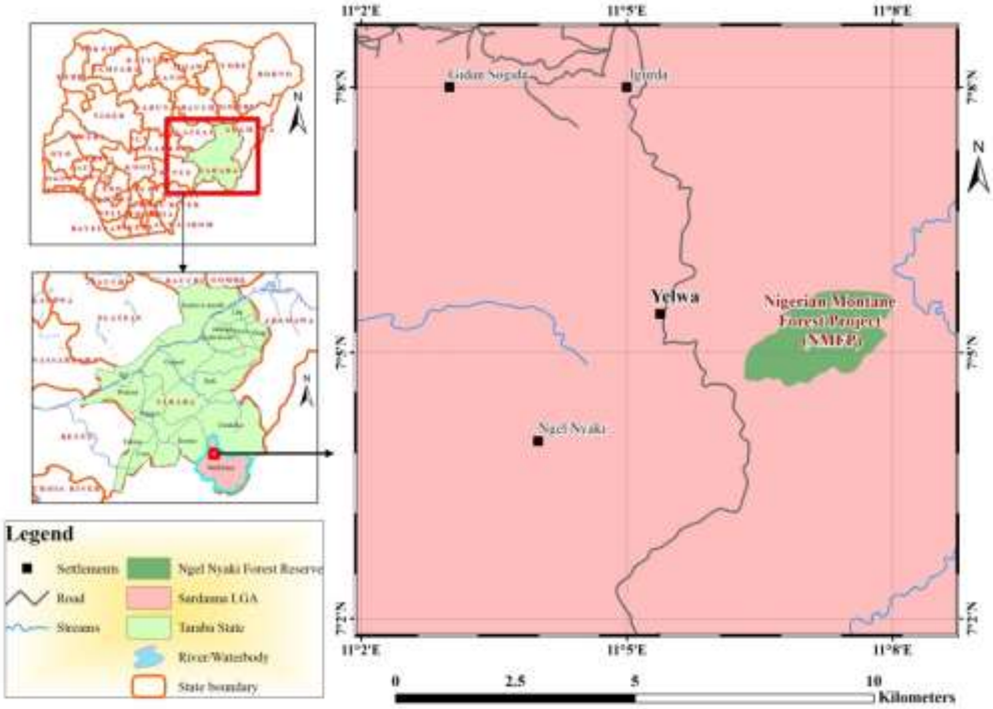

Fig. i. Map of Ngel Nyaki forest Reserve (right) and locator map of Ngel Nyaki and Taraba State (left).

Abundance estimation

Line transect census technique was used to estimate diversity and abundance of sunbirds found within the study site.

Line transect sampling in accordance with Bibby *et al*. (2000) was carried out between (06:30-09:30 GMT) and between (15:30 -18:30 GMT) each day. The survey took place between November, 2012 to February, 2013, and later between November 2013 and February 2014. Wet season assessment was conducted in April and May, 2013. A total of 19 transect ranging between 336 m to 1,737 m in length and covering a total distance of 16,654 m or 16.7 km were surveyed.

Transects were selected with a view to cover the entire Ngel Nyaki Forest reserve or such that we could obtain a representative data set that would account for the diversity of sunbird species at Ngel Nyaki Forest reserve. Nine transects fell along the edges of the core forest on the eastern side of the reserve, four in the core, while the other six were scattered within riparian fragments (Figure. ii). Each transect was surveyed twice in each season (November 2012 and February, 2013), making a total of four sessions per transect (morning and evening).

A pair of Nikon binoculars (8 x 10) was used to confirm the identity of birds located by eye. Only birds visually identified were included in the census data, as it was difficult to estimate the actual number of individuals based on calls alone. Other parameters recorded during transect monitoring sessions include; time an individual sunbird species was sighted, the number of individuals sighted, the species sighted and the closest flowering tree species (within a radius of approximately 20 m) to the location of the bird species at the time of sighting.

Additional information on species diversity was obtained from observing five individuals each of 16 flowering tree species in the two habitat types within the reserve to record sunbird interactions with floral resources such as pollen and nectar. Although this data was primarily generated for a comprehensive sunbird-tree pollination network (Nsor, 2014), it was helpful to complement the effort of identifying the various species found in the study area.

In a similar manner data from mist-netting to obtain pollen load on various sunbirds for pollen transport network, was used to complement sunbird diversity assessment (Nsor, 2014). This was achieved through intensive trappings at various locations across the forest (Fig iv). Mist nets were set up and monitored in the morning (18:00 hrs to 22:00 GMT, and evening at 15:30 to 17:30 GMT). Pollen extraction was achieved following the method of Kearns and Inuoye (1993). Pollen samples that were difficult to identify in the field were labelled and identified in the laboratory as described in Kearns and Inuoye (1993). However, about 10% of pollen could not be identified to the level of species. Captured sunbirds were identified to species and sex (if matured).

Fig.ii. Map showing layout of transects used during Sunbird species abundance and diversity survey at Ngel Nyaki forest (map was generated using GPS supported map application software on Samsung galaxy note 10.1").

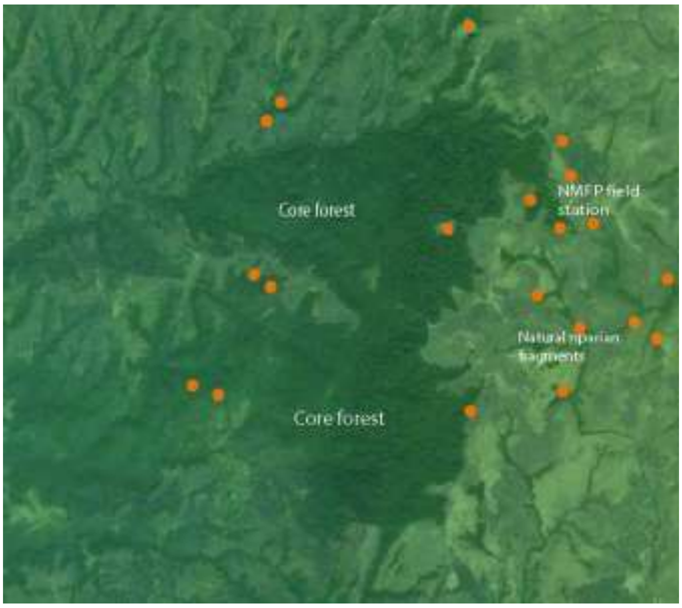

Fig iii. Map showing the various locations were bird-trapping (mist-netting) was conducted at Ngel Nyaki.

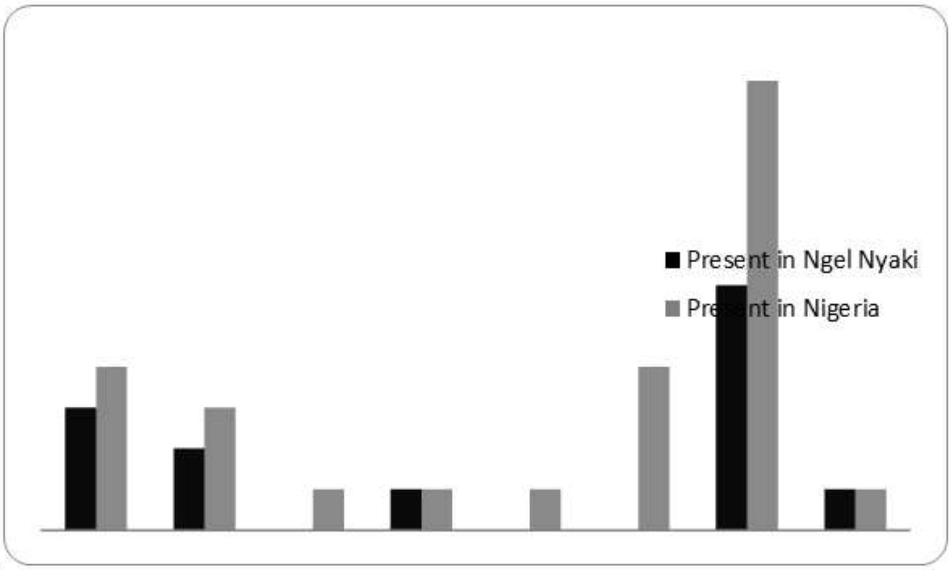

Fig iv: Generic distribution of sunbird species in the study area.

Data Analysis

Data were analyzed using SPSS version 15.0 (2013) and Excel. Specific analysis include: Independent sample T-test was used to compare the differences in diversity between the two habitat classes. We compared the rank abundance of species using a one-way ANOVA (Manu *et al*., 2010). The residuals of the dataset were tested for normality.

Sunbird Diversity

The diversity of sunbird species was estimated using Shannon Wiener Diversity index. The index which ranges from 0 to 1(with values close to 0 indicating low species diversity and values close to 1, indicating high species diversity); accounts for both the abundance and "evenness" of the species present. Species evenness is a measure of biodiversity, which quantifies how equal species in a community are numerically (Mulder *et al.*, 2004).

To determine species diversity, the proportion of species (i) relative to the total number of species (pi) was calculated, and then multiplied by the natural logarithm of this proportion (lnpi).

The equation is given below:

$$H' = -\ pi \ln pi$$

Where pi = is the proportion of individuals of species "i" in relation to the total population of all species.

Hi = Shannon Wiener Diversity Index.

ln = natural logarithm of base n

Two functional habitat groups were identified edge of core forest (yellow) and riparian fragments (red) (Figure 2). Diversity was estimated independently for transects found in each habitat category and also for the entire forest. This approach was to enable comparison of abundance and diversity between the two major habitat types.

RESULTS

Eleven (11) species of sunbirds accounted for a total of 3,035 individuals sighted and recorded during the transect survey. Species abundance varied significantly between sites (that is, edge of core forest and fragments), (ANOVA F_1=56.171, P = 0.00) (Table 1.). Similarly, there was a significant difference in species diversity between the two sites (t_1=18.17, P<0.04) as highlighted by Shannon Weiner Index (Hi for Edge = 1.145 and Hi for Fragment = 1.034). However, the overall diversity was found to be high at Ngel Nyaki forest; Hi = 1.19

The distance covered during the assessment correlated positively with abundance or number of species encountered (r=0.315, N=556, P = 0.00). Sunbird species were not evenly (spread) or spatially distributed (Fig. ii). Similarly, the number of bird species encountered increased with total transects length.

Table 1: Relative abundance of sunbird species at Ngel Nyaki Forest Reserve

S/n	Species	Number of individuals (edge)	Relative abundance (Pi)	Number of individuals (Fragment)	Relative abundance (Pi)
1	Northern double collared	72	0.29	196	0.45
2	sunbird	119	0.48	41	0.09
3	Variable sunbird	46	0.18	180	0.42
4	Orange tufted sunbird	0	0	10	0.02
5	Green headed sunbird	9	0.3	0	0
6	Copper sunbird	0	0	0	0
7	Collared sunbird	0	0	0	0
8	Pygmy sunbird	0	0	0	0
9	Olive bellied sunbird	0	0	0	0
10	Olive sunbird	0	0	0	0
11	Cameroon sunbird	0	0	0	0
12	Western violate backed sunbird	0	0	0	0
	Splendid sunbird	**246**		**427**	
	TOTAL				

H^i for **Edge** = 1.145, H^i for **Fragment** = 1.034, H^i for Ngel Nyaki forest = **1.19**
(H^i =Shannon Weiner diversity index)

Sunbird Species diversity at Ngel Nyaki Forest Reserve

At Ngel Nyaki, we found 11 species occurring at different seasons with varying degrees of abundance. Five (5) of these 11 species were sighted and recorded during the month-long survey (Table 1). Three species (olive bellied sunbird *Cinnyris chloropygius*, olive sunbird *Cyanomitra olivaceus* and Green sunbird *Anthreptes rectirostric*) were captured during mist-netting and pollen load assessment, while an additional 2 (pygmy sunbird *Anthodiata platura* and collared sunbird *Hedydipna collaris*) were recorded as visitors to the flowers of some focal tree species during visitation observation studies. In terms of generic differentiation, the results show that of the eight (8) occurring genera in Nigeria, five genera were represented at Ngel Nyaki forest. Cinnyris, the most common genus had 6 out of the 11 known species in this genus that occur in Nigeria. While Cyanomitra the second most abundant genus, had 3 out of four species known to occur in Nigeria (Fig iv).

DISCUSSION

Sunbird species diversity

In Nigeria, twenty seven (27) species of sunbirds occur with status ranging from very common; common; to uncommon or rare (Borrow and Demey, 2002). In this survey, 11 of the 27 species of sunbirds known to occur in Nigeria at Ngel Nyaki forest were recorded (Table 2). This forest therefore, accounts for about 46.2 % of the total species of sunbirds in Nigeria and about 36.4% in the West African sub-region (Mann and Cheke, 2001; Borrow and Demey, 2002). In terms of generic diversity, five of the eight generic groups of sunbirds known to occur in Nigeria were recorded at Ngel Nyaki forest (Fig iv). The genus Cinnyris was the most diverse and sunbirds from this genus were also the most common and abundant at Ngel Nyaki forest. However, the Cameroon sunbird *C. oritis*, and western violet-backed sunbird *Anthreptes longuemarei*, were never encountered in the study sites during any of the experimental assessments but based on regional distribution and local checklist; these species are known to occur at Ngel Nyaki (Borrow and Demey, 2002).

A growing body of empirical evidence suggests that the temporal stability of communities increases with diversity (Tilman, 1999; Cottingham *et al*., 2001; Valone and Hoffman, 2003; Tilman *et al*., 2006). This implies that knowledge of species diversity of a given locality or ecological community can inform on the functional dynamics and stability of that particular community. This assertion is built around the premise that certain species have obligate associations or interactions with species from other taxa for example fig trees and certain wasp species. It is on the basis of this that the congruence between floral resources and sunbird distribution/abundance at Ngel Nyaki forest was explored. As can be seen (Table 3) our results indicate that majority of the flowers of the tree species observed attracted sunbird species, with the exception of two species - *Newtonia buchananii* and *Deibolia pinnata*, where no single individual sunbird species was observed.

Although the scope of this study did not cover questions around resource preference and selection, knowing why sunbirds avoided this species despite the presence of some insects would have been insightful considering that the diets of sunbird species is basically composed of insects apart from their traditional diet of floral resources of pollen and nectar. For instance, At Ngel Nyaki the location of this present study, Nsor (2014) observed diet switch from nectar to insects in the variable sunbirds during the birds' breeding season in the months of January-February (Mann and Cheke, 2001). This switch by the brooding mother was found to be due to the high demands of protein for the growing fledglings in the nest.

From the results, it can be reasoned that in terms of sunbird diversity, and in fact avian diversity generally, the bird-tree community structure in this forest, is bound to be temporally stable, as the results indicate a relatively high level of diversity (Valone and Hoffman 2003; Tilman *et al.,* 2006).

Table 2: Sunbird Species in Ngel Nyaki relative to sunbird species occurrence in Nigeria.

S/N	Sunbird Species	Scientific Name	Genus	Ngel Nyaki	Local Status	Country status
1	Western Violet backed	*Anthreptes longuemarei*	Anthreptes	Yes	Resident/uncommon	Common regionally
2	Brown sunbird	*Anthreptes gaboricus*	Anthreptes	No	Not Recorded	Very rare resident
3	Pygmy sunbird	*Anthodiaeta platura*	Anthodiaeta	Yes	Breeding visitor	Seasonal migrant/CV
4	Frazer's sunbird	*Deleomis fraseri*	Deleomis	No	Not recorded	CR in Southern
5	Olive sunbird	*Cyanomitra olivaceus*	Cyanomitra	Yes	Resident/uncommon	Nigeria
6	Collared sunbird	*Hedydipna collaris*	Hedydipna	Yes	Resident/uncommon	CR
7	Bates sunbird	*Cinnyris batesi*	Cinnyris	No	Not recorded	CR
8	Little green sunbird	*Anthreptes seimundi*	Anthreptes	No	Not recorded	Regionally
9	Buff throated sunbird	*Chalcomitra adelbeti*	Chalcomitra	No	Not recorded	common/UC
10	Reichenbach's sunbird	*Anabathmis reichenbachii*	Anabathmis	No	Not recorded	URR
11	Green headed sunbird	*Cyanomitra verticalis*	Cyanomitra	Yes	Resident/uncommon	URR
12	Cameroon sunbird	*Cyanomitra oritis*	Cyanomitra	Yes	Resident/uncommon	Rare Resident
13	Blue throated brown	*Cyanomitra cyanolaema*	Cyanomitra	No	Not recorded	Common Resident
14	Camelite sunbird	*Chalcomitra fuliginosa*	Chalcomitra	No	Not recorded	Range restricted
15	Green throated	*Chalcomitra rubescens*	Chalcomitra	No	Not recorded	Uncommon Resident
16	Scarlet chested	*Chalcomitra senegalenses*	Chalcomitra	No	Not recorded	Very rare resident
17	Variable sunbird	*Cinnyris venestrus*	Cinnyris	Yes	Resident/PM	URR
18	Tiny sunbird	*Cinnyris minullus*	Cinnyris	No	Not recorded	Common resident
19	Olive bellied sunbird	*Cinnyris chloropygius*	Cinnyris	Yes	PM	Common Resident/PM
20	Northern double collared	*Cinnyris reichenowi*	Cinnyris	Yes	Most Common R	Very Rare
21	Orange tufted	*Cinnyris bouvieri*	Cinnyris	Yes	Very Common R	Common resident/PM
22	Copper sunbird	*Cinnyris cuprues*	Cinnyris	Yes	Uncommon resident	Range restricted
23	Splendid sunbird	*Cinnyris coccinigastrus*	Cinnyris	Yes	Uncommon resident	Range restricted
24	Beautiful sunbird	*Cinnyris pulchellus*	Cinnyris	No	Not recorded	Common Resident
25	Superb sunbird	*Cinnyris superbus*	Cinnyris	No	Not recorded	Common Resident
26	Johanna's sunbird	*Cinnyris johannae*	Cinnyris	No	Not recorded	CRR
27	Green sunbird	*Anthreptes rectilostris*	Anthreptes	Yes	Very rare	Rare resident
						Very rare resident
						New in range

Source Field survey and Borrow and Demey, 2001

URR=uncommon regional resident, CR=Common resident, CRR= Common Regional Resident, CV= Common Visitor, PM=Partial Migrant. **NOTE** *Of the 13 notable species at Ngel Nyaki, 11 were recorded in this study while two species (Cameroon sunbird and Western-violet backed sunbird) included below were absent throughout the study*

Table 3: Flowering Tree Species monitored at Ngel Nyaki Forest Reserve.

S/N	Tree Species	Family	Habitat	Local Status	IUCN	Total number of flowers used
1	*Deinbolia pinnata*	Sapindaceae	FE/FF	Common	LC	0
2	*Harungana madagascariensis*	Hypericaceae	FC	Uncommon	LC	137 (3)
3	*Anthonotha noldea*	Leguminaceae	FE	Common	LC	3223 (6)
4	*Anthocleista vogelli*	Gentianaceae	FF	Common	LC	3164 (4)
5	*Croton macrastachyus*	Euphorbiaceae	FF	Common	LC	85 (5)
6	*Nuxia cogesta*	Loganiaceae	FE/FF	Common	LC	6246 (4)
7	*Albizia gummifera*	Fabaceae	FF	Common	LC	4215 (5)
8	*Newtonia buchananii*	Fabaceae	FE	Common	LC	0
9	*Syzygium guinensis*	Myrtaceae	FF	Common	LC	338 (3)
10	*Dombeya ledermannii*	Sterculiaceae	FE	Common	CR	35 (4)
11	*Canthium Sp.*	Rubiaceae	FE	Common	LC	46 (4)
12	*Dalbergia latifolia*	Fabaceae	FE	Common	VU	5824 (4)
13	*Polyscias fulva*	Araliaceae	FE/FF	Common	LC	10 (3)
14	*Symphonia globulifera*	Clausiaceae	FE	Common	LC	2898 (5)
15	*Vitex doniana*	Verbanaceae	FE	Common	LC	13 (1)
16	*Sterculia lanceolata*	Malvaceae	FE	Common	LC	10 (1)

Source: Field survey2013

Note: FE= Forest edge, FF= Forest Fragment, FC= Forest Core, LC= Least Concern, CR= Critically Threatened, VU= Vulnerable. Values in bracket in the fifth column = total number of sunbird species, while those outside the bracket are the total number of flowers contacted.

Endemism

The occurrence of *C. reichenowi* and *C. bouvieri* at Ngel Nyaki forest and probably other adjoining forest within their range in the Mambilla Plateau, makes these forests the only other landscape in Nigeria besides Obudu plateau home to these species (Borrow and Demey 2002; Manu *et al.*, 2010). This finding further strengthens and supports the view of a high degree of endemism and diversity of birds in most forest within this eco-region (Elgood *et al.,* 1994; Stattersfield *et al*., 1998; Ezealor *et al*., 2002; Manu *et al.*, 2010). Ngel Nyaki forest, therefore, could serve as an ecological refuge for many other species not yet recorded and may be crucial habitats for the survival of sunbird species, especially those that are endemic or range restricted, should the need arise for specific steps to be taken towards their protection and conservation.

Rarity

Although some sunbird species (example northern double collared sunbird, Orange tufted sunbird, and variable sunbird) recorded in this assessment fall among the most common bird species encountered daily at Ngel Nyaki; species such as splendid sunbird, collared sunbird, olive sunbird and olive bellied sunbird were rarely encountered (Plates 1 a –h). However, others such as the Cameroon sunbird and the western violet backed sunbird were never encountered regardless of the fact that recent and past literature suggest that they are present in this forest. (Borrow and Demey, 2002, Tony Disley, unpublished checklist). The absence of these species in our records suggests that they are probably highly seasonal, very elusive and rare in this forest. Our result could also imply that these species have probably shifted their range or are undergoing serious depression in population.

One remarkable contribution of this assessment was the record of green sunbird, a species that was previously excluded from this forest and in fact the entire Mambila plateau region as indicated in existing field guides of West African birds and related taxonomic literature (Borrow and Demey, 2002). Although quite rare at Ngel Nyaki, the sighting of this species further confirms our view that avian diversity at Ngel Nyaki forest has been undermined and under-explored.

Plates 1(a-h) Sunbird diversity in the study area.

a) Northern double collared sunbird (adult male)

b) Olive sunbird (adult)

c) Orange tufted sunbird (adult male)

d) Green headed sunbird (adult male)

e) Variable sunbird (male)

f) Olive-bellied sunbird (adult female)

g) Green sunbird

h) Splendid sunbird

Abundance and habitat preference

Sunbird species varied in their spatial distribution and relative abundance. *C*. *reichenowi* was the most abundant throughout the period of investigation while *C. bouvieri* and *C. venustrus* were the second and third most abundant species, respectively (Table 1). Generally, there were more sightings of individuals of all species in 2012 than in 2013, indicating a variation in species abundance with season. Species evenness (that is, numerical equality of species in a given community) was low (Table 1), The poor species evenness and relatively high species diversity implies that sunbird species community at Ngel Nyaki forest would most likely exhibit multiple-ecosystem functions (multi-functionality) besides their quintessential roles of pollination as some studies have recently shown (Maestre *et al*., 2012). This possibility of multi-functionally will have strong implications for ecosystem stability and productivity.

Furthermore, the relative abundances of sunbird species derived from the results of this study give an idea of the number of possible (sunbird-tree) interactions that could be realized at Ngel Nyaki forest (Vazquez and Aizen, 2003). This assumption is in accordance with the report of Vazquez and Aizen, 2003, “that the number of interactions per species is strongly related to the relative abundance of species”. In addition, it can also be inferred on the types of inter and intra-specific interactions between sunbird species, especially in relation to resource utilization (for instance, floral resources).

While sunbird species differed in their distribution and abundance numerically; overall species distribution indicates that habitat preference was of a generalized nature at least for the three most abundant species (*C. reichenowi, C. bouvieri and C. venustrus*) (Table 1)

However, Green headed sunbird (*Cyanomitra verticalis*) and Copper sunbirds (*Cinnyris cupreus*) were restricted in their distribution and were recorded only at the fragment and edge of core forest respectively. *C. venustrus*, a species that ranked third in terms of overall abundance, was the most sighted and abundant species at the edge of the core forest throughout the entire period of the assessment. From our findings, this distribution pattern displayed by *C. venustrus* was conditioned by its breeding ecology. Each year one or more nest and even nestlings in 2014 of *C. venustrus* were discovered at the grassland habitats near the forest edge during transect observations. These birds built their nests about 2 feet above the ground on grass stems and spend a great deal of time hawking for insects to feed their young, hence their relative abundance during this period (January-February) and within this part of the forest. The fact that these nests were found only around the edges of the core forest is most likely an indication of the suitability of this particular habitat for the well-being and fitness of this species.

By intuition, it does appear that sunbird species showed a preference in their distribution across the two habitat types, especially with our finding that; *C. reichenowi*, the most common species at Ngel Nyaki forest was most abundant only within the fragment (Table 1). However, we lack empirical data to support any claim of habitat preference. It is most likely that the pattern of distribution of sunbird species at Ngel Nyaki forest is only a response to spatio-temporal variation in abundance of resources and fitness requirements of the focal species and not preference. This line of thought (especially fitness requirements), is supported by the seasonal abundance and almost ubiquitous presence of variable sunbird during the months of January and February when these birds engage in breeding. The high demand for energy to support the nestlings drives this species to look for insects to supplement the high-protein requirements in the diets of the nestlings. This dietary requirements result in daily expansion of their fundamental niche.

Although, the most plausible reason for their distribution is the spatio-temporal significance and suitability of the forest edge for its *C. venustrus* breeding requirements, which coincided with the period of the survey. We also contend that the distribution and relative abundance of *C. venustrus* at the edge compared to the fragment may also be an indication of its sensitivity and vulnerability to fragmented landscapes such as the riparian fragments of Ngel Nyaki. Although the scope of this assessment did not include testing habitat variables responsible for distribution and preferences by sunbird species, the results suggest that in line with most findings, vegetation structure, particularly availability of flowering tree species is a proximate factor accountable for the spatial distribution of sunbird species at Ngel Nyaki forest. The sighting and capture of Green sunbird, a species previously excluded from the distribution maps of the Mambilla plateau eco-region, is indicative of the fact that there could still be other un-assayed species in the study area.

CONCLUSION

This research results provide the background and framework for the development of comprehensive sunbird-tree pollination network. The generalized pattern of distribution of species, low species evenness and relatively high species diversity derived from the results of this assessment suggest that bird-tree interactions would not be limited by spatial distribution of resources at least for most species that have been found to be habitat generalist. Ngel Nyaki forest is indeed rich in sunbird diversity, probably the richest in the entire Mambilla plateau.

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CONFLICTING INTEREST

Authors are in agreement with all aspects of this publication and declare no conflicting interest.

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