Ethiopian Journal of Environmental Studies & Management 11(2): 215 – 230, 2018.
ISSN:1998-0507 doi: https://ejesm.org/doi/v11i2.8
Submitted: February 12, 2018 Accepted: April 13, 2018

SPECIES RICHNESS AND DIETS OF BATS FROM TWO SITES IN SOUTH-WEST, NIGERIA

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Abstract
Information pertaining to bat species diversity, ecology and distribution is grossly inadequate and sparse. This study examines bat species richness and diets of some bats in two reserves in Nigeria. Bats were trapped using mist nets from 1800hrs to 2300hrs for 20 nights at each site. Faecal samples released by captured bats held in bags for 60mins were stored in 70% ethanol and carefully examined using a stereomicroscope with magnification strength of 20-40 times to examine the remnants and aid identification of prey. Habitat variables: tree density, number of snags, litter cover and canopy cover were measured and tested for varying effects on diversity of bats. A total of 149 individuals in 6 families and 22 species were trapped during the survey. More insectivorous bats were trapped at Omo forest reserve (12), in contrast, at the International Institute of Tropical Agriculture, only three insect bats were trapped. Mean bat diversity at IITA was higher in the plantation compared to the forest area (One-way ANOVA: $F_{(13)} = 6.51$; $P= 0.03$; $R^2= 0.28$). At OMFR, a reverse observation was observed, diversity of bat was higher in the forest compared to the plantation (One-Way ANOVA: $F_{(14)} = 1.54$; $P= 0.23$; $R^2=0.24$). Eleven insect orders were identified from analyzed faecal samples with the beetles (Coleoptera) showing the highest percentage prevalence and damselflies (Odonata) having the least prevalence. This would mean that the insect groups that possess larger proportions are not evenly digested as others which are available in low proportions.

Key Words: *Bats, Diets, Insects, Conservation, Management*

Introduction

One of the greatest challenges to biodiversity all over the world is habitat loss through fragmentation and land use alteration (Meyer *et al*., 2010; Russo and Ancillotto, 2014). This loss is more severe and pronounced in tropical regions where habitats are constantly lost either through degeneration or full conversion of natural areas possessing balanced ecosystem processes into man-made landscapes; These events have continued unabated, with species requiring specialized niches declining in abundance and distribution shrinking to isolated patches (Meyer *et al*., 2010). Howbeit, most bat species rely on cover in one form or the other for their survival; cover in this sense could be either artificial or natural (Fenton *et al*., 1998; Taylor, Monadjem, and Steyn, 2013). Bats have been recorded to forage along forest edges, riparian vegetation, forest roads and trails, natural forest gaps or harvest–created openings (Barrett *et al*., 2001; Taylor, 2006). Chiropterans worldwide have a wide variety of preferences for food, generally they may feed on or have a mixture of the following; insects, fruits, blood, fish and small vertebrates (Barrett *et al*., 2001; Bohmann *et al*., 2011; Courts, 1998). The nutritional requirements of bats are still hard to understand and not well known to research but their dietary strategies is gaining more degree of attention (Adams *et al*., 2003; Ahmin and Moali, 2013; Courts, 1998; Stier and Mildenstein, 2005; Vaughan, 1997). Insect bats have been proposed as primary consumer of insects that are active at night *(Kunz et al*., 2011; Swift and Racey, 2002) and have the ability to act as biological pest control agents in farmlands (Kunz *et al*., 2011; Whittaker, Willis, and Field, 2001). Insectivorous bats have high metabolic rates during flight and therefore need large amounts of food (Adams *et al*., 2003). Conflicting reports raise questions as to whether bats select insect species as food or consume those that are simply available in the greatest amounts (Adams *et al*., 2003; Brigham *et al*., 2008; Salsamendi *et al*., 2008). It seems reasonable to assume that as in other animals, nutrients requirements of bats would probably vary among age and sex (Adams *et al*., 2003; Brigham *et al*., 2008; Salsamendi *et al*., 2008). There are few studies that have tried to identify the important dietary components with list of dietary items used but no quantification of what is used (Bambini *et al*., 2006; Brigham *et al*., 2008). This study assessed bat species richness and diets of some bats observed from two sites in south-west, Nigeria.

Methodology

Study Sites

The campus of IITA (7°30′ N, 3°55′ E) occupies *c* .1000 ha with a 360 ha relict of secondary dry semi-deciduous rainforest (Adeyanju *et al*., 2014). Omo Forest Reserve (OMFR) is located on 4°30′ E, 6°51′ N with an area of 132,000 ha and an altitude of 15-300 m (Amusa *et al*., 2017; BirdlifeInternational, 2012; Ezealor, 2001; Olmos and Turshak, 2009).

Methods

Bats were captured using mist-nets within two habitat types (Forest and plantation), using stratified sampling method to place nets at 20 points from May–July. We calculated bat species diversity for the two study sites using Shannon-Weiner diversity index, H and techniques were adapted after Adeyanju *et al*. (2017).

Diet Identification from Faecal Matter

Collection of faecal matter from each individual was carried out by allowing each bat in the extraction bag for about 30-60 mins (Andrafidson *et al*., 2007; Kellner, Harestad, and Lewis, 2005). The faecal matter collected was preserved in plastic vials containing 70% alcohol. Pellets from faecal matter were placed on glass slides with few drops of 70% alcohol to keep the samples wet so as to have a clear view of the faecal sample to aid in easy identification of insect parts. Stereo-microscope was used for observation and magnification strength between 20 and 40 times to identify remnant parts from invertebrates (parts such as thorax, cerci, antennae, appendages, wing scales) from the faecal matter (Kellner *et al*., 2005) and identification guide was used to support identification to order level (Castner, 2000).

Species Effort Curve

Species effort curve for IITA (Fig.1) shows a slow climb and leveling off intermittently throughout rest of the curve. EstimateS (Version 8.2.0) was used to derive Sample based asymptotic species richness estimated by the Chao 1 non-parametric species richness estimator for the bats captured in both sites. The estimators do not stabilize meaning that more species could be added with increase in number of samples.

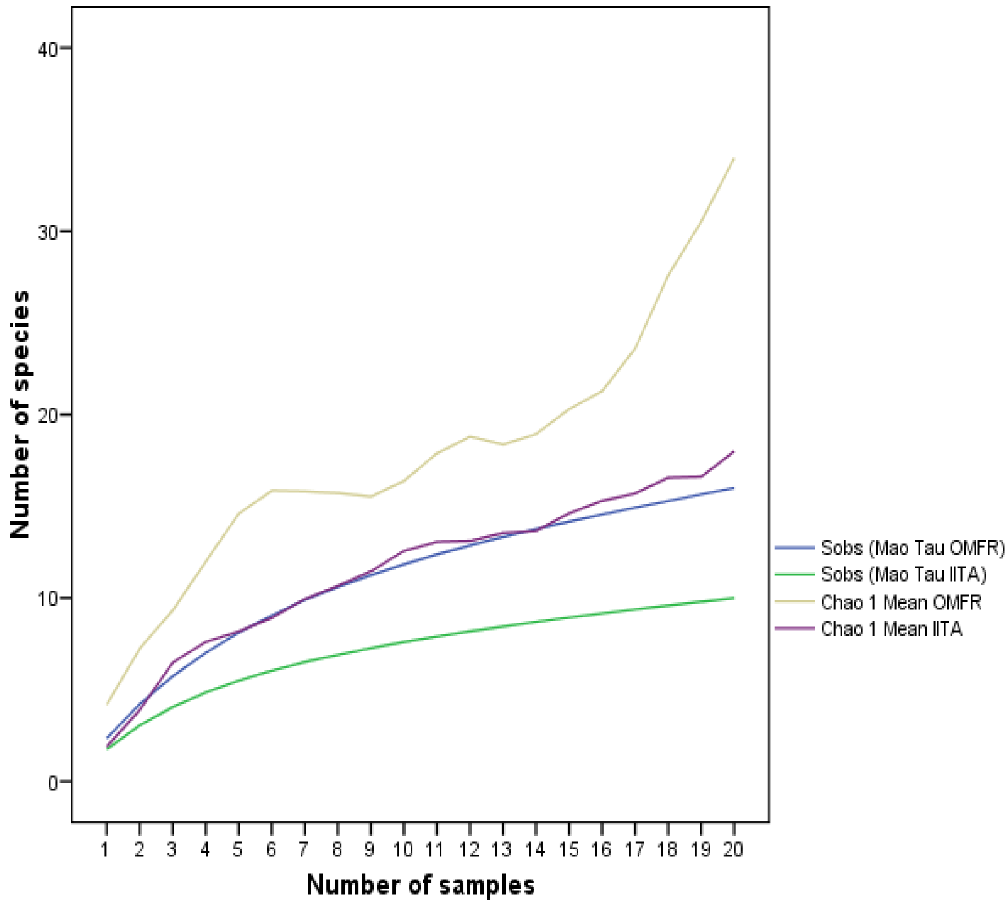

Fig. 1: Sample based species richness observed and estimated compared between IITA and OMFR. About 17 and 5 bat species can still be detected at OMFR and IITA respectively.

Results

Bat Species Richness

A total of 149 individual bats in 6 families and 22 species were trapped during the survey (Table 1). Eighty three individuals were trapped in IITA belonging to 8 species in 3 families (9 Ptreropididae, 1 Nycteridae and 2 Vespertilionidae) as shown in Table 1 while 66 individuals were trapped at the OMFR belonging to 15 species in 6 families (6 Nycterididae, 1 Vespertilionidae, 3 Hipposideridae, 1 Megadermatidae, 4 Pteropodidea, and 3 Rhinolophidae;) as shown in Table 1.

Table 1: A checklist of the number and species of bats captured at IITA and OMFR in south-west Nigeria

Common Name	Scientific Name	Family	OMFR	IITA
Common African leaf-nosed bat	*Hipposiderous caffer*	Hipposideridae	1	
Cyclops bat	*Hipposideros cyclops*	Hipposideridae	3	
Jones Leaf-nosed bat	*Hipposideros jonesi*	Hipposideridae	3	
Yellow-winged bat	*Lavia frons*	Megadermatidae	1	
Bates's slit-faced bat	*Nycteris arge*	Nycteridae	9	
Hairy-slit faced bat	*Nycteris hispidia*	Nycteridae	17	1
Large-eared Slit-faced bat	*Nycteris macrotis*	Nycteridae	1	
Egyptian Slit-faced bat	*Nycteris thebaica*	Nycteridae	1	
Large Slit-faced bat	*Nycteris grandis*	Nycteridae	3	
Franquet's Fruit-bat	*Epomops Franqueti*	Pteropodidae		26
Gambian Epaulet Fruit-bat	*Epomophorous gambianus*	Pteropodidae		36
Hammer-headed Fruit-bat	*Hypsignathus monstrous*	Pteropodidae		1
Lesser Epaulet -bat	*Micropteropus pusillus*	Pteropodidae		12
Little Collared Fruit-bat	*Myonycteris torquata*	Pteropodidae	2	
Long-tongue Fruit-bat	*Megaloglossus woermanni*	Pteropodidae	10	1
Zenker's Fruit bat	*Scotonycteris zenkeri*	Pteropodidae	5	
Straw-coloured Fruit bat	*Eidolon helvum*	Pteropodidae		
Abbysinian Horseshoe-bat	*Rhinolophus fumigatus*	Rhinolophidae	9	
Halcyon Horseshoe bat	*Rhinolophus alcyone*	Rhinolophidae	1	
Beatrix bat	*Glauconycteri sbeatrix*	Vespertilionidae	1	
Serotine bat	*Eptesicus spp*	Vespertilionidae		1
Yellow House-bat	*Scotophilus dinganii*	Vespertilionidae		1

Comparison of Mean Bat Diversity and Abundance between Habitat Types within Sites

At IITA, mean bat diversity was higher in the plantation compared to the forest area and the difference in mean diversity of bat between the two habitats was significant (One-way ANOVA: $F_{(13)} = 6.51$; P= 0.03; R^2= 0.28, Fig. 2). The difference in abundance between the two habitats within IITA was significant (One-Way ANOVA: $F_{(13)} =6.20$; P=0.02; R^2=0.27, Fig. 3).

At OMFR, diversity of bat was higher in the forest compared to the plantation but the difference in mean diversity between the two habitats was not significantly different from each other (One-Way ANOVA: $F_{(14)} = 1.54$; P= 0.23; R^2=0.24; Adeyanju et al., 2017). The abundance of bat captured was higher in the forest compared to the plantation but the difference in mean abundance between the two habitats was not significant (One-Way ANOVA: $F_{(14)} = 2.22$; P= 0.15; R^2=0.075; (Adeyanju et al., 2017).

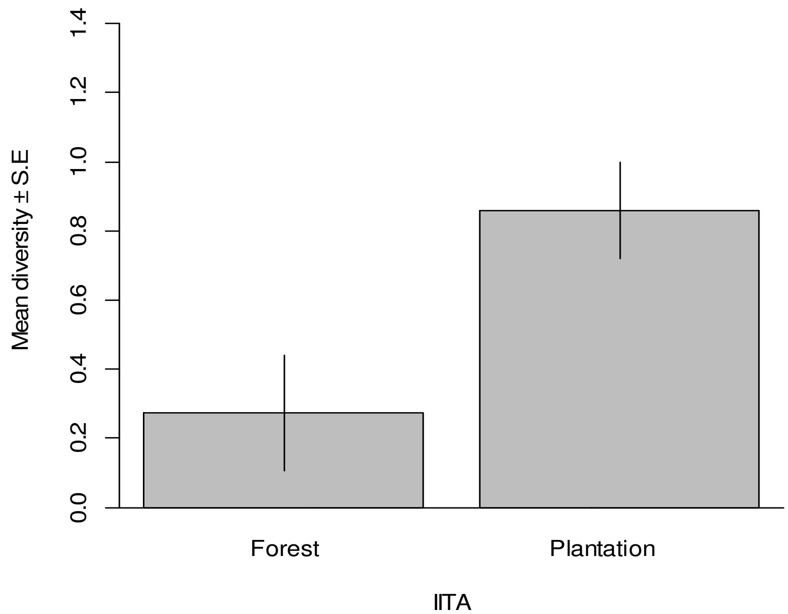

Fig. 2: Mean diversity of bats within two habitats in IITA.

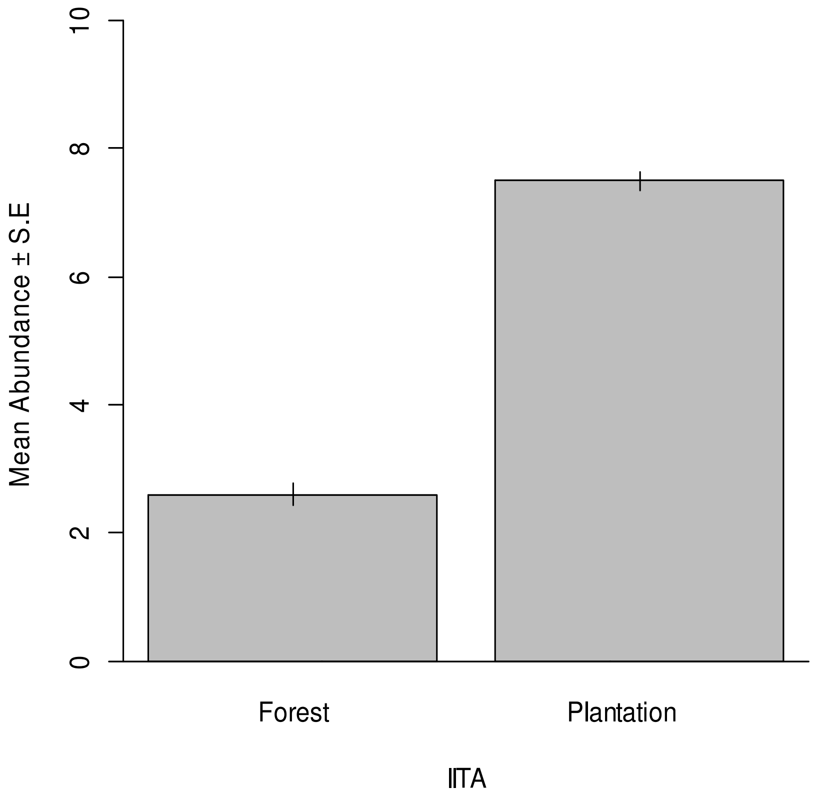

Fig. 3: Mean abundance of bats in two habitats in IITA.

Comparison of Mean Bat Diversity and Abundance between IITA and OMFR

Though there were more species trapped at OMFR as compared to IITA, the mean diversity between the two sites was not significantly different (t =-1.23, df = 28.44, P = 0.17, Fig.4). The number of bat individuals captured from the IITA were more compared to those captured from the OMFR but comparing the means of the bat captured, there was no significant difference (t = 1.40, df = 22.05, P = 0.22, Fig. 5).

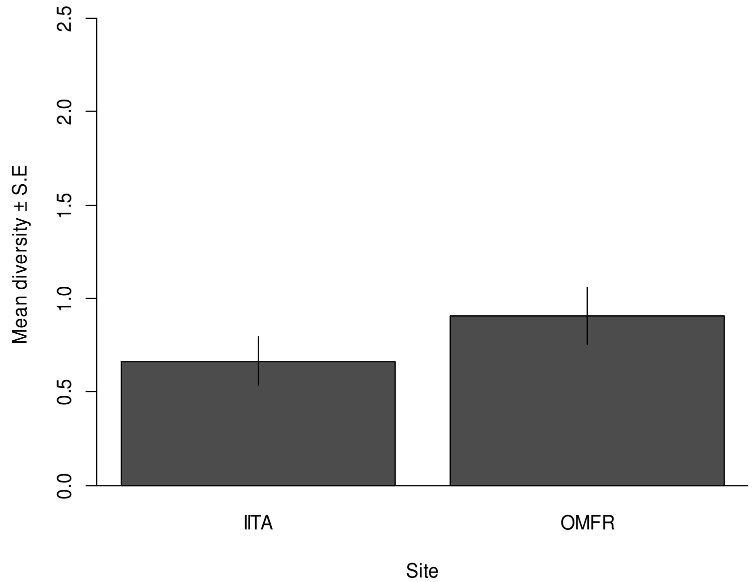

Fig. 4: Mean diversity of bat species at two sites in south-west, Nigeria

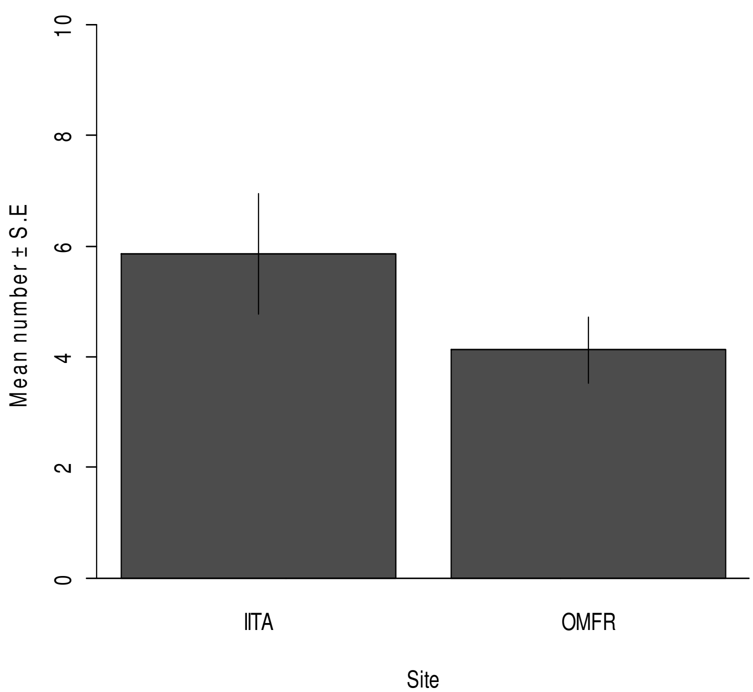

Fig. 5: Mean number of bat species at two sites in south-west, Nigeria

Effects of Habitat Variables on Mean Bat Diversity and Abundance within Sites

At IITA, though there was significant relationship between bat diversity with tree density and litter cover (Table 2), diversity was affected negatively. As the density of trees and litter cover increased, the mean diversity of bat captured decreased respectively as demonstrated in Fig. (6 and 7). For IITA, there was a significant relationship between bat abundance and density of trees (Table 3), bat abundance was negatively affected; as number of trees increased, the mean abundance of bat captured decreased respectively (Fig. 8).

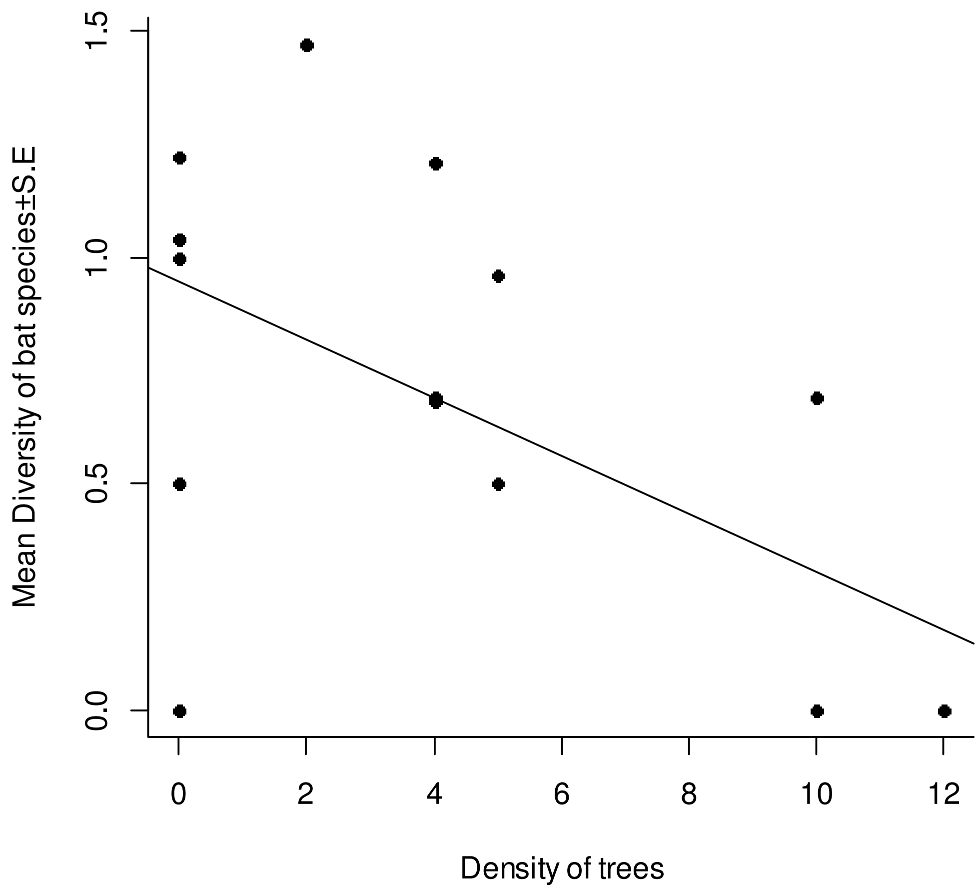

Fig. 6: Relationship between mean diversity of bats and tree density at IITA.

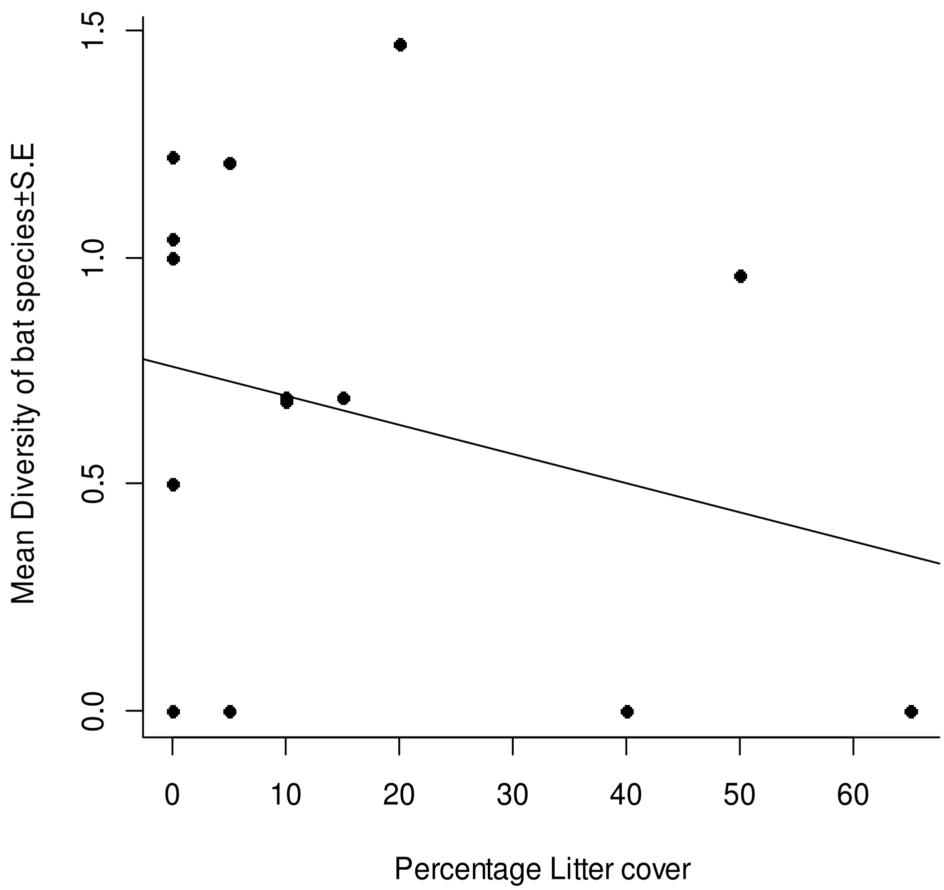

Fig. 7: Relationship between mean diversity of bats and percentage litter at IITA

Table 2: Analysis of covariance between habitat variables and average bat diversity in IITA

Variable	Parameter estimate	df	Sum of Squares	F	P
Intercept	0.80	1			0.08
Density of trees	-0.08	1	1.05	0.79	0.06
Litter cover	0.03	1	0.04	0.32	0.03 *
Fruiting trees	0.14	1	0.02	0.19	0.10
Flowering trees	0.08	1	0.04	0.32	0.31
Density of trees: Litter cover	-0.003	9	0.92	6.19	0.03 *

R^2=0.40

Table 3: Analysis of covariance test between habitat variables and mean bat abundance in IITA

Variable	Parameter estimate	df	Sum of Squares	F	P
Intercept	8.65	1			0.11
Density of trees	-0.95	1	109.37	8.80	0.03 *
Litter cover	0.06	1	11.45	0.92	0.32
Fruiting trees	0.19	1	0.13	0.01	0.77
Flowering trees	0.31	10	2.52	0.20	0.66

R^2=0.30

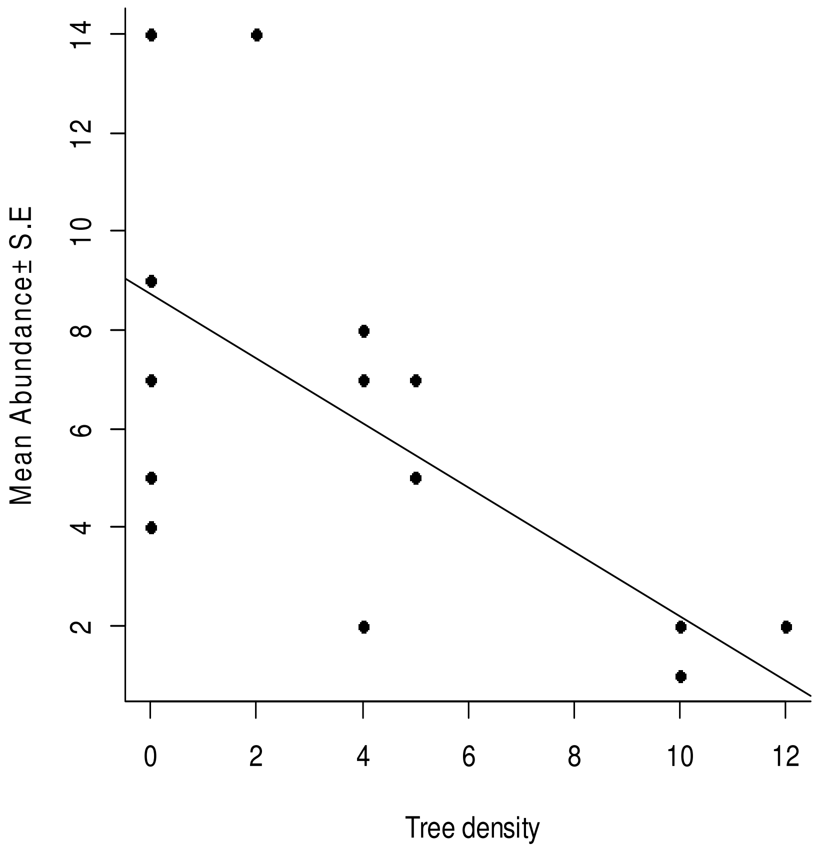

Fig. 8: Relationship between mean abundance of bats and tree density in IITA

Bat Diet

Eleven insect orders were identified from the faecal matter analysis of some of the insectivorous bats (Fig. 9). All faecal matter sampled was from the OMFR with order Coloeptera having the highest percentage frequency (17.14%, Fig. 9). There was no faecal matter collected at IITA because the majority of bats trapped were fruit eating bats, Pteropodidae as shown in Table 1 and Fig. 10). Fruits of *Ficus polita* and *Luffa cylindrica* were retrieved from some trapped individuals.

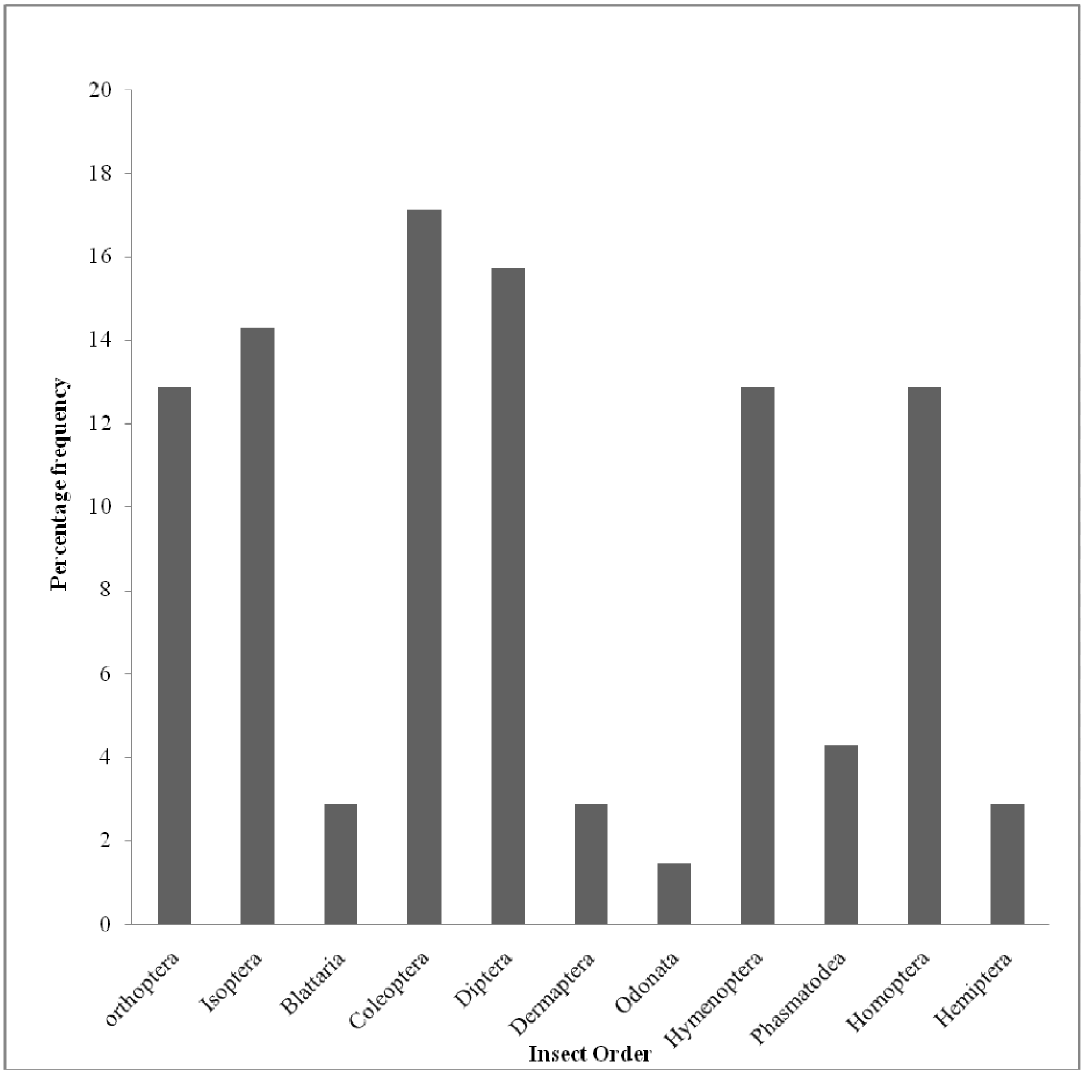

Fig. 9: Frequency percentage of each insect order in the diet of some insectivorous bats trapped (n=20) during mist netting survey from May to July at Omo Forest Reserve, Ogun State, Nigeria

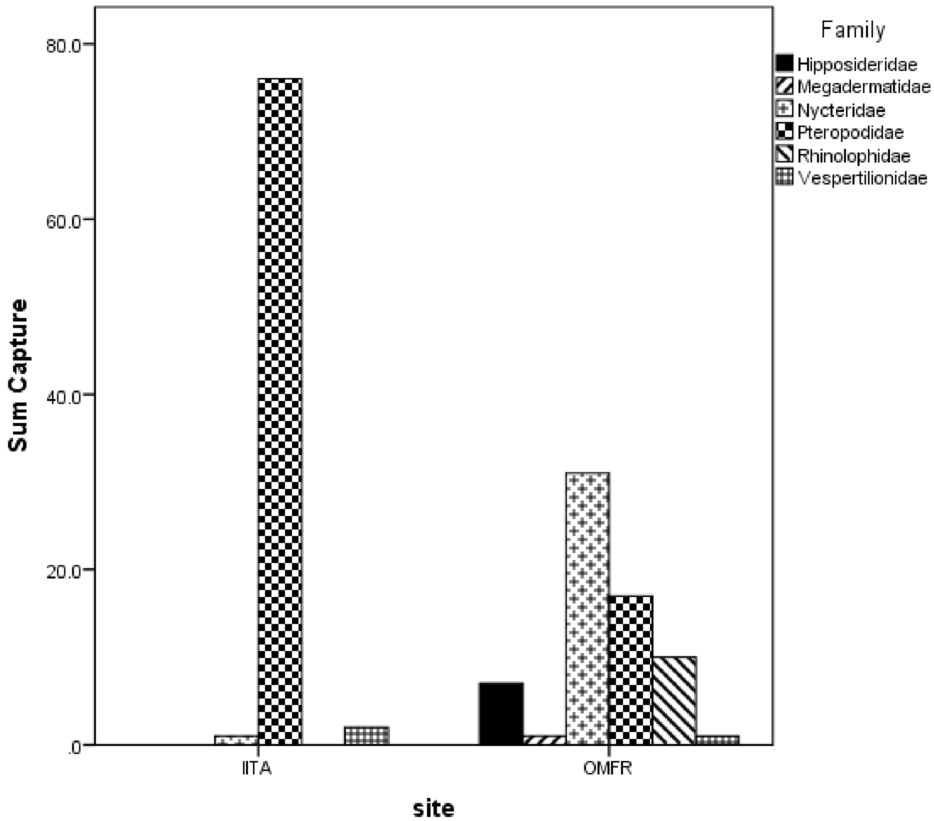

Fig. 10: General distribution of Bat Families trapped during the survey at IITA and OMFR

Discussion

Bat Species Richness

Most bat studies in southwestern Nigeria have focused on a single species of bats, the well-known *Eidolon helvum* (Okon, 1977). This study reports the presence of 22 species of bats from two sites within the south western axis of Nigeria with both sites possessing some level of protection and agricultural intensification where pesticides are applied to improve crop productivity. This report contributes about 40% of bats known to occur in Nigeria. Bat species diversity of Omo forest reserve has been discussed by the authors in detail (Adeyanju *et al*., 2017).

Diet of some Bat species

There are several limitations incurred by using percent frequency to examine diets because percent occurrence does not account for the different prey sizes. The frequency of soft bodied insects may be underestimated due to the difficulty in identifying insects from dissociated body parts (Kellner *et al*., 2005) Nevertheless, percent occurrence gives a list of insect consumed by bats as an index of their importance in diets given enough sample sizes. This study reveals that of the faecal matter of insectivorous bats that were sampled, more Coleoptera was consumed compared to other insect orders that were identified especially from the bat family Nycteridae. This difference may be due to availability of prey due to habitat selection or differences between the bat species in ability to catch or consume certain prey groups (Kellner *et al*., 2005) as compared to Order Diptera found in the diet of *Rhinolophus Ferrumequinum* (Ahmin and Moali, 2013). Though Order Diptera ranked the second most consumed prey, more studies is still required to establish prey consumption. It could also be to due to the structure of fibre in each of the insect groups, meaning that some insects have larger proportions of fibre digested than others. This would mean that the insect groups that possess larger proportions are not evenly digested as others which are available in low proportions. Assessing the insect diversity available during capture may help to thin out this bias. Though most studies on diet focus on a single bat species (Andrafidson *et al*., 2007; Brigham *et al*., 2008; Leelapaibul, Bumrungsri, and Pattanawiboon, 2005; Salsamendi *et al*., 2008; Stier and Mildenstein, 2005). Our study looked into the diets of bats from 6 families within which Nycteridae were favored due to higher number of captured individuals. Prey group consumed were largely consistent with some studies that have been carried out before (Ahmin and Moali, 2013; Kellner *et al*., 2005), although some other studies have revealed other insect order at higher percent especially Lepidoptera and Homoptera (Ahmin and Moali, 2013; Bohmann *et al*., 2011; Leelapaibul *et al*., 2005). It is also possible that the effect of season affects prey and fruit availability, as revealed in the study by (Salsamendi et al., 2008). Local prey availability and effects of seasons should be investigated to also affirm prey consumption and preference. Diet consisting of mainly fruits by some individuals especially the *Epomophorus gambianus* from which some fruits were retrieved during extraction from the nets; and the fruits belonged mainly to the *Ficus spp*. No faecal matter was gotten from the majority of fruit bats and the few samples gotten could not be analyzed due to unavailability of experts to aid in identification of seeds from faecal matter. Seeds would have to be grown in nurseries and catered for to produce flowers to be able to detect precisely what species they are or Real-time/next generation PCR could be carried out to detect DNA available. Another method would be to take an assessment of fruit trees during the study and then draw out inferences from literature (Stier and Mildenstein, 2005) based on fruits retrieved from some trapped individuals which we suggest for further studies. Also based on personal interviews, it has been noted that within one of the study sites (IITA) fruit bats are important in dispersing seeds of *Ceiba pentandra* and *Milicia excelsa* (Iroko tree), and the latter ranks as one of Africa's most valuable hardwood (Deni Bown pers. comm.).

Bat Species Diversity and Abundance across Two Habitats

Species diversity and abundance were found to be significantly higher in the plantation habitat compared to the forest habitat for IITA. A total of eighty fruit bats were netted (*Pteropodidae*) and 3 insectivorous bats in IITA. The result of this study site was heavily influenced by the presence of the fruit bats. This could be due to the change in behaviour of fruit bats to make use of human- modified environments in terms of access to food and roost sites. it was observed that were fruiting trees and plantations of *Musa spp* that were set up for experimental purposes. Also, IITA has been observed to serve as one of the largest roost sites for some *Pteropodidae*. This is however not consistent with some past studies (Lee *et al*., 2007; Yoshikura, Yasui, and Kamijo, 2011). The other factor responsible for the observed diversity and abundance may be due to the presence of riparian-like habitat that surrounds the plantation area, as this allows for the presence of several flowering and fruiting trees such as *Ficus spp* (Monadjem and Reside, 2008) and *Leucaena leucocephala* as this forms an important part of the diets of these bats (Stier and Mildenstein, 2005). *Epomophorus* spp has been radio tracked in Zimbabwe where they stayed within riparian area (Townsend, Rimmer, and Mcfarland, 2012).

The low incidence of insect bats might also be attributed to the use of insecticide and or pesticide or the planting of insect resistant crops (Leelapaibul *et al*., 2005) by the IITA management as the plantation is basically an agricultural plantation (Pers. Obs.) in which it is expected that there should high insect activities as insectivorous bats have been suggested as primary consumer of insects and are observed to prey on a number of farmland pest (Leelapaibul *et al*., 2005). Studies have also shown that plantations may be inadequate for most frugivorous and insectivorous bats *(Randrianandrianina et al*., 2006). Also the high capture rate of fruit bats in the plantation may be linked with bats roosts in the hollow stems of dead or damaged bamboo (Larsen *et al*., 2007).

There was a significant negative relationship between bat species diversity and percentage litter cover. Bat species diversity declined as the number of trees and percentage litter cover increased. Several studies have reported that high vegetation clutter decreases bat activity (Tibbels and Kurta, 2003).

Conclusion and Recommendations

Our study has shown that both sites International Institute of Tropical Agriculture and Omo forest reserve offer cover which still support a high diversity of bat species which are representative of both insectivorous and frugivorous bats. Nonetheless, management and anthropogenic activities involving the use of pesticides have been suggested a possible cause for the low trap rate of insectivore bats at IITA environs. Fruit bats are very important agents of dispersal which have become very conspicuous today due to the absence of larger keystone species such as primates well known for dispersal of fruits in the past. Faecal dropping from bats can be used to infer foraging resources such as insects though percentage occurrence does not account for the size variations of each insect included in diet during foraging. The use of fecal droppings to quantify insect use by bats needs to be interpreted with caution as several factors can impinge biological interpretation. Management of the two reserves should prevent hunting and clearing, improve more on protection programs especially logging activities on old trees as these are important for bat activities, illegal use of forest reserves for agricultural use and practices that are unfavourable to wildlife and their resource needs. There is a need for increaselevel of awareness especially in the site closer to the urban areas on the importance and continued presence of bat species and stressing the effects of habitat destruction on the species as well as other members of the ecosystem.

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