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ABUNDANCE, ROOST CHARACTERISTICS AND FLORA DISPERSED BY AFRICAN STRAW-COLOURED FRUIT BAT *EIDOLON HELVUM* FROM TWO SITES IN SOUTHWEST, NIGERIA

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ABSTRACT

We examined abundance, roost characteristics, and flora dispersed by *E. helvum*. This study was conducted at two locations which are; University of Ibadan, Oyo and Bowen University Iwo, Osun State. Estimate of bat counts per roost tree were obtained by enumerating the number of clusters on each branch of the tree. Data on ejecta and feaces were collected twice in a week below roost tree for 12 weeks at the two locations, by placing polythene bags in a randomly chosen $1m^2$. Seventy-One Thousand, Nine Hundred and One (71,901) *E. helvum individuals* were counted within the observation period on fifty-nine (59) trees comprises twenty (20) species. *Funtumia elastic*a species had the largest percentage ground cover among the roosting trees while *Piptadenniastrum africana, Peltophorum pterocarpum, Ceiba pentandra, Mangifera indica* roost tree species had largest circumferences. *Eidolon helvum* feed on the genus "*Ficus*", identified as "*F. mucuso,* F. *polita, F. exasperata* and F. *lutea*"; *Psidium guajava* and *Carica papaya*. The study concluded that *Eidolon helvum* helps in the dispersal of seedlings commonly of the genus "*Ficu*s", and some edible fruits consumed by humans such as common *P. guajava* and *C. papaya*, therefore playing an important role in mediating habitat loss and succession respectively in many peri-urban areas in southwest, Nigeria

Keywords: *Eidolon helvum*, abundance, Roost characteristics, Diets

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INTRODUCTION

Fruit bats are popularly known as *Adan* among the Yoruba tribe (one of the dominant tribes in south western Nigeria) and are commonly used for various consumptive purposes as bush meat, traditionally used in preparation of concoction for pregnancy and treatment of various ailments (Adeyanju, 2018), though scientifically, they play an essential role in the ecosystem by reseeding of fragmented spaces among habitats through seed pollination and plant dispersal, regulation of insect populations (Taylor, 2006; Weller and Lee, 2009; Webala *et. al*., 2014). According to Magloire *et al*., (2017), frugivore favour seed germination of Iroko (*Milicia excelsa*), which is a threatened species in West Africa. Fruit bat species food choice varies from fruits, nectar, or pollen; while most insect feeding bats eat insects; others feed on fruit, nectar, pollen, fish, frogs, small mammals, or blood (Holland, 2004). Many bats are opportunists, switching between plants for their nutritional requirements depending on food availability in different seasons (Fleming, 1982). The African straw-coloured fruit bat (*Eidolon helvum*) are most widely distributed of Pteropidids in Africa, with massive colonies of at least 100,000 and sometimes massing up to one million (Beamer, 2019). The species forms large colonies in widely scattered locations across the central belt of Africa, and on some offshore islands including the Gulf of Guinea islands and Zanzibar, Pemba and Mafia (off Tanzania), Western Kenyan (Webala *et. al*. 2014). It has been explained by Fleming (1982) and Dumont (2003) that foraging strategies of *E. helvum* depends on risk of predation and distribution of fruit resources.

Roosting in vertebrates can be communal or maternal. Roosting is a behavior/habits common among the animals capable of true flight typically of the same species, conjugate/congregate in an area for a few hours either to exhibit an activity or based on an external and environmental signal such as high tide, rainfall, nightfall etc. (Finkbeiner *et. al*., 2012); and this can be a limiting factor for mating and rearing/care for young ones. Bats use roosts as a means of shelter to protect themselves from predators, thermoregulation and as an agent of social interaction (Jeffrey and William, 2013). The locations chosen by many roosting animals vary across different cycles/seasons (e.g. winter roosts, summer roosts, diurnal roosts and nocturnal roosts) (Kunz and Fenton, 2003). Anthropogenic disturbances of many roost sites such as caves and forest have been reported such as overexploitation of caves, mining, deforestation, bush burning and urbanization are anthropogenic disturbance (Funmilayo, 1978, Westcott *et al*., 2011; Eby, 2002). This has resulted to decrease in reproductive success, abandonment and loss of preferred roost sites, increase rates of predation as a result of loss of preferred roost sites and overcrowding of bats on few available roost trees (Miller and Jenson, 2013; Webala *et al*., 2014).

A number of fauna species such as mammals, reptiles, insects and birds are often used as indicators of forest health; due to the relationship between species abundance, richness and habitat variables in different habitats. In West Africa, bats have been cited as good indicators of forest health because both abundance and diversity of bat species was lower in disturbed forest (Medellin and Gaona 2000). According to the study carried out by Bernard and Fenton (2007), some species of bat can adapt to tempered ecosystem due to their ability to commute between different habitats in search of food, provided that corridors of old growth remains and persist. This disturbance can have some positive effects as it encourages important roles involved regeneration through seed dispersal, reduction of insect-pest biomass (Jones *et al*., 2009; Morrison and Lindell, 2012)

There have been observations on abundance, population dynamics, roost characteristics, dispersal ability, migration and dietary composition of *Eidolon helvum* in some countries in East and West Africa countries (Taylor 2005; Makau *et. al*., 2012; Abedi-Lartey *et al*., 2016; Magaloire *et al.*, 2017; Adeyanju *et al*., 2019). Other studies on bats in southwest have focused of bats abundance and diversity but did not focus on roost characteristics, seed dispersal ability, species dispersed by bats (Adeyanju *et al*., 2017; Adeyanju and Adeyanju, 2018). However, information on roost characteristics, seed dispersal ability and plant species dispersed by bats in Nigeria is still sparse, though this is a follow up on previous observations by Adeyanju *et al*. (2019) where observation was focused on one roost characteristics of two fruit bats in University of Ibadan. Therefore, by focal observation we have assessed flora dispersed by *Eidolon helvum*, by collecting ejecta and fecal droppings, roost characteristics and population dynamics at two sites in southwestern Nigeria.

MATERIALS AND METHODS

Study Area

The two study areas are University of Ibadan and Bowen University. University of Ibadan is located in Ibadan, and capital of Oyo state. University of Ibadan is situated 6 kilometers to the north of the city of Ibadan. It is located between Latitude: 7°23'28.19"N, Longitude: 3° 54' 59.99"E, at a mean altitude of 277 meters above sea level. The University of Ibadan started off as the University College, Ibadan (UCI) which was founded in 1948, which covered over 2,550 acres of land. The topsoil is freely drained, fairly acidic and of moderate fertility with colluvial deposits in the valley. The geology of the area is underlined by rocks of basement complex, mostly gneiss. The University of Ibadan is located in the Northern limit of lowland rainforest zone. It lies in a transitional zone between the rainforest and derived savannah zone with annual rainfall of about 1220mm with double peak during June and August which last for almost 8months (April to October) and dry season between November and March. The vegetation of the area is rich with highly diverse species comprising of a wide variety of woody trees, shrubs, collection of herbs, palms and climbers which are well represented (Adeyanju and Adeyanju, 2012).

Bowen University is located in Iwo town, Osun State. It is a private Baptist Christian Nigerian University. It is located between Latitude: 7° 37' 22.8"N Longitude: 4° 11' 26.1"E, at a mean altitude of 312m above sea level. It is housed in the old 1300 acres campus of the Baptist College, teacher-trained institution on a hill just outside the city.

Bat Population Estimation: Following Makau *et al*.; (2012), Bats were counted cluster by cluster, branch after branch and tree after tree. The bat counting was done at University of Ibadan (Vice Chancellor lodge) and this was done for 4 consecutive weeks. Total bat numbers per roost tree were obtained by counting the number of clusters on each branch on the tree and multiply this figure by the estimated mean number of bats in each cluster. Summations of bat numbers per tree were done to obtain total numbers of bats per roosting camp.

Roost Identification and Assessment Parameters measurement

DBH Diameter at Breast Height: DBH (Diameter at Breast Height) of tree were measured at 1.3 meter using a meter rule.

Tree Height: The height of trees at the roosting site was measured using Alga-altimeter.

Canopy cover: The canopy cover of trees was measured in percentage by ocular estimation based on the penetration of light through the canopy using the opposite side of a binocular.

Ground cover: The percentage of land covered with biomass (plant habitat) under the roost trees were done via direct observation.

Roost Tree Identification

Trees used as roost were systematically identified by a taxonomist using standard keys.

Fecal and Ejecta Dropping Collection: Seed rain refers to the pattern of seed fall to the ground (Wang and Smith, 2002). Ejecta refers to fruit fragments dropped by bats while feeding. Data on ejecta and fecal were collected twice in a week below roost tree for twelve (12) weeks at the two locations. This was done by placing polythene bags in a randomly chosen 1m^2 quadrats following Bleher and Böhning-Gaese, (2001), Kirika *et al*.; (2008). The polythene bags were placed randomly within the radius of the crown of the selected tree (Duncan and Chapman, 1999). The polythene bags were placed at 18:00 hours, the fecal dropping and ejecta were harvested daily at 07:00 hours to ensure that only seeds generated by bats were collected.

Seed Handling: After collection, the seeds were dried for two consecutive days in the open air to reduce water content and improve germination (Djossa *et al*., 2008).

Propagation of Fecal Droppings

Planting medium: Cured saw dust was prepared from a carefully collected wood shaving, it was spread on a clear platform. The wood dust was exposed to sunlight and rain for two months till it got decayed.

Planting procedure: Nursery bed was made with the cured saw dust. The dried fecal droppings and ejecta were planted directly on the bed under a tree to give shade to nursing bed. The seed bed was covered with a net to prevent introduction of external seed dispersing agents. After germination, the growing seedlings were transferred into polypot for proper monitoring for 4 weeks.

Seedlings Identification: The seedlings were systematic identified by a taxonomist using standard plant keys to plant identification.

Statistical Analysis

All analysis was done using Microsoft excel spreadsheets and Statistical package for Social

Sciences (SPSS). The descriptive statistics (mean, standard deviation and standard error) was used to examine the abundance of the bats and the roost trees characteristics. Correlations and Regression were used for testing for relationships between two or more variables (at α = .05).

RESULTS

Seventy-one thousand, nine hundred and one *Eidolon helvum* individuals were estimated roosting on fifty trees (comprising 20 trees species) (Table 1). The largest tree roots of *E. helvum* were recorded on *Pycnanthus angolensis* and *Triplochiton scleroxylon* species (Fig. 1).

Table 1: Population of *Eidolon helvum* estimated per roost tree for four consecutive weeks from University of Ibadan.

Trees Species	N	Total number of Bats	Mean	Std. Dev.	(S.E)
Albizia ferruginnea	4	396	99	83.61	41.81
Antiaris africana	20	2372	119	73.47	16.43
Blighia sapida	12	3607	301	189.21	20.48
Bosqueia angolensis	24	5607	234	100.33	77.12
Ceiba pentandra	8	2171	271	218.14	59.95
Celtis zenkeri	4	878	220	119.89	19.17
Entorolobium cyclocarpum	24	3238	135	93.93	41.02
Funtumia alata	4	394	99	82.03	72.60
Funtumia elastica	4	1172	293	145.19	26.66
Khaya spp	4	498	125	53.33	76.81
Newbouldia spp	8	2430	304	349.34	104.06
Mangifera indica	12	4620	358	266.06	28.14
Milicia excelsa	8	3385	423	294.33	123.51
Nesogordonia papaverifera	32	6396	200	159.20	35.93
Peltophorum pterocarpum	12	3273	273	124.47	144.14
Piptadenniastrum africana	12	5295	441	499.33	293.82
Pycnanthus angolensis	12	11509	959	1017.82	34.04
Spondias monbin	4	965	241	68.09	33.71
Trichila heudelotii	8	1117	140	95.35	159.78
Triplochiton scleroxylon	20	12903	645	714.56	26.51
Total	**236**	71901	**305**	**407.23**	**41.81**

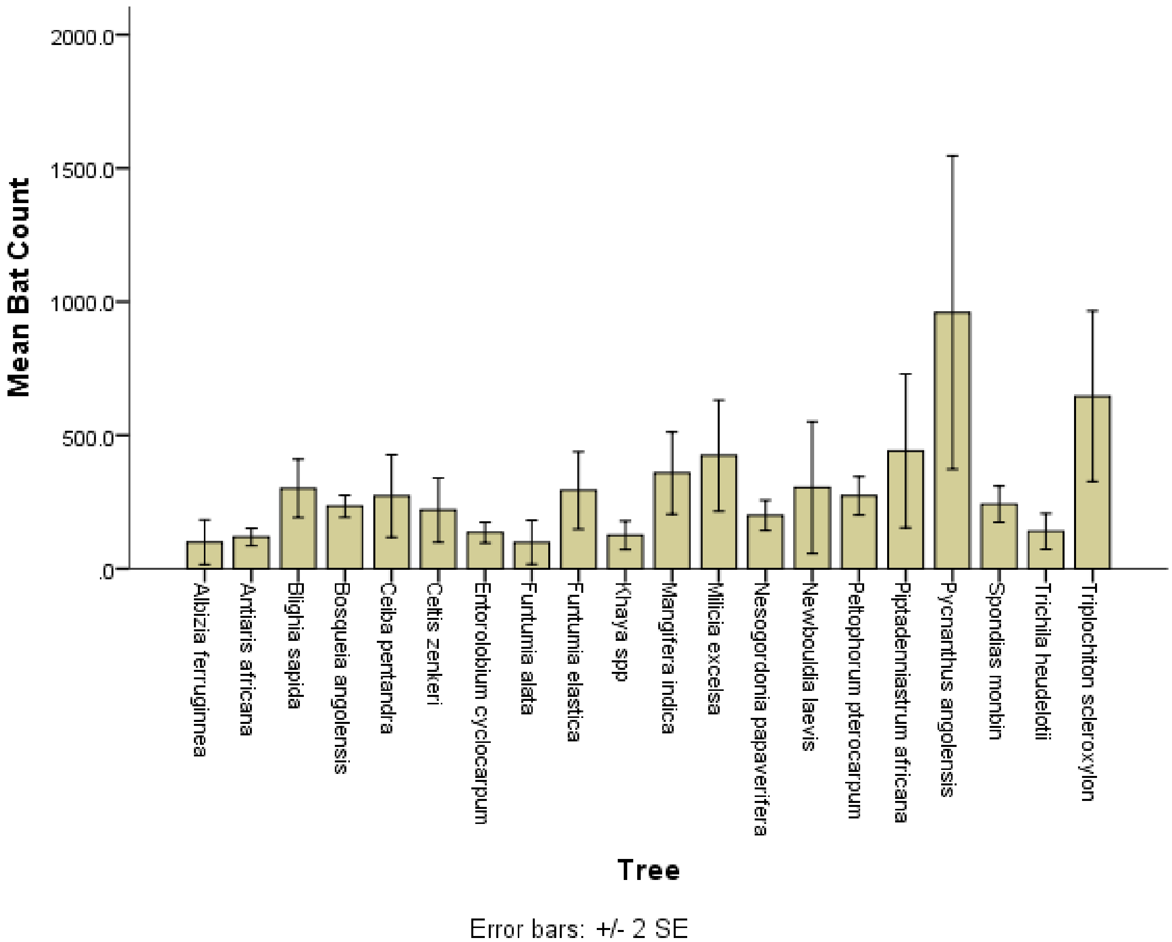

Figure 1: Mean Abundance of bats on the roost trees species

Table 2: Test of Homogeneity of Variances of Roost Trees Characteristics

Trees characteristics	Levene Statistic	df1	df2	Sig.
Tree Height	9.564	19	216	.000
Canopy Cover	18.797	19	216	.000
Ground cover	11.415	19	216	.000
Circumference (DBH)	27.444	19	216	.000

Table 3: Non-parametric correlation (Spearman's rho)

Variable	r_s value	Df	Prob. value (p-value)	Decision
Tree height	.341**	236	.000	Sig.
Canopy cover	.069	236	.289	Not Sig.
Ground cover	.082	236	.211	Not Sig.
Circumference (DBH)	1.000	236	-	Inconclusive

Table 4: Regression table

R	R Square	Adjusted R Square	Std. Error of the Estimate
.404[a]	.164	.142	377.2960

Coefficients

Model	**B**	**Std. Error**	**T**	**Sig.**
(Constant)	224.404	105.485	2.127	.034
Tree Height	-4.900	2.780	-1.763	.079
Canopy Cover	-3.200	1.071	-2.987	.003
Ground Cover	.625	1.026	.609	.543
F-stat			7.461	.000[b]

a. Dependent Variable: Bat Count
b. Predictors: (Constant), Tree height, Canopy Cover, Ground cover.

Roost Trees Characteristics

Tree height, canopy cover, ground cover and circumference at breast height of the roost trees species were estimated. Normality tests were carried out on data and Levene test of homogeneity of variance assumption were violated for all the roost trees characteristics ($p < .05$). Therefore, non-parametric correlation (spearman's rho) was used and we report a positive association between the mean height of the roost trees and bats abundance (r_s (236) = .341) which are statistically significant (p = .000), a positive association between the canopy cover of roost trees and bats abundance have (r_s(236) = .069), which were statistically insignificant (p = .289), a positive association between the ground cover of roost tress and bats abundance (r_s(236) = .082), which were not statistically significant (p = .211) and a positive association between mean circumference at breast height of the roost tree species (r_s (236) = 1.000) (see Table 2 and 3).

Regression Analysis on Bat count and roost characteristics

We report a negative relationship between bat abundance and tree height (B = -4.900), abundance and canopy cover (B = -3.200) but a positive relationship between abundance and ground cover (B = 0.625). Bat abundance changed inversely with tree height and canopy cover but changed directly with ground cover. Canopy cover of roost trees was significant in predicting bat abundance ($p < .05$) however, tree height and ground cover did not significantly predict abundance of bats on tree species ($p > .05$). Roosts characteristics were suitable in predicting bats abundance. F-stat 74.61 (.000), R-square = 16.4% and Adjusted R-square = 14.2% (see Table 4).

Plant species identified from fecal and ejecta of *Eidolon helvum* African straw-coloured fruits bats from Iwo (Osun State) and university of Ibadan (Oyo State) in the selected sites

From the fecal and ejecta of bats collected from Iwo roosting sites, seedlings propagated revealed that *Eidolon helvum* fed on *Ficus mucuso* (Forest Sycomore Fig), *Ficus exasperata* (Sandpaper fig), *Psidium guajava* (Guava), *Ficus polita* (Heart leaved fig) and *Ficus lutea* (Giant leaved fig). The seedlings germinated from ejecta and fecal collected from University of Ibadan were *Psidium guajava* (guava) and *Carica papaya* (pawpaw).

Physical observations of ejecta showed presence of remains of fig fruit which included *Ficus mucuso* (Forest Sycamore Fig), *Ficus exasperata* (Sandpaper fig) and *Ficus polita* (Heart leaved fig).

DISCUSSION

Eidolon helvum populations still use the environs of the University of Ibadan to roost. Some myth in the southwestern axis of Nigeria among some Yoruba’s defer the presence of this peculiar species as a mark of peaceful coexistence. There have been attempts in the recent past to remove trees from a second roost in the University. The response was abandonment of the roost; however, they are reported to be very much dedicated to roost sites once chosen. During this study the *E. helvum* were completely absent from the second roost, however during the preparation of this manuscript (May 2021) *E. helvum* have been noted to return to the abandoned roost. Continuous monitoring of roost population, characteristics and plants dispersed give a measure of environmental health in the face of current zoonosis attached to large wildlife populations in close proximity to human habitations. The trees monitored in this report have not been disturbed for decades, however the management of the University has now marked some of these trees to be cut down. Will this notable roost of *E. helvum* also abandon roost, will they return or move out completely to the recolonized roost also once abandoned? What are the ecosystem services to be lost in the face of this abandonment? The fear and phobia oozing off from the current pandemic plaguing the globe, though refuted as originating from bats.

Monitoring of roosts have been carried out on *E. helvum* in Sunyani, Ghana by Agyei-ohhemeng (2015) who examined population, plants eaten and dispersed and roost tree morphology; Webala *et al*. (2014) on roost occupancy, roost site selection and diet of *E. helvum in* Western Kenyan. This is the second study to report on population estimates and roost site selection of *E. helvum* in University of Ibadan, Nigeria (Adeyanju *et al*., 2019). Adeyanju *et al*. (2019) reported that the population of *E. helvum* is largely fairly distributed in the sites and colonies find it suitable to roost in the area. This might be due to the nature of the site, where restriction was placed on hunting of fauna and illegal cutting of trees.

The preferred factor in the choice of *Triplochiton scleroxylon* and *Pycnanthus angolensis* as roost trees is not yet known but (we can relate it with tree height and tree girth (DBH), *etc*. as possible reason for choice); but according to Hodgkison *et al*. (2004), the abundance and predictability of food sources may possibly determine the density of fruit bats that an environment can support.

Findings from this study show that tree morphology of the roost trees had an effect on how colonies were spread in the study area. In addition, the abundance of bats on roost trees have a significant effect on canopy cover of tree species. Therefore, trees with larger number of bats were found to have lower canopy cover. The study carried out by Agyei-Ohemeng *et. al*. (2020) revealed that one of the greatest nuisances caused by African straw-coloured fruit bat is breaking of tree branches among others, they identified to be defoliating tree barks, covering the sky after roost and unwanted noise. A group of 100 bats on a branch add averagely 20 kg to the weight of the branch. This study show that tree height did not significantly determine the abundance of bats, as the tallest trees was observed to have the lowest bat counts. According to Webala *et al*. (2014) "tree size and height were not important factors for the choice of roosts for *E. helvum* in Kenya". However, we report that the girth size, mirrored by the Diameter at Breast Height of the tree species has a perfect positive relationship with bat abundance. According to Agyei-ohemeng (2015), his findings revealed that *E. helvum* selects and occupies all trees with larger basal area. *Funtumia elastic*a species were observed to have the largest percentage of ground cover among the roosting trees, although it had a low canopy cover and the mean height shorter than the average mean of overall roosting trees. *Albizia ferruginnea* were observed to possess the shortest height and few bats roosted on it (can be inferred directly that safety is a cogent reason for choosing taller trees). However, *Piptadenniastrum africana, Peltophorum pterocarpum, Ceiba pentandra, Mangifera indica* were observed to have the largest circumferences with mean (m) of 5.4, 4.2, 3.6 and 3.3 respectively, and noted to be above the total average of the tree diameter found in the site. The average diameters of the two trees (*Pycnanthus angolensis* and *Triplochiton scleroxylon*) with the highest number of bat count have a similar mean diameter which is slightly above the total mean diameter. Therefore, the circumference of trees did not strongly predict bat abundance.

Fecal droppings of *Eidolon helvum* collected and planted from Iwo and University of Ibadan showed that bats fed on fruits and therefore helped in dispersal of seedlings that fall under the genus "*Ficus*" as plants that grew from the feacal samples included "*Ficus mucuso, Ficus polita, Ficus exasperata* and F*icus lutea*". Other seeds germinated from the fecal and through direct observation are fruits eaten by man which includes guava (*Psidium guajava*) and pawpaw (*Carica papaya*). According to Webala *et al*., (2012), *E. helvum* helped to disperse seeds of 32 plant species belonging to 17 families, including economically important fruit trees in western Kenya that provide their main diet. The common guava (*Psidium guajava*) appeared to be the commonest in the seed traps but this was probably because of the visibility of its large-sized seeds. C*arica papaya* and guava found mostly in any forest or abandoned land/field in South West are dispersed by bats and which tends to germinate over a period of time. These ecosystem services are offered freely, though very often overlooked by our urge to transform and increase control over our environments through landscaping fondly known as urbanization

CONCLUSIONS AND RECOMMENDATION

Our study concludes that viable populations of *E. helvum* are present in University of Ibadan Vice Chancellor Lodge. The relatively undisturbed tree network has preserved the roost for many decades and therefore disturbance of the trees (via removal) will only result in a temporary displacement of the population. The abundance of trees at the VC lodge in University of Ibadan is attributed to prohibition and restrictions placed on illegal hunting of flora and fauna. The number of bats roosting on a tree significantly affect the canopy cover of the tree in the long run while other roost trees characteristics were significant determiners in estimating bat abundance on a roost tree.

Although the choice of indigenous trees such as *Triplochiton scleroxylon* and *Pycnanthus angolensis* as roost trees with highest observed numbers of bats in this study cannot be attributed to height or girth size alone, social factors could be alternative options future studies will need to measure in addition to habitat parameters.

African straw-coloured fruits bats helps in the dispersal of seedlings commonly of the genus "*Ficu*s" and some seed fruits eaten by man such guava and pawpaw. Considering the economic importance of *E. helvum* in the dispersal of useful seedlings and in pollination, it is essential that regulations are put into place to mitigate against the illegal exploitation of both bats and trees roosts especially in area that allow over-exploitation of flora and fauna.

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