RENEWABLE 2025

FACULTY OF RENEWABLE NATURAL RESOURCES
UNIVERSITY OF IBADAN
HYBRID CONFERENCE

IN CONJUNCTION WITH
POSTGRADUATE COLLEGE, UNIVERSITY OF IBADAN

RENEWABLE NATURAL RESOURCES MANAGEMENT AND USE :

A PATH TO SUSTAINABLE DEVELOPMENT

1ST BANK BUILDING,
Faculty of Agriculture, University of Ibadan

16TH-20TH JUNE, 2025

KEYNOTE SPEAKER : PROF. LABODE POPOOLA
Professor of Forest Economics & Sustainable Development.
Executive Secretary, African Forest Forum

PROCEEDINGS OF THE 1ST FACULTY OF RENEWABLE NATURAL RESOURCES, UNIVERSITY OF IBADAN CONFERENCE

EDITORS:
Akinyele, A. O., Omitoyin, S. A., Ige, P. O., Coker, O. M., Fasoro, O. A. & Ajiboye, A. O.

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Held at the University of Ibadan, Ibadan, Oyo State, Nigeria
16 – 20 June, 2025

Editors
Akinyele, A.O., Omitoyin, S.A., Ige, P.P., Coker, O.M., Fasoro, O.A., and Ajiboye, A.O.

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**FACULTY OF RENEWABLE NATURAL RESOURCES,
UNIVERSITY OF IBADAN, IBADAN, OYO STATE NIGERIA**
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Correct citation of this proceeding:

Omole, A. O; Azeez, I. O; Olaifa, F and Ojo, S. O. (2025). Strategic conservation of renewable natural resources in Nigeria. In Akinyele, A. O; Omitoyin, S. A; Ige, P. O; Coker, O. M; Fasoro, O. A and Ajiboye, A. O (Eds), *Renewable Natural Resources Management and Use: A path to sustainable development*: Proceedings of the 1st Faculty of Renewable Natural Resources, University of Ibadan Conference, 16-20 June, 2025, 1 – 27pp. ISBN: 978-978-697-875-8

PREFACE

It is with great pleasure that I present the official proceedings of the First Faculty of Renewable Natural Resources, University of Ibadan Hybrid Conference (RENEWABLE 2025) with the theme **"RENEWABLE NATURAL RESOURCES MANAGEMENT AND USE: A PATH TO SUSTAINABLE DEVELOPMENT."**

This is a compilation of well thought out research findings of a landmark gathering of visionaries, researchers, and industry leaders dedicated to shaping the future of sustainable renewable natural resources. As the world intensifies efforts toward sustaining renewable natural resources leading to ahealthier ecosystem, this conference serves as a unique platform for exchanging groundbreaking research, innovative / adaptive technologies, and bold policy strategies.

Throughout this compilation, you will find insightful discussions and transformative ideas covering the realms of Blue Economy and Coastal Resources Management, Circular Economy, Climate change, Environmental Protection and Recovery , Governance and Policies, Natural Resources Management (Aquaculture, Fisheries, Forest, Wildlife), Resource Saving and Management, Ecosystem protection, Water Conservation and Natural Disaster prevention, Sustainability, Society and Education, Sustainability driven innovation and emerging renewable technologies. These contributions is a reflection of a collective commitment to addressing the pressing challenges of climate change and its impact, environmental degradation, and irrational resource utilisation that could drive a greener tomorrow.

Renewable 2025 symbolises the spirit of collaboration, creativity and innovation. It is our hope that the knowledge shared here will stimulate continued progress and meaningful impact in the journey toward a sustainable world with rational utilisation of Renewable Natural Resources.

Our sincere appreciation goes to all authors, reviewers, organizers, and participants whose dedication, commitment and expertise have made this conference a huge success.

Let these proceedings serve as a beacon for innovation, guiding the way toward a more renewable and sustainable ecosystem.

Thank you.

Dr Siyanbola Omitoyin
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- Provision of trained guides with in-depth knowledge of local birdlife and habitats to enhance the tourist experience will greatly be of immense help. Highlighting IBAs as a key tourism asset and promote them through targeted marketing campaigns.
- Finally, continued monitoring of bird populations and habitat conditions within IBAs to ensure their long-term viability and attract researchers.

REFERENCES

Adesiyan, J. K., & Garba, S. (2018). Bird census and survey techniques. In *Bird Ecology and Conservation: A Handbook of Techniques* (pp. 17-55). Cambridge University Press.

Agraveas, P. D., Collins-Kreiner, N., Malkinson, D., Labinger, Z., & Shtainvarz, R. (2019). Are birders good for birds? Bird conservation through tourism management in the Hula Valley, Israel. *Tourism Management*, *38*, 31-42.

Anderson, S. B. (2016). What inspires birders to migrate South towards Africa? A quantitative measure of international avitourist motivation. *Southern African Business Review*, *17*(1), 128-167.

Bernardon, B. G., & Nassar, P. M. (2017). Birdwatching in the Mamiraua Lake as an appeal to ecotourists/birdwatchers. *UAKARI*, *8*(2), 49-64.

BirdLife Int'l. (2018). *Important Bird Areas are recognized internationally as critical sites for bird conservation*.

BirdLife International. (2012). *Ethical Birding Guidelines*. Retrieved April 15, 2025, from http://www.birdlife.org.au/documents/POL-Ethical-Birding-Guidelines.pdf

BirdLife International. (2013). *Datazone Species Search*. Retrieved April 15, 2025, from http://www.birdlife.org/datazone/species/search

Buckley, R. C. (2004). *Environmental Impacts of Ecotourism*. CAB International.

Bucknor Dickie, I., Hughes, J., & Esteban, A. (2020). *Watched like never before the local economic benefits of spectacular bird species*. RSPB.

Che, D. (2003). Guided birding tours: An examination of the market, important tour parameters, and participant demographics. In J. J. Murdy (Ed.), *Proceedings of the 2003 Northeastern Recreation Research Symposium* (pp. 194-202). USDA Forest Service.

Christopher, Y. K. (2019). The popularity of birding is still growing. *Birding*, *34*(476), 54-61.

Collins. (2011). *Ethic and science of bird call playback*. Retrieved April 15, 2025, from http://www.kolkatabirds.com/callplayback.htm

Davidson, J. L. (2021). Group living in the Black-breasted Wood-quail and the use of playbacks as a survey technique. *The Condor*, *108*(1), 107-119.

Dmytry, J. P. (2014). Golden Wings. *American Demographics*, *18*(12), 47-49.

Edwards. (2014). Sustainable tourism practices are essential for mitigating the potential negative impacts of visitors on sensitive habitats. *International Journal of Anthropogenic Studies*, *23*(8), 229-238.

Esteves, R. K., Burger, J., Gochfeld, M., & Niles, L. J. (2011). Ecotourism and birds in coastal Northern Ireland Jersey: Contrasting responses of birds, tourists, and managers. *Environmental Conservation*, *22*(1), 345.

Farinloye, K., Oseni, T., Olawoyin, M., Fashola, K., & Isaac, A. (2025). An assessment of socio-economic and environmental sustainability of tourism management in the UK airline industry. *World Journal of Advanced Research and Reviews*, *25*(03), 2373-2378.

Fredrick, T. L. (2018). *Sustainable financing of protected areas: A global review of challenges and options*. IUCN.

Gadrill, D. U., Eubanks, T., Kerlinger, P., & Payne, R. H. (2013). Avitourism in England. *Research and analysis report. Newcastle Journal of birding, 7*(3), 11-117.

Gallagher, A. J., & Hammerschlag, N. (2011). Global currency: The distribution, frequency, and economic value of BIRD ecotourism. *Current Issues in Tourism*, *14*, 797-812.

Halloway, F. G. (2017). *Anoraks to zitting cisticola – a whole lot of stuff about birdwatching*. Allen & Unwin.

Hubert, P. A. (2019). Ornithophilia: Thoughts on geography in birding. *The Geographical Review*, *100*(2), 139-151.

UNIVERSITY OF IBADAN LIBRARY

Jason, E. H. (2014). *Financial sustainability of protected areas in Latin America and the Caribbean: Investment policy guideline*. United Nations Development Programme (UNDP) and The Nature Conservancy (TNC).
Keyes, W. J. (2013). Wildlife-based recreation as economic windfall: A rhetorical analysis of public discourse on birding. *Applied Environmental Education and Communication*, *9*(4), 224-232.
Khan, A. F. (2012). Research priorities in park tourism. *Journal of Sustainable Tourism*, *22*(4), 528-549.
Kirk, B.V., (2011). Planning and development of community-based tourism: Bird watching destinations. In S. Richardson, L. Fredline, A. Patiar, & M. Ternel (Eds.), *Proceedings of the 18th Annual CAUTHE Conference* (on Disc). Griffith University.
Newsome, F. L., Cole, J. S., & Scott, D. (2012). Segmenting participation in wildlife watching: A comparison of casual wildlife watchers and serious birders. *Human Dimensions of Wildlife*, *4*(4), 44-61.
Regina, A. B. (2015). *Principles of Birding Ethics*. Last accessed April 15, 2014, from http://www.aba.org/about/ethics.html
Stevenson, G.H,. (2021). Birdwatching, twitching and tourism: towards an Australian perspective. *Australian Geographer*, *40*(2), 203-217.
Tinsdale, S. M. (2018). *Recreation specialization and reports of potential impact behaviors among birders attending birding festivals* (Unpublished master's thesis). University of Florida.
Vahedi, N., Farinloye, K., Khan, S., & Kumar, R. (2025). Relationship between environmentally sustainable project management and financial profitability ratios. *International Journal of Science and Research Archive*, *14*(1), 1631-1634
William, T. B., Hasley, M. K., Booth, J. E., Gaston, K. J., Evans, K. L., & Arnsworth, P. R. (2015). The value of species rarity in biodiversity recreation: A birdwatching example. *Biological Conservation*, *144*, 2728-2732.
Williams, R. M. (2019). Agreement of the international avitourist market to ecotourism principles: A South African development perspective. *African Journal of Business Management*, *7*(30), 3013-3021.
World Bank. (2020). Dataset: World Development Indicators (WDI): Country official statistics, National Statistical Organizations Ecotourism estimates reports. (WB-45898)
Yidall, H. S., Biggs, D., Turpie, J., Fabricius, C., & Spenceley, A. (2018). The value of avitourism for conservation and job creation – An analysis from South Africa. *Conservation and Society*, *9*(1), 80-90.

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Roost Characteristics, Dietary Composition and Echolocation of *Hipposideros ruber* (Noack's Round Leaf Bat) from a Roost at Obafemi Awolowo University

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ABSTRACT

Insectivorous bats play key roles in maintaining ecosystem balance in different ecological setups, relying on echolocation to navigate obstacles, escape predators and obtain food and mate. Understanding Insectivorous bats and the roles played in altered landscapes are important to food security and one health. We assessed Hipposideros ruber roost characteristics (sex ratio, morphometrics), diet and echolocation at a roost in Obafemi Awolowo University, Nigeria. Twenty bats were captured using mist nets following standard protocol, they were then extracted and placed in cotton bags to allow for release of faecal pellets. Ten pellets were collected from each bat and stored in 70% ethanol for identification of insect diet using a stereomicroscope. Blatteria was dominant in the diet followed by Lepidoptera. Hipposideros ruber echolocation ranged from 109-111 kHz. Insect order consumed varied by sex and contributes to controlling important pests of agriculture (livestock and crops) and disease vectors. Conservation of Hipposideros ruber roost sites will ensure continuous supply of biological control services required for food security and sustainable agriculture.

***Keywords**: Biological Control, Hipposideros ruber, Acoustics, Nocturnal, Small Mammal*

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INTRODUCTION

Insectivorous bats are widely distributed and utilize an array of habitats while providing ecosystem services (Aziz *et al*., 2021, Tuneu-Corral *et al.* 2023). The nocturnal habit of bat species has caused the taxa to develop feeding strategies for nocturnal prey such as arthropods, small sized rodents, aves, fish and amphibians. Insectivorous bat species have been reported to be economically valuable as they play key roles as pest control agents (Aizpurua *et al*., 2018; Puig-Montserrat *et al*., 2023). Several studies report important interactions between chiropterans (bats) and insect diet or prey through faecal analysis (Long and Kurta, 2014). There are suggestions that clarifying roles played by bats as biological pest control agents will facilitate building effective and sustainable pest control strategies through a process known as "integrated pest management", thereby reducing application of pesticides to minimal levels and turning the faeces into fertilizer (Put *et al*., 2018). Insect pests can destroy 30-50% of any production of cotton today (Chen *et al*., 2020) by direct destruction or disease transmission. Worldwide, Cotton alone has grown on over thirty-four million hectares and therefore if the ecosystem services provided by bats are conserved, benefits will be derived by doing it sustainably.

Several studies have reported how different bat species play key roles in insect pest regulation by controlling agricultural pests. Examples of bat species reported include *Lasiurus borealis* and pest of peacan (Clare *et al*., 2009, Braun de Torrez *et al.,* 2019); *Tadarida brasiliensis* and pest of maize (Mc Craken *et al.*, 2012). *Epitecus fuscus* controls insect pest in apple orchards and soyabeans (Long and Kurta, 2014; Put *et al.*, 2018). *Chaerephon plicatus* (Nguyen *et al*., 2019) and *Scotophilus kuhlii* in Thailand have been identified to control insect pests in rice paddy helping high rice yields (Wagner *et al*., 2014).

Bats have been reported to hold significant roles in the reduction of insect herbivores in cocoa plantation (Maas *et al*., 2013). In coffee plantation in Mexico and Costa Rica, bats have been reported to help in the reduction of insect density. The role of bats in reducing insect population belonging to the cotton boll worms have resulted in cotton yields that amounts to over 700,000 USD every year in the southern states of the United States of America. However, the introduction of *Bacillus thuringiensis* cotton altered genetically to release its own pesticide and deterring certain important crop pest (López-Hoffman *et al*. 2014), has resulted in the decline in the contribution of the Mexican free-tailed bats in terms of ecosystem services due to biological control by 19 million U.S. dollars (López-Hoffman *et al*. 2014). Currently the pesticide transgenically induced resistance is waning due to resistance developed by insect pest and this means the natural predator contribution will bounce back.

A total 1123 species of insectivorous bats classed in 19 families are described (IUCN, 2021) and yet only sparse information is available as regards their insectivorous diets. The challenge is that intensification in land use changes will favor species with a wider variety of dietary prey compared to the specialist group with fewer prey diet choice. If the current rate of land use change is unchecked, there will be a large but negative effect on food security as many natural biological control agents will be affected leading to increasing loss in agricultural outputs because of intensive pest control and associated anthropogenic negative impacts. Therefore, sustainable pesticide alternatives are being sought (Malinga and Laing, 2022).

Bat population declines have been shown to affect the food security of many local people negatively (Wagner *et al*., 2014). This has resulted in lower harvest quality vegetables, reducing the value of agricultural products due to insect damage. Agricultural products are then sold locally as they do not meet standards for exportation. Reduction in the number of bat species would lead to reduction in food availability (Wagner *et al*., 2014). Several African representatives in the taxa Hipposideros and the interactions between the species within the taxa are poorly understood (Monadjem *et al*., 2013, Webala *et al*. 2019).

Bats navigate the night via echolocation and although echolocations have been reported for *Hipposideros* spp across Africa (Guillen *et al*. 2000) very little is known about bat echolocations for Nigeria. Calls for *H. caffer* a sister spp to *H. ruber* are much higher (154-157 kHz) as reported for Heller (1992). The *H. Caffer* is predominantly a savanna species, while *H. ruber* is a forest species but both occur sympatrically (Hayman and Hill, 1971; Happold 1987). Pye 1972 reported *H. ruber* of 131-133 kHz and fore-arm (47-48.5 mm) for Shagamu, Ogun state Nigeria. Heller (1992) suggested the species with lower frequency possibly belonged to a different species. Happold (1987) stated that *H. caffer* and *H.ruber* could not be distinguished by forearm length but only by skull size and shape.

Ecosystem services offered by insectivorous bats in different landscapes cannot be fully quantified, especially in agricultural landscapes (López-Hoffman *et al*. 2014). There is therefore a need to have an in-depth understanding of the role's secondary consumers as bats play, especially in areas experiencing rapid land use changes. Also, there are still gaps in the distribution (Monadjem *et al*. 2024) and therefore foraging ecology gaps of many bat species in Africa. This study assesses some aspects of the roosting ecology, insect prey in diets and echolocation of *Hipposideros spp* in a roost at the Obafemi Awololowo University, Southwestern Nigeria.

MATERIALS AND METHODS

Study Population

The Center for Energy Research and Development is located within Obafemi Awolowo University (OAU), Ile-Ife found within the latitude of 7.50177 and 7.52076 N and longitude 4.51569 and 4.53031ºE (Figure 1). It experiences rainfall between April to October with total

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yearly rainfall ranging between 1,000-1,500 mm and a dry season between November and March (Konwea *et al*. 2023). The CERD is a roost site for *Hipposideros spp*.

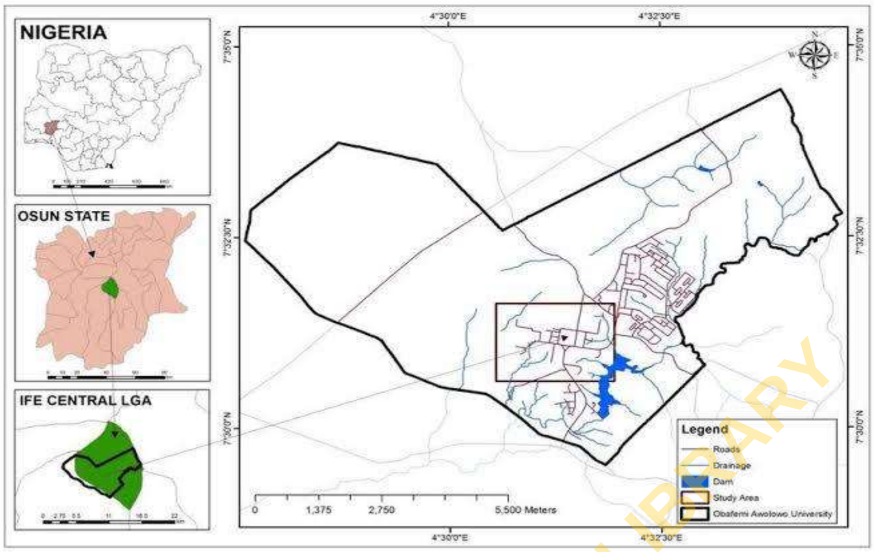

Figure 1: Obafemi Awolowo University Campus, Ile-Ife, Osun State
Source: Popoola *et al*. (2016)

Twenty individuals from the *Hipposideros spp* roost were captured using ground mist net at the CERD, OAU (Figure 1). The roost was allowed to disperse and feed for the night and then a mist net was set inside the roost to trap returning individuals, trapping continued until the first twenty individuals had been extracted and then nets were closed. The captured individuals were then placed in a cotton bag and transported to the sampling station.

Morphological characteristics (weight to 1 g, forearm length -to 0.1 mm, tail length-to 1 mm, tibia length- to 1 mm and ear length -to 0.1 mm) were collected with the aid of pesola spring balance, rulers and veneer calipers. All individuals were identified as *Hipposidros ruber* using field key (Happold and Happold., 2013). Each individual was tagged so that faecal droppings and morphological parameters matched. All extracted bats were placed in a holding bag for an hour to allow for fecal collection and 10 fecal droppings were collected from each bat to ensure a representative sample for diet analysis. The bats were released after morphological characteristics were taken and the fecal samples were collected, and the fecal pellets collected were preserved in vials with 70% ethanol.

Echolocation Recording
With the aid of an acoustic recording instrument Echometer Touch 2 Pro and SM4FS bat detectors, echolocation of *Hipposideros ruber* were recorded upon hand release of each individual. Ultrasonic calls were analyzed using Kaleidoscope Pro from Wildlife acoustics. A typical hipposiderid echolocation consists first of a short (6-9 ms) constant frequency segment and secondly, a steep descending frequency modulated swoop (Guillen *et al*., 2000).

Faecal Analysis
Five pellets were randomly selected from each individual for diet investigation using the stereomicroscope. Following standard procedures (Whitaker and Karatas, 2009), prey fragments were identified to Order level based on Castner (2002). Faecal samples were analyzed using a dissecting microscope to identify insect exoskeletons. Each fecal sample

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"pellet" was carefully placed on a petri-dish and moistened with a few drops of distilled water to soften the droppings, making it easier to separate the insect parts. Using a dissecting microscope of magnification 20x, the softened fecal matter was examined. The microscope allowed for the identification of insect exoskeleton fragments based on their morphological characteristics. Insect exoskeletons were identified by comparing the observed fragments with reference images and keys of known insect parts. This included identifying specific features such as wing scales, leg segments, and antennae, which are indicative of particular insect orders or families (Whitaker and Karatas, 2009).

Data Analysis

Descriptive statistics such as bar charts was used to display the diet of *Hipposideros ruber,* Tables were used to display diet across order and sex. Echolocation frequency characteristics were also presented in tables. While T-test was used to compare differences in morphological parameters between sex.

RESULTS

Morphological parameters in *Hipposideros* spp

Body weight was significantly different between sex (t=1.163, df=84, F=15.1=491, P<0.001; Table 1), The forearm length (FA) was not significantly different between sex (t=1.807, df=84, F=3.531). Males had significantly longer ears than females (t=3.421, df=84, F=15.351, P<0.001). Females' possessed significantly longer tarsus than males (t=797, df=84, F=0.954, P<0.01) and Tail Length did not show significant variation among sex (t=-0.463, df=84, F=17.012, P<0.001).

Insectivorous diet

Table 2 reveals the following distribution of insect parts. The most frequently observed insect part was the wing (n = 37, 43.0%), followed by the antenna (n = 23, 26.7%) and leg (n = 21, 24.4%). Blattaria were the most prevalent in the female samples, accounting for 41.2%, while Diptera and Odonata made up 17.6% and 17.6% of occurrence in female samples. This was followed by Lepidoptera accounting for 11.8% while Coleoptera and Hymenoptera accounted for 11.6% and 5.9% of the female samples (Table 3). Blattaria accounted for 36.2% of the male faecal pellets, making them the most common, Coleoptera was represented by 11.6% while Diptera and Odonata each made up 8.7%. Isoptera, Orthoptera, Ephemeroptera, and Hymenoptera collectively accounted for 10%.

Echolocation

The analysis showed that the calls covered a broad range of frequencies. They ranged between 109-111 kHz and dropped to about 74 kHz at the end. The central power frequencies were approximately 105 kHz. The average intensity was around -54 dB, with the lowest intensity being -77 dB and the highest at -28 dB.

Table 1: Group statistics for morphological characteristics of *Hipposideros ruber*

	Sex	N	Mean	Std. Deviation	Std. Error Mean	Assumptions on variances	F	Sig. (1-tailed)	Sig. (2-tailed)	t	df
Weight	Male	69	9.75	0.53	0.06	Equal	15.49	0.00	0.25	1.16	84.0

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	Female	17	9.53	1.22	0.29	Not Equal			0.468	0.742	17.5
FA	Male	69	52.15	2.05	0.24	Equal	3.53	0.06	0.074	1.807	84.0
	Female	17	51.18	1.63	0.39	Not Equal			0.046	2.078	29.9
Ear length	Male	69	14.81	2.28	0.27	Equal	15.35	0.00	0.001	3.421	84.0
	Female	17	12.82	1.42	0.34	Not Equal			0	4.503	39.0
Tarsus Length	Male	69	21.74	1.1	0.13	Equal	0.00	0.95	0	-4.797	84.0
	Female	17	23.15	0.98	0.23	Not Equal			0	-5.165	27.0
Tail length	Male	69	33.19	1.9	0.22	Equal	17.01	0.00	0.645	-0.463	84.0
	Female	17	33.41	1.12	0.27	Not Equal			0.533	-0.628	41.8

Table 2: Frequency of insect body parts in *Hipposideros ruber* pellet

	Frequency	Percent
Abdomen	2	2.3
Antenna	23	26.7
Body	1	1.2
Leg	21	24.4
Mouthpart	1	1.2
Thorax	1	1.2
Wing	37	43.0
Total	86	100.0

Table 3: Frequency and percentage occurrence of insect orders

Sex		Frequency	Percent	Cumulative
Female	Blattaria	7	41.2	41.2
	Coleoptera	1	5.9	47.1
	Diptera	3	17.6	64.7
	Hymenoptera	1	5.9	70.6
	Lepidoptera	2	11.8	82.4
	Odonota	3	17.6	100.0
	Total	17	100.0	
Male	Blattaria	25	36.2	36.2
	Coleoptera	8	11.6	47.8
	Diptera	6	8.7	56.5
	Ephemenoptera	1	1.4	58.0
	Hymenoptera	1	1.4	59.4
	Isoptera	3	4.3	63.8
	Odonota	6	8.7	72.5
	Orthoptera	2	2.9	75.4
	Unkwnown	17	24.6	100.0
	Total	69	100.0	

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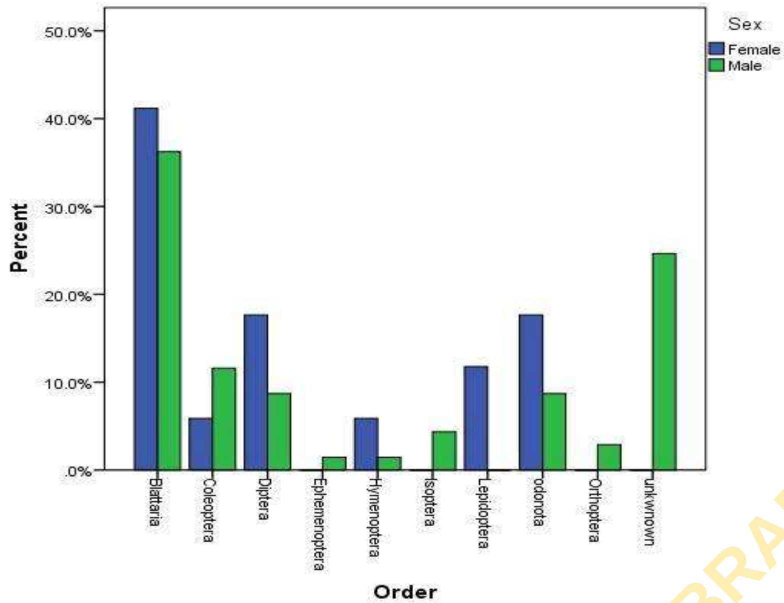

Figure 2: Occurrence of insect orders in *Hipposideros ruber*

Table 3: Acoustic Characteristics of *Hipposideros ruber*

Tstart (s)	Tend (s)	Fstart (kHz)	Fend (kHz)	Fpmin (kHz)	Fpmax (kHz)	Fpmean (kHz)	Fppeak (kHz)	dBmin	dBmax	dBmean
3.25	4.56	70.00	135.00	99.61	111.33	104.82	105.08	-67.93	-28.89	-43.77
0.05	1.00	68.75	132.50	101.56	109.38	98.77	105.73	-68.48	-52.27	-61.62
1.14	2.85	77.50	121.25	91.80	0.00	104.22	104.89	-70.44	-40.48	-54.53
0.49	1.50	76.80	119.04	102.00	111.00	106.49	106.96	-76.98	-51.74	-60.2
1.56	2.07	77.44	115.84	91.80	0.00	105.11	105.18	-71.22	-34.19	-44.26
0.84	1.35	77.44	118.40	99.61	109.38	104.21	104.23	-70.58	-40.37	-50.59

Note: T means Time and F means Frequency

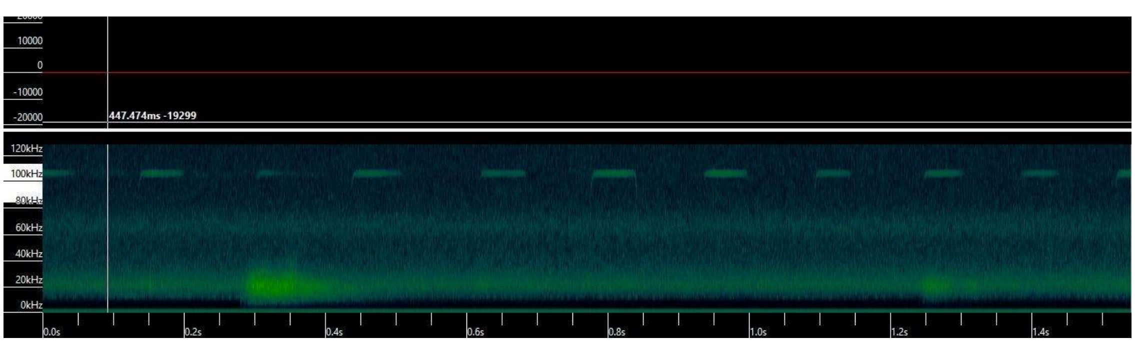

Plate 1. *Hipposideros ruber* echolocation call spectogram.

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DISCUSSION

The Peak frequency for *H. ruber* in our study ranged from 120-122 kHz which seems significantly lower (a difference of 10 kHz) than that reported for *H. ruber* (132-138 kHz) for individuals reported from Irangi, Kivu province, Zaire) or 132.6-134.5 kHz with very short pulses (Webela *et al*. 2019). Dietary analysis from fecal samples indicates that *H. ruber* primarily consumed Blattaria (cockroaches), Diptera (flies), and Lepidoptera (moths). A sex-based dietary variation was observed, with males exhibiting a broader range of insect orders compared to females.

Blattaria (cockroaches) represented 41.2% of prey items in females and 36.2% in males, suggesting that *H. ruber* helps manage urban pest populations. Cockroaches are recognized as vectors of bacterial and viral pathogens, presenting considerable health threats to both human and livestock populations (Donkor, 2020). The steady occurrence of Diptera (flies) in the diet, with 17.6% in females and 8.7% in males, emphasizes *H. ruber's* importance in vector management, given that flies are recognized for transmitting diseases like malaria, dengue fever, and typhoid (Cohen *et al.,* 2020). Eating Leopidoptera (moths) and Coleoptera (beetle), *H. ruber* agricultural settings can be an important insect management tool. Coleoptera made 5.9% of females' diets and 11.6% of males', in which insects such as root borers and veil are known with severe disadvantages for agriculture (Sophia, 2010). Lepidoptera, or moths, female bats make 11.8% of the diet, suggest that *H. ruber* feeds on active night agricultural insects such as bollworms and armyworm, which are quite low in crop yields in items such as cotton, maize and other main mainstay (Baroja *et al.,* 2019). Additionally, incorporating the Orthoptera (grasshoppers) and Isoptera (termites) of the diet indicates that *Hipposideros ruber* helps managing population that causes agricultural damage and deforestation (Zhu *et al.*, 2024). Various nutritional compositions of male and female bats can also reflect changes in nutritionasl requirements, especially for fertility females who may require high diet in nutrients and high diets in large prey like cockroaches and beetles (Adeyanju and Adeyanju 2018).

Diptera and Blattaria, which are found to be high in the diet of Hipposideros, consists of many insect species that especially cause nuisance to humans in urban and agricultural sites. This bat can serve as biological insect controllers and reduce the dependence on pesticides and other chemicals that negatively alter the ecosystem. In farming areas, the function of bats in controlling pests is important to improve crop production and reduce financial losses (Baroja *et al.*, 2019). Research has speculated that insect-eating bats contribute billions of dollars to pest management services every year, especially for crops such as rice, cotton and maize (Cohen *et al.*, 2020, López-Hoffman *et al*. 2014). By targeting beetles, moths and termites, *H. ruber* probably reduces the population density of important crop pests, reducing the dependence on chemical pesticides, which later supports biodiversity and human health *H. ruber*'s diet, like beetles, cockroaches suggest a benefit for public health benefits as insects consumed are important vectors of diseases.

CONCLUSION

Although natural roosting sites are being occupied by man through urban development, the *Hipposideros ruber* has high capability to adapt successfully in man-made structures which shows its ecological resilience and population stability. The faecal analysis of *H. ruber* offers an understanding of its ecological role in managing insect populations. A sex-based dietary variation was observed, with males exhibiting a broader range of insect orders compared to females. Diptera and Blattaria, which are found to be high in the diet of Hipposideros, consists of many insect species that especially cause nuisance to humans in urban and agricultural sites. The conservation of *Hipposideros ruber* roost sites needs integration of bat-friendly policies in urban planning and biodiversity management. Elimination of this insectivorous bat can have

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an adverse effect on the ecosystem balance, which can increase the insect population and increase the use of chemicals to control their population that affects the environment and then humans in turn. Echolocation analysis showed that *H. ruber* produces high-frequency calls ranging from 70 kHz to 135 kHz, with a peak frequency of 105 kHz. The recorded calls exhibited both constant-frequency (CF) and frequency-modulated (FM) components. The call range could be connected to the use of habitat as well as insect-pest or prey consumption. The continual change in landuse could impede the call structure thereby affecting the ability of bat species to feed and consequently a drastic decline in bat population. To maintain the bat's population, it is necessary to protect both artificial and natural roasting areas so that it can continue its ecological contribution to the environment.

REFERENCES

Adeyanju, T. E. and Adeyanju, A. T. (2018). Species richness and diets of bats from two sites in South-West, Nigeria. *EJESM*, 11(2): 215-230.

Aizpurua. O., BudinskI. I., Georgiakakis. P., Gopalakrishnan,.S., Ibañez. C., Mata. V., Rebelo, H., Russo, D., Szodoray-Parádi, F., and Zhelyazkova. V. (2018). Agriculture shapes the trophic niche of a bat preying on multiple pest arthropods across Europe: evidence from DNA metabarcoding. *Mol Ecol*, 27(3): 815- 825.

Aziz, S.A., McConkey, K.R., Tanalgo, K., Sritongchuay, T., Low, M.-R., Yong, J.Y., Mildenstein, T.L., Nuevo-Diego, C.E., Lim, V.-C. and Racey, P.A. (2021) The Critical Importance of Old World Fruit Bats for Healthy Ecosystems and Economies. *Frontiers in Ecology and Evolution* 9.

Baroja, U., Garin, I., Aihartza, J., Arrizabalaga-Escudero, A., Vallejo, N., Aldasoro, M., and Goiti, U. (2019). Pest consumption in a vineyard system by the lesser horseshoe bat (Rhinolophus hipposideros). *PloS One*, *14*(7), e0219265.

Braun D.E., Torrez E. C., Brown. V. A., MCcracken. G. F., and Kunz. T. H. (2019). Sympatric bat species prey opportunistically on a major moth pest of pecans. *Sustainability*, 11(22): 6365.

Castner, J. L (2002). Photographic Atlas of Entomology and Guide to Insect Identification Feline Press. 174 pp + 607 colour photos.

Chen P,. Xiao Q,. Zhang J,. et al. (2020). Occurrence prediction of cotton pests and diseases by bidirectional long short-term memory networks with climate and atmosphere circulation. *Comput Electron Agric*.176:105612.

Clare, E.L, Fraser, E.E., Braid, H. E., Fenton, M. B., Hebert, P. D. (2009). Species on the menu of a generalist predator, the eastern red bat (Lasiurus borealis): using a molecular approach to detect arthropod prey. *Mol Ecol*.18(11):2532-42.

Cohen, Y., Bar-David, S., Nielsen, M., Bohmann, K., and Korine, C. (2020). An appetite for pests: Synanthropic insectivorous bats exploit cotton pest irruptions and consume various deleterious arthropods. *Molecular Ecology*, *29*(6), 1185–1198.

Donkor E.S (2020). Cockroaches and Food-borne Pathogens. *Environ Health Insights*. Apr 30;14:1178630220913365.

Guillen, A., Juste B. J. and Ibanez C. (2000). Variation in the frequency of the echolocation call of *Hipposeros ruber* in the Gulf of Guinea: an exploration of the adaptive meaning of the constant frequency value in the rhinolophoid C.F bats. *J. Evol. Biol* 13:70-80.

Happold, DC.D. (1987). The mammals of Nigeria. Clarendon Press, Oxford.

Happold, D., and Happold, M. (2013). *Mammals of Africa (Volume 4: Chiroptera)*. Bloomsbury Publishing.

Hayman R.W. and Hill, J. E. (1971). Order Chiroptera. In: The mammals of Africa, an identification manual (Meester, J., ed.) – Smithsonian Institution, Washington.

Heller, K. (1992). The echolocation calls of *Hipposideros ruber* and *Hipposideros caffer*. Prague *Studies in Mammalogy*. Horaoek, I and Vohralik V. (Eds.) Charles Univs Press. PP 75-77

IUCN (2021, June 17). The IUCN Red List of Threatened Species. Version 2021-1. https://www.iucnredlist.org.

Konwea, C. I., Eziagor, F. C., Evurani, D. E. and Ajayi, O. (2023). Characterization and assessment of groundwater from Obafemi Awolowo University campus, southwestern Nigeria, Physics and Chemistry of the Earth, Parts A/B/C, Volume 129, :103354.

UNIVERSITY OF IBADAN LIBRARY

Long. B. L., and Kurta. A. (2014). Activity and diet of bats in conventional versus organic apple orchards in southern Michigan. *Can Field Nat*, 128(2): 158-164.
López-Hoffman L,. Wiederholt R., Sansone C., Bagstad K. J., Cryan P., Diffendorfer JE., Goldstein J., Lasharr K, Loomis J., McCracken G., Medellín R. A, Russell A, and Semmens D. (2014) Market forces and technological substitutes cause fluctuations in the value of bat pest-control services for cotton. *PLoS One* 9(2):e87912.
Maas B., Clough.Y., and Tscharntke. T. (2013). Bats and birds increase crop yield in tropical agroforestry landscapes. *Ecol Lett*, 16(12): 1480-1487.
Malinga L. N and Laing M. D. (2022). Efficacy of Biopesticides in the Management of the Cotton Bollworm, *Helicoverpa armigera* (Noctuidae), under Field Conditions. *Insects*. 2022;13(8):673.
MC Craken, G. F., Westbrook. J. K., Brown. V. A., Eldridge. M., Federico. P., and Kunz. T. H. (2012). Bats track and exploit changes in insect pest populations. *Plos One*, 7(8): e43839.
Monadjem, A., Richards, L., Taylor, P. J., Denys, C., Dower, A., Stoffberg, S. (2013). Diversity of Hipposideridae in the Mount Nimba massif, West Africa, and the Taxonomic Status of *Hipposideros lamottei*. *Acta Chiropterologica*, 15(2), 341-352.
Monadjem, A., Montauban, C., Webala, P.W., Laverty, T.M., Bakwo-Fils, W. M., Torrent, L., Tanshi, I., Kane, A., Rutrough, A. L., Waldien, D. L. and Taylor, P.J.. (2024). African bat database: curated data of occurrences, distributions and conservation metrics for sub-Saharan bats. *Sci Data* **11**, 1309
Nguyen. T. N., Ruangwiset. A., and Bumrungsri. S. (2019). Vertical stratification in foraging activity of Chaerephon plicatus (Molossidae, Chiroptera) in Central Thailand. *Mamm Biol*, 96: 1-6.
Popoola, O., Salami, A., and Adepoju, K. (2016). Assessment and inventory of palms in a plantation by template matching of unmanned aerial vehicle (UAV) image. *Journal of Scientific Research and Reports, 11*(2), 1–8.
Puig-Montserrat. X., Flaquer. C., Gómez-Aguilera. N., Burgas. A., Mas. M., Tuneu. C., Marquès. E., and López-Baucells. A. (2020). Bats actively prey on mosquitoes and other deleterious insects in rice paddies: potential impact on human health and agriculture. *Pest Manag Sci,* 76(11): 3759-3769.
Put. J. E., Mitchell. G. W., and Fahrig. L. (2018). Higher bat and prey abundance at organic than conventional soybean fields. *Biol Conserv*, 226: 177-185.
Pye, J.D. (1972). Bimodal distribution of constant frequencies in some hipposiderid bats (mammalia: Hipposderidae). *J. Zool., Lomdon* 166:323-335.
Sophia, E. (2010). Foraging behaviour of the microchiropteran bat, Hipposideros ater on chosen insect pests. *Journal of Biopesticides*, *3*, 68–73.
Tuneu-Corral C., Puig-Montserrat X., Riba-Bertolín D., Russo D., Rebelo H., Cabeza M., and López-Baucells A. (2023). Pest suppression by bats and management strategies to favour it: a global review. *Biol Rev Camb Philos Soc*. 98(5):1564-1582.
Wagner,T. C., darras, K., Bumrungsri, S., Tscharntke, T., and Klein. A.M. (2014). Bat pest control contributes to food security in Thailand. *Biol Conserv*, 171: 220-223.
Webala, P. W., Rydell, J., Dick, C. W., Musila, S. and Patterson B.D. (2019). Echolocation calls of high duty-cycle bats (Hipposideridae and Rhinonycteridae) from Kenya. *Journal of bat research and conservation* 12(1) 10-20.
Whitaker, J. O. and Karataş A. (2009). "Food and Feeding Habits of Some Bats from Turkey," *Acta Chiropterologica* 11(2), 393-403.
Zhu, D., Liu, Y., Gong, L., Si, M., Wang, Q., Feng, J., and Jiang, T. (2024). The consumption and diversity variation responses of agricultural pests and their dietary niche differentiation in insectivorous bats. *Animals: An Open Access Journal from MDPI*, *14*(5), 815.

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