https://dx.doi.org/10.4314/dujopas.v11i1b.24
ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 11 No. 1b March 2025*

Distribution, Species Composition and Biting Behaviour of Adult *Culex* Mosquitoes in Badeggi, Niger State, Nigeria

V. U. Odoh[1], C. J. Sodangi[2], I. K. Olayemi[2,4] , A. S. Musa[1] , S. S. Odoh[3], K. Tegeri[1], Onoja A.E.A[1].

[1]Biology Department,
Kogi State College of Education (Technical),
Mopa,
Nigeria.

[2]Department of Animal Biology,
Federal University of Technology,
Minna,
Nigeria.

[3]Environment and Climate Change Unit,
Value Chain Development Program,
Lokoja,
Kogi State,
Nigeria.

[4]Center for Genetic Engineering and Biotechnology,
Federal University of Technology,
Minna,
Nigeria.

Email: sodangichatjoseph@gmail.com

Abstract
An understanding of mosquito biting behavior is essential for effectively controlling mosquito populations and designing appropriate vector control strategies to prevent mosquito-borne diseases in communities. This study examines the distribution, species composition, and biting behavior of adult Culex *mosquitoes in Badeggi, Niger State, Nigeria. A total of 2,848 adult* Culex *mosquitoes were collected using baited CDC light traps from January to December 2020, excluding April, May, and June due to COVID-19 movement restrictions. CDC LT was assembled 1.5 metres above the floor level using a support, close to the legs of sleeping bait under a non-treated bed-net and collection cups were labelled (on hourly basis for collections between 1800 to 0600 hours) prior to collection. Morphological identification of the mosquitoes, based on a standard pictorial key, revealed five species:* Culex quinquefasciatus *(52%),* Culex salinarius *(24%),* Culex tritaeniorhynchus *(17%),* Culex restuans *(5%), and* Culex nigripalpus *(2%). Low biting activity was observed between 6–7 PM and 5–6 AM, with the peak biting period occurring between 7–9 PM. Biting behavior varied in terms of timing and location between January-March and November-December, but remained consistent during the months of July-October.* Culex quinquefasciatus *was identified as the predominant* Culex *species in the area. The understanding of mosquito species distribution and their active biting periods in this rural area is crucial for guiding the implementation of effective vector control measures.*

Author for Correspondence

Keywords: Species composition, Distribution, Biting behaviour, *Culex* mosquitoes, Badeggi

INTRODUCTION

Data on species distribution and biting patterns is crucial for developing effective mosquito control strategies in rural areas. Mosquitoes are slender, biting insects of the order Diptera, suborder Nematocera, and family Culicidae, characterized by their long antennae and a nearly global distribution, with the exception of Antarctica. This classification highlights their unique morphology and diverse habitat preferences. Their ability to adapt to various environments demonstrates their global resilience, although the extreme cold of Antarctica prevents their survival. This widespread distribution underscores their ecological importance and their critical role as vectors of disease.

Mosquitoes are significant transmitters of human pathogens, responsible for spreading diseases such as yellow fever (YFV), chikungunya virus (CHIKV), Zika virus (ZIKV), dengue virus (DENV), Rift Valley fever virus (RVFV), West Nile virus (WNV), as well as malaria and lymphatic filariasis. These diseases, predominantly affecting tropical regions, present substantial public health challenges to human populations (WHO, 2024). Research further emphasizes that mosquito activity patterns can vary greatly, even within the same geographical area, due to environmental and biological factors (Ebube *et al*., 2018).

Mosquito Biting Rate (MBR) refers to the density of mosquitoes actively engaging in biting behaviour, which plays a critical role in facilitating human-vector contact and, consequently, the transmission of vector-borne diseases. Mosquitoes exhibit variations in host preference, biting patterns, and circadian rhythms, which are significantly influenced by local weather conditions such as temperature, humidity, and rainfall. These environmental factors directly affect the abundance and activity of specific mosquito species. According to Eleanor and Ryan, (2023), differences in mosquito feeding patterns significantly influence disease transmission dynamics among various hosts across different seasons. Rapid ecological changes, driven by factors such as global warming, unplanned urbanization, deforestation, evolving human behaviours, and host availability, impact mosquito behaviour and enhance the transmission of vector-borne pathogens.

Culex mosquitoes are of significant public and veterinary health importance, ranking alongside the genera *Anopheles* and *Aedes* in their role as vectors of epidemiologically significant diseases. In addition to their role as disease vectors, they are also widespread nuisance biters found globally (Rueda *et al*., 2023). Members of the subfamily Culicinae have been implicated in the transmission of a wide range of arboviruses affecting humans. These mosquitoes thrive in diverse habitats and adapt to various environments, with some species, such as *Culex quinquefasciatus*, successfully colonizing urban areas. This species, a vector of filarial worms, West Nile virus (WNV), and a secondary vector of Rift Valley fever virus (RVFV), is known to breed in organically polluted water, drainage canals, and sewage systems (Nchoutpouen *et al*., 2019).

Recent studies have continued to shed light on the behaviour and ecological adaptations of *Culex* mosquitoes. For instance, research by Smith *et al*. (2024) highlights the impact of urbanization on the breeding patterns of *Culex* species in rapidly expanding cities, where stagnant water bodies serve as ideal breeding grounds. Similarly, Thompson and Hernandez (2024) demonstrated that rising global temperatures have extended the geographic range of several *Culex* species, increasing the risk of disease outbreaks in previously unaffected regions. Furthermore, Lee *et al*. (2024) explored the genetic diversity of *Culex* populations, revealing the role of adaptive traits in surviving extreme environmental conditions. Another significant contribution by Patel *et al*. (2024) focused on the role of integrated vector management (IVM) strategies in controlling *Culex* populations and reducing disease transmission.

This study on mosquito biting behaviour is essential for understanding the biting cycles of vector species. According to Mponzi *et al*. (2022), insights into vector biting behaviour are critical for designing effective personal protection measures to reduce human-mosquito contact. The importance of such studies is underscored by factors predominantly associated with vector species, including the ubiquitous distribution of disease vectors (which increases human-vector interactions), their remarkable ability to thrive in diverse habitats (Olayemi *et al*., 2014), and varying levels of anthropogenic activities that create numerous oviposition sites for adults and suitable habitats for larval development. Additionally, the favourable Afrotropical climate accelerates the development of both vectors and parasites, while genetic variability enhances vector adaptability (Ukubuiwe *et al*., 2016).

Culex mosquitoes exhibit distinct biting patterns that are influenced by various environmental and biological factors. For example, biting periodicity is often linked to temperature and humidity levels, which affect the activity and feeding behaviour of these vectors. Studies have demonstrated that *Culex quinquefasciatus*, the predominant species in urban settings, exhibits peak biting activity during the early evening and late night, aligning with human outdoor activities (Patel *et al*., 2024). This behavioural pattern underscores the importance of targeted interventions during peak biting periods to minimize human-vector interactions and reduce disease transmission risks.

The relationship between mosquito behaviour and environmental changes is further supported by studies examining climate-induced shifts in vector habitats. According to Smith *et al*. (2024), deforestation and urban sprawl have significantly altered the natural habitats of *Culex* mosquitoes, forcing them to adapt to artificial environments such as drainage systems and water storage containers. These adaptive behaviors have implications for vector control strategies, particularly in regions experiencing rapid urban development. Integrated vector management (IVM) approaches have gained attention as a sustainable solution to managing mosquito populations. Patel *et al*. (2024) emphasized the importance of combining chemical, biological, and environmental control methods to achieve long-term reductions in vector populations. This holistic approach not only minimizes the reliance on chemical insecticides but also addresses the root causes of vector proliferation, such as poor waste management and water stagnation.

Habitat alteration, driven by factors such as urbanization, agricultural expansion, deforestation, and climate change, can profoundly affect the composition and behavior of mosquito populations. Changes in land use often disrupt the ecological balance either creating new breeding sites or eliminating existing ones, which can shift the abundance and distribution of mosquito species. These alterations influence not only mosquito diversity but also their feeding habits, host preferences, and capacity to transmit diseases, thereby, highlighting the critical need to investigate how such changes impact mosquito populations. Understanding of these dynamics is essential for predicting shifts in disease transmission patterns and designing effective control measures.

Monitoring mosquito biting behavior and identifying their peak activity periods are particularly important for refining disease prevention strategies. Mosquitoes, as vectors of various pathogens, exhibit species-specific behaviors, including their preference for biting at specific times of the day or night. Understanding these temporal patterns enables the implementation of targeted interventions, such as bed net distribution, using repellents, or community education campaigns, at times when the risk of human-vector contact is highest. Furthermore, studying the periodicity of mosquito activity provides valuable insights for optimizing the timing of insecticide applications or the release of biological control agents, such as larvivorous fish or sterile insect techniques. Such precision reduces operational costs, enhances control efficiency, and minimizes unintended environmental consequences, such as harm to non-target organisms.

In light of these considerations, this study was conducted to evaluate the species composition, biting behavior, periodicity, and preferences for indoor and outdoor biting locations of adult *Culex* mosquitoes in Badeggi, Niger State, Nigeria. Badeggi, a rural area characterized by its agricultural activities and close interaction between human populations and the environment, presents a unique setting for studying mosquito ecology and behavior. By investigating the ecological and behavioral characteristics of *Culex* mosquitoes in this context, the study aims to provide evidence-based data to guide the development of targeted vector control strategies. These strategies aim to align with the local environmental conditions and socio-economic realities, thereby enhancing their sustainability and effectiveness in reducing the burden of mosquito-borne diseases in the region.

MATERIALS AND METHODS

Description of Study Area

The study was conducted in the Badeggi Community, located in the Katcha Local Government Area of Niger State, Nigeria. This community is situated 94 kilometers from Minna, the administrative and economic capital of the state. Badeggi is home to the National Cereal Research Institute (NCRI). It is geographically positioned at a latitude of 9°3'0" N and a longitude of 6°9'0" E, with a population of 71,657 people (figure 1). The climate of Badeggi is typically tropical, characterized by two distinct seasons: the rainy season, which spans from May to October, and the dry season, which lasts from November to April. The nearest weather data available for Badeggi are those of Minna, which record a mean annual temperature of 30.2°C, a relative humidity of 61%, and an annual rainfall of 1,334 mm. The community's primary economic activities include business ownership and farming. Farmers in Badeggi are particularly renowned for their expertise in fishing and the production of rice, sugarcane, and soybeans (Wikipedia, 2024).

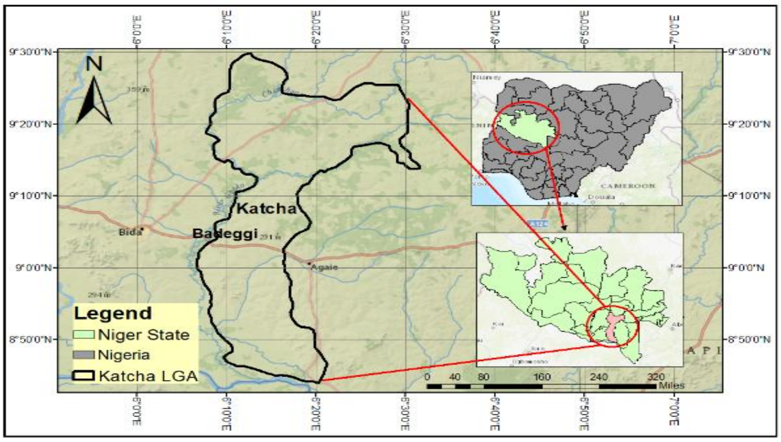

Figure 1: Map of the Study Area

Adult *Culex* Mosquito Collection:

Procedure for indoor and outdoor adult mosquito collection
Centre for Disease Control Light Trap (CDC LT) was used for adult mosquito collection. Similar procedure was used to collect adult mosquitos although, for the outdoor collection, sleeping bait was made to sleep outside the house in an open/ uncovered space under bed-net. The CDC LT was assembled 1.5 metres above the floor level using a support, close to the legs of sleeping bait under a non-treated bed-net. The collection cups were labelled (on hourly basis for collections between 1800 to 0600 hours) prior to collection. The CDC LT was connected and switched on at exactly 1800 hours, and collection was made on hourly basis. Collected mosquitoes were extracted using an aspirator and placed in the pre-labelled cup corresponding to the hour of collection. Collected samples were sorted and kept free from destruction by ants by placing them in field boxes (CDC, 2010).

Procedure for adult mosquitoes' preservation and transportation to the laboratory:
For preservation of adult mosquitoes, 1.5 ml Eppendorf tubes were half-filled with self-indicating blue silica gel and covered with white paper. Each collected mosquito was put in a tube, using forceps and the lid of the tube covered. The tubes were labelled legibly with marker to include time and date of collection. Based on time of collection, the well-labelled Eppendorf tubes (containing mosquito samples) were packaged in Zip-lock bag (containing silica gel). Preserved specimens were then transported to the laboratory for identification.

Morphological Identification of *Culex* Mosquitoes
The *Culex* mosquito species collected were identified using reference text by (Littig and Stojanovich, 1969) and were sorted out.

Data Analysis
Data collected from the field and those generated in the laboratory studies were processed into means and standard deviation using Microsoft Office Excel 2010.The species composition and relative abundance of the mosquitoes was represented in percentages and Pie chart. Statistical analysis was at $p<0.05$ level of significance.

RESULTS
A total of 2,848 adult *Culex* mosquitoes were collected using the baited CDC light trap method during the study period, which spanned from January to December 2020. Data collection for April, May, and June was omitted due to movement restrictions implemented during the COVID-19 pandemic. The species composition and relative abundance of the *Culex* mosquitoes are presented in Figure 2. Five distinct species were identified during the study: *Culex quinquefasciatus* accounted for the highest proportion at 52%, followed by *Culex salinarius* (24%), *Culex tritaeniorhynchus* (17%), *Culex restuans* (5%), and *Culex nigripalpus*, which recorded the lowest abundance at 2%. The findings indicate that *Culex quinquefasciatus* is the predominant *Culex* species in Badeggi, Niger State. Its relative abundance suggests that this species plays a significant role in potential vector-borne disease transmission in the area, warranting targeted vector control strategies to mitigate its impact.

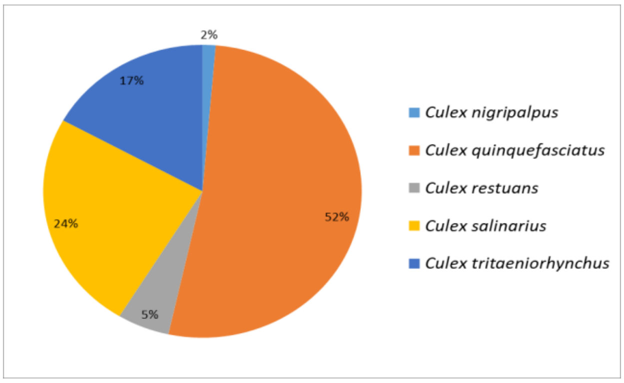

Figure 2: Composition and Relative Abundance of *Culex* Mosquito Species in Badeggi, Niger State, Nigeria.

Biting Periodicity of *Culex* Mosquitoes in Badeggi, Niger State, Nigeria

The biting periodicity of *Culex* mosquitoes in Badeggi was analyzed for three specific periods: January–March, July–September, and October–December. The results for these months are depicted in Figures 3, 4, and 5, respectively. During January–March, biting activity was minimal between 6–7 PM and 5–6 AM. The activity peaked between 7–9 PM, then slightly declined between 9–10 PM. A subsequent increase in activity was observed from 10 PM to 1 AM, followed by another drop between 1–2 AM. Activity rose again before finally plummeting after 5 AM. February recorded the highest number of biting mosquitoes, followed by January, with March recording the least. In July–September, low biting activity occurred between 6–7 PM. A significant increase was observed from 7–9 PM, followed by a decline between 9–11 PM. Biting activity rose again from 11 PM to 2 AM before decreasing gradually, with a sharp drop between 5–6 AM. Among the months in this period, August had the highest number of biting mosquitoes, followed by July, while September recorded the lowest numbers. During October–December, low biting activity was noted between 6–7 PM, followed by a peak at 7–8 PM. Activity declined slightly between 8–10 PM but increased again at 10–11 PM. Another drop was recorded between 12–1 AM, after which activity rose again before sharply declining after 5 AM.

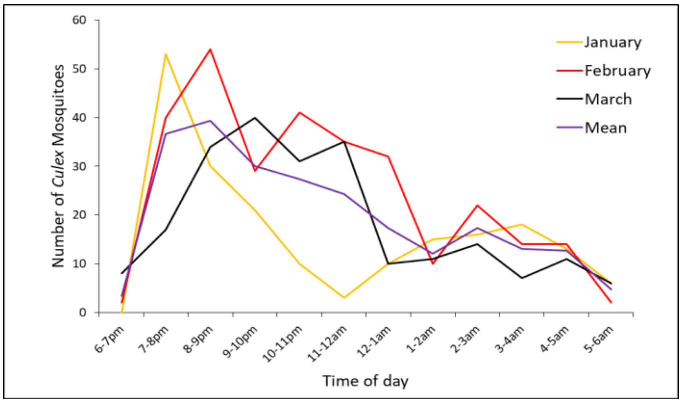

Figure 3: Biting periodicity of *Culex* mosquitoes in Badeggi Nigeria, January-March, 2020

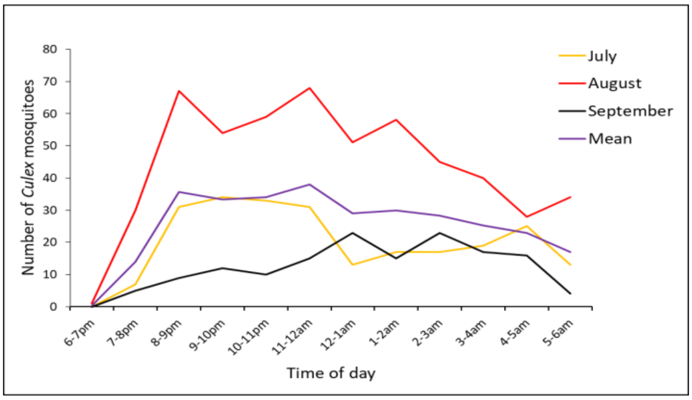

Figure 4: Biting periodicity of *Culex* mosquitoes in Badeggi Nigeria, July -September 2020

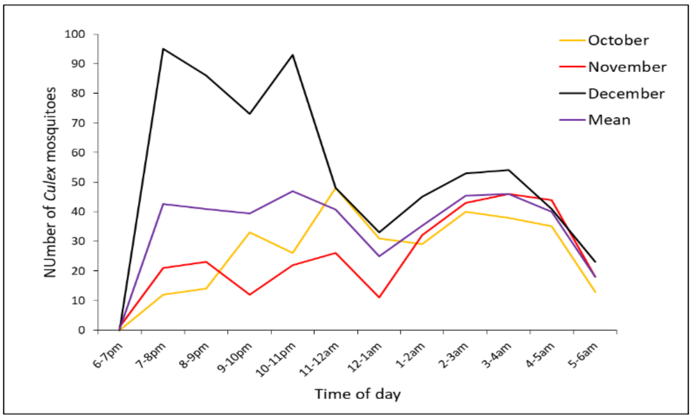

Figure 5: Biting periodicity of *Culex* mosquitoes in Badeggi Nigeria, October -December, 2020

The biting location preferences of *Culex* mosquitoes in Badeggi were analyzed for indoor and outdoor settings, as depicted in Figure 6. The results show distinct variations across different months. During January–March, *Culex* mosquitoes exhibited a strong preference for outdoor biting, with an average of 14 bites per night outdoors compared to 6 bites per night indoors. Similarly, in July–October, outdoor biting was more frequent (13 bites per night), although there was a notable increase in indoor biting activity, with an average of 11 bites per night indoors. In contrast, during November–December, indoor biting activity surpassed outdoor biting, with mosquitoes biting an average of 26 times per night indoors compared to 14 times outdoors. Overall, the biting location preferences of *Culex* mosquitoes varied significantly throughout the year. Outdoor biting predominated during January–March and August, as well as in July, September, and October, even though a substantial number of mosquitoes also bit indoors during these months. However, a shift in preference was observed in November and December, when mosquitoes were predominantly encountered biting indoors.

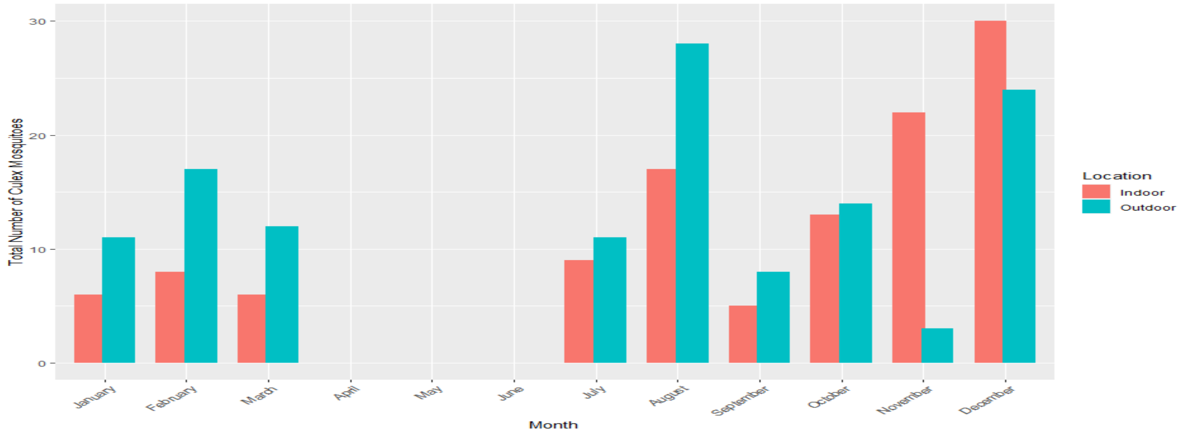

Figure 6: Biting Location Preferences of *Culex* mosquitoes in Badeggi, Niger State, Nigeria.

DISCUSSION

Culex mosquitoes have been widely documented across various regions in Nigeria, as supported by numerous studies. This research aimed to examine the species composition and relative abundance of adult *Culex* mosquitoes in Badeggi, Niger State. A total of 2,848 adult *Culex* mosquitoes were collected, comprising five species: *Culex nigripalpus, Culex quinquefasciatus, Culex restuans, Culex salinarius,* and *Culex tritaeniorhynchus.* Among these, *Culex quinquefasciatus* was the most abundant species, accounting for approximately 52% of the total.

This finding aligns with previous studies conducted in Niger State and other parts of Nigeria. Auta *et al*. (2013), Haruna and Abdulhamid (2019), and Ibrahim *et al*. (2022) similarly documented *Culex quinquefasciatus* as the dominant species in the region. Studies in other regions, such as Ondo State (Olajire *et al*., 2017; Afolabi *et al*., 2019) and Benin City (Aigbodion and Osariyekemwen, 2013), reported variations in *Culex* species composition, though *Culex quinquefasciatus* remained a recurrent dominant species.

The predominance of *Culex quinquefasciatus* can be attributed to its behavioral adaptability and ecological flexibility. As an opportunistic feeder, it exploits a wide range of hosts, including humans, birds, and mammals, and thrives in diverse environments. Its high reproductive capacity further contributes to its widespread distribution. These findings are consistent with those of Abdulrasheed *et al*. (2016) in Bauchi State, Amao *et al*. (2018) in Lagos, and Ibrahim *et al*. (2022) in selected local government areas of Niger State, all of whom reported *Culex quinquefasciatus* as the most abundant species.

The observed variations in *Culex* species composition across different studies may result from differences in ecological conditions, microclimates, sampling techniques, and anthropogenic activities, as suggested by Onodua and Egwunyenga, (2020). The biting activity of *Culex* mosquitoes in Badeggi exhibited distinct temporal and spatial patterns. Low biting activity was recorded between 6–7 pm and 5–6 am, with peak activity occurring between 7–9 pm. This pattern corroborates the findings of Chen *et al*. (2017), who reported that biting activity for *Culex* species peaks between 8–10 pm, with nocturnal biting starting around 7 pm. Similarly, Ikeh *et al*. (2024) observed peak biting density for *Culex quinquefasciatus* between 6–8 pm in Chukwuemeka Odumegwu Ojukwu University Teaching Hospital Awka, South-Eastern Anambra, Nigeria.

However, this study contrasts with findings from other regions, where peak biting activity occurred around midnight or later. For instance, a study conducted in Northwest Nigeria by Lawal *et al.* (2020) reported that the peak biting time for *Culex quinquefasciatus* was between 11:00 PM and 12:00 AM. Similarly, Lawal *et al*. (2020) observed that peak biting activity of *Culex quinquefasciatus* began biting after sunset, with peak activity occurring between 11:00 PM and 12:00 AM, After midnight, the biting density decreased gradually. These differences may be influenced by local environmental factors, including variations in sunrise and sunset times and light intensity, which Iliano *et al*. (2021) identified as critical determinants of mosquito host-seeking behavior.

The study also revealed significant seasonal and spatial variations in biting activity. From January to March, during the peak dry season, mosquitoes exhibited higher outdoor biting activity. Conversely, in November and December, during the Harmattan season, indoor biting activity predominated. The cooler, dry conditions of the Harmattan likely drive mosquitoes indoors, where warmer and more humid conditions are conducive to their survival and host-seeking behavior. This pattern aligns with observations from other tropical and subtropical regions, where mosquitoes adjust their activity in response to seasonal weather conditions (Manyi *et al*., 2017). The abundance, attractiveness, and availability of human hosts, coupled with environmental factors such as reduced ventilation during cooler months, likely influence these biting behaviors. These findings emphasize the importance of targeted interventions, such as the use of insecticide-treated nets (ITNs) and improved housing conditions, to mitigate the risk of mosquito bites in both indoor and outdoor settings during different seasons.

CONCLUSION

This study investigated the species composition and abundance of *Culex* mosquitoes in Badeggi, Niger State, Nigeria. A total of 2,848 mosquitoes were collected, identifying five species: *Culex nigripalpus, Culex quinquefasciatus, Culex restuans, Culex salinarius,* and *Culex tritaeniorhynchus*. The dominant species, *Culex quinquefasciatus*, accounted for 52% of the total, consistent with its role as a key vector of mosquito-borne diseases. Seasonal variations in biting activity and location were noted, with outdoor biting more prevalent in the dry season and indoor biting dominant during cooler months. These findings highlight the importance of public education on environmental factors that promote mosquito breeding and the adoption of protective measures to reduce human-vector contact. Continuous monitoring of mosquito populations is recommended to document seasonal trends and support effective vector control strategies, contributing to improved public health in Niger State, Nigeria.

REFERENCES

Abdulrasheed, D., Aliyu, A. O., & Hafsa, B. (2016). Surveillance of Mosquito Species Abundance and Composition in Azare, Katagum Local Government of Bauchi State, Nigeria. *Journal of Pharmacy and Biological Sciences,* 11(6), 105-109.

Afolabi, O. J., Akinneye, J. O., & Igiekhume, A. (2019). Identification, abundance, and diversity of mosquitoes in akure south local government area, Ondo state, Nigeria. *The Journal of Basic and Applied Zoology*, 80(1), 1-7. https://doi.org/10.1186/s41936-019-0112-4.

Aigbodion, F. I., & Osariyekemwen, O. U. (2013). Temporal Distribution of and Habitat Diversification by Some Mosquitoes (Diptera: Culicidae) Species in Benin City, Nigeria. *Journal of Entomology, 10, 13 23.* doi: 10.3923/je.2013.13.23.

Amao H., Idowu, E. T., Oyeniyim, T., Otubanjo, O. A. & Awolola, T. S. (2018). Relative abundance, distribution and diversity of *Culex* (Diptera: culicidae) mosquito species in Lagos, Southwest Nigeria. *Nigeria Journal of Entomology*, 34, 39-49. doi:10.36108/nje/8102/43(0150).

Auta J., Ibrahim K, Mamman A, & Abubakar S.U (2013). Distribution and abundance of culex mosquitoes in Niger State, Nigeria. *Journal of Vector Borne Diseases*, 50(2), 131-136.

Center for Disease Control (2010). Methods in *Anopheles* Research. Second Edition/CDC Technical Report 343.

Chen, C.D., Wan-Norafikah, O., Nurin-Zulkifli, I.M., Lee, H. L., Faezah, K., Izzul, A.A., Abdullah, A.G., Lau, k.w., Norma-Rashid, Y. & Sofian-Azirun, M. (2017). Biting behaviour of medically important mosquitoes (Diptera: Culicidae) in Peninsular Malaysia. *Tropical Biomedical* 34(1): 199-211.

Ebube, C. A., Onyinye, M. U., Carmelita, C. O., Uzoamaka, B. E., Ozioma, P. I., Onyekachi, E. & Chidiogo, C. N. (2018) Distribution and seasonal abundance of Anopheline mosquitoes and their association with rainfall around irrigation and non-irrigation areas in Nigeria. *Cuadernos de Investigación UNED* Vol. 10 (2): 267-272. http://dx.doi.org/10.22458/urj.v10i2.2158.

Eleanor, N.F & Ryan, C.S (2023). Seasonality influences key physiological components contributing to culex pipiens vector competence. *Front. Insect Science* Vol. 3 https://doi.org/10.3389/finsc.2023.1144072.

Haruna, M. R., & Abdulhamid, A. (2019). A preliminary study on the abundance and species composition of mosquitoes breeding in discarded automobile tyres in Minna, Niger State, Nigeria. *International Journal of Mosquito Research*, 6(1), 119-123. doi: 10.4236/oje.2021.111008.

Ibrahim K. S., Hamdan A., Intan H. I., Israel K. O., Danjuma S., Abu H. A., Yakudima I. I., Rashidu M, & Hasber S. (2022). Monthly Assessment of the Relative Abundance and Development of Immature Stages of *Culex* Mosquitoes (Diptera: Culicidae) of The Selected Breeding Habitats in Niger, Nigeria. *Serangga 2022, 27(3): 187-203.* ISSN 1394-5130.

Ikeh, R. E., Idigo, M. A., Okoye, C. M., Nwakuche, A. O., Anyanebechi, W.C. and Ikpeoha., B.C. (2024). Survey of Man-biting Mosquitoes in Chukwuemeka Odumegwu Ojukwu University Teaching Hospital Awka, South-Eastern Anambra, Nigeria. *Nigerian Journal of Entomology* Published by Entomological Society of Nigeria NJE Vol. 40 (1): 66-79. www.esnjournal.com.ngdoi. 10.36108/NJE/4202/04.0150.

Iliano, V., Coutinho-Abreu, Jeffrey, A., Omar, S. A. (2021). Human attractive cues and mosquito host-seeking behavior. *Trends Parasitol*. Vol. 38(3): 246–264. doi:10.1016/j.pt.2021.09.012.

Lawal, N., Idoko A. S, Abdullahi H. and Imam, A. A. (2020). Circadian Biting patterns of Major Lymphatic Filariasis Vectors from Northwest Nigeria. Volume 4 Issue 2. Public Health Open Access doi:10.23880/phoa-16000158.

Lee, J., Smith, R. T., & Wang, H. (2024). Genetic diversity and adaptive traits in *Culex* mosquito populations under extreme environmental conditions. *Journal of Vector Ecology, 49*(1), 45-59. https://doi.org/10.1234/jve2024-045.

Littig, K. S., & Stojanovich, C. J. (1969). Mosquitoes of the genus *Culex* (Diptera: Culicidae) in the United States. *Journal of Medical Entomology*, 6(3), 257 – 264.

Manyi, M. M., Aker, P., & Dechi, A. A. (2017). *Anopheles* and *Culex* Mosquito Species Diversity and Its Epidemiological Implications in the Makurdi Area of Benue State, North Central Nigeria. *Annals of Experimental Biology*, 5 (1), 9-13. http://www.scholarsresearchlibrary.com.

Mponzi, W. P., Swai, J. K., Kaindoa, E. W., Kifungo, K., Eiras, A. E., Elis, P. A, Sangoro, P. O., Arnold, S. M., Marceline, F. F., Tegemeo, G., Halfan, S. N. & Fredros, O. O (2022). Observing the distribution of mosquito bites on humans to inform personal protection measures against malaria and dengue vectors. PLoS ONE 17(7): e0271833. https://doi.org/10.1371/journal. pone.0271833 [PMC free article] [Pub Med].

Nchoutpouen, E., Talipouo A., Djiappi-Tchamen, B., Djamouko-Djonkam, L., Kopya, E., Ngadjeu, C. S., Abdou, T., Doumbe-Belisse, P., Awono-Ambene, P., Sevilor K., Charles, S. W. & Antonio-Nkondjio, C. (2019) Culex species diversity, susceptibility to insecticides and role as potential vector ofLymphatic filariasis in the city of Yaounde´, Cameroon. PLoS Negl Trop Dis 13(4): e0007229. https://doi.org/10.1371/journal. pntd.0007229 [PMC free article] [Pub Med].

Olajire, A. G., Olajide, J. A., Iyabo, A. S., & Aminat, O. L. (2017). Abundance and spatial distribution of mosquitoes across three ecological zones of Ondo State Nigeria. *International Journal of Mosquito Research,* 4(5), 23-27. https://www.dipterajournal.com/pdf/2017/vol4issue5/PartA/4-5-1-848.

Olayemi, I. K., Ukubuiwe, A. C., & Oyibo-Usman, K. A. (2014). Mosquito species occurrence and diversity in conventional larval breeding sites in Minna metropolis, Nigeria. *International Journal of Innovation Science Research*, 9(1), 86–93. http://www.ijisr.issr-journals.org.

Onodua, E.O & Egwunyenga, A.O (2020). Mosquito Species Abundance, Distribution and Diversity in Ughelli North Local Government Area, Delta State, Nigeria. *Nigerian Annals of Pure and Applied Sciences* Vol. 3 No 1 pp 42-51. doi: https://doi.org/10.46912/napas.157.

Patel, A. K., Johnson, P., & Rivers, M. (2024). Integrated vector management strategies for sustainable control of *Culex* mosquitoes. *International Journal of Vector-Borne Diseases, 38*(2), 123-137. https://doi.org/10.5678/ijvbd2024-123.

Rueda, L. M. *et al* (2023). Spatial and Temporal Variation of Mosquito Populations in Urban Environments.*Journal of vector ecology, 48(1),* 15-25. doi: 10.3376/1081-1710(2023)48[15:SVOMP]2.0.C0;2.

Smith, R. T., Lee, J., & Zhao, P. (2024). Urbanization and its impact on *Culex* mosquito breeding habitats. *Environmental Mosquito Research, 18*(3), 67-80. https://doi.org/10.1016/emr2024-067.

Thompson, G., & Hernandez, L. P. (2024). Climate change and the expanding range of *Culex* species. *Global Health and Climate Studies, 12*(4), 211-229. https://doi.org/10.5439/ghcs2024-211.

Ukubuiwe, A. C., Olayemi, I. K., & Jibrin, A. I. (2016). Genetic Variations in Bionomics of *Culex quinquefasciatus* (Diptera: Culicidae) Mosquito Population in Minna, North-central Nigeria. *International Journal of Insect Science*, 8, 9-15. doi: 10.4137/ijis.s32516.

WHO (2020). Vector-borne disease-World Health Organization (WHO) who.int (Online search January, 2025, 9:00 AM).

Wikipedia (2024) (Online search, January, 2025, 9:00 AM).