# Mosquito species composition, diversity and relative abundance in Science Village, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

Okeke, Obiageli Anthonia[1], Muoghalu, Chiazam Victor[1], Udeh, Nwabundo Peace[1], Nnatuanya, Ifebunandu Okwudilichukwu[1], Nwadike, Chidiogo Comfort[1], Afoemezie, Philippa Ifeyinwa[1], Ikeh, Ifeanyi Mulumba[1], Ishar, Cornalus Orjighjigh[1], Imakwu Cyril Ali[2], Ubaka, Uchenna Athanasius[2]

[1]Department of Zoology, Faculty of Biosciences, Nnamdi Azikiwe University, Awka.
[2]Department of Parasitology and Entomology, Faculty of Biosciences, Nnamdi Azikiwe University, Awka.

*Submitted: 2nd Oct., 2023; Accepted: 18th April, 2024; Published online: 30th June, 2024*
*DOI: https://doi.org/10.54117/jcbr.v4i3.4*
**Corresponding Author: Okeke, Obiageli Anthonia; oa.okeke@unizik.edu.ng +2348066095967*

## Abstract

Mosquitoes species diversity and abundance was studied at Science village, Nnamdi Azikiwe University, Awka, Nigeria. To the best of our knowledge, no previous studies have been conducted on the species composition and abundance of mosquitoes in the study area. Given that mosquitoes can act as vectors for various diseases, including malaria, yellow fever, and dengue fever, understanding the species composition of mosquitoes in the study area is crucial in assessing the potential public health implications associated with each species present. The objectives of this study were to identify different species of mosquitoes and determine their abundance and diversity in the study area. The study adopted a descriptive survey and was carried out from March to June 2023. The area was divided into two sampling sites for convenience; site 1 and Site 2. Four methods were used to collect mosquito samples namely an ovitrap (for egg collection), light trap, human landing catch and knock-down method (Spray sheet collection method). The mosquitoes were identified using morphological methods and experts. Mosquito diversity was determined using Shannon Weiner indices, dominance was determined by Simpson's dominance indices and species richness was determined using the Margalef species richness. A total of 440 mosquitoes comprising 5 species: *Anopheles gambiae, Culex quinquefasciatus, Aedes aegypti, Aedes albopictus* and *Aedes luteocephalus,* were identified during the study period. Out of the 5 species, *C. quinquefasciatus* was the highest (190/43.2 %) collected species followed by *Ae. aegypti* (111/25.2%), *An. gambiae* (s.l) (84/19.1 %), *Ae. albopictus* (54/12.3 %)

and *Ae., luteocephalus* (1/0.2 %). Mosquito diversity was higher in site 1 (1.2779) than in site 2 (1.2313). The high rate of *C. quinquefasciatus* mosquito species is of utmost concern in this study because it is the vector of many pathogens to man and some domestic animals. It is, therefore, recommended that control measures aimed at eliminating the breeding sites and reducing their contact with the students and staff should be embraced and practised to minimize disease transmission among the students.

**Keywords:** Mosquitoes, Species Diversity, Abundance, Nnamdi Azikiwe University Awka.

**Introduction**

Mosquitoes exist across the world, except Antarctica (Hawkes and Hopkins, 2022). More than 3, 500 mosquito species have been identified (Hawkes and Hopkins, 2022). The relative abundances of mosquito species within a region and the composition of mosquito communities change across space and time (Diallo *et al*., 2018). About three-quarters known species of mosquitoes consume blood. Female mosquitoes of those species are equipped with tubular mouthparts that can pierce the skin of their human and animal hosts to consume blood (Breedlove and Arguin, 2017). The loss of blood by the host to mosquito bites is seldom of any importance to the host (Timothy, 2019). The diversities of aquatic habitats for mosquito breeding frequently make them occur in adequate populations to constitute biting nuisance or vectors of disease-causing organisms (Afolabi *et al.,* 2019). Mosquitoes are known to show a preference for water with suitable pH, optimum temperature, dissolved oxygen, concentration of ammonia, and nitrate (Ghosh *et al.,* 2020). High-quality mosquito surveys are an essential tool for predicting mosquito-borne disease transmission and for mosquito control (Valentine *et al*., 2019).

Urbanization in Nigeria is one of the risk factors for the breeding and spread of mosquito vectors of disease pathogens. This has created urban health crises of inadequate water supply, squalor and shanty settlements, sanitation, solid waste management, and a double burden of diseases (Aliyu and Amadu, 2017). Anambra State is among the states undergoing rapid urbanization of settlements in areas where only a scattered rural population existed formerly.

Agricultural changes in the landscape such as afforestation, deforestation, irrigation and desertification provide a conducive breeding ground for the proliferation of mosquito species (Lapang *et al.,* 2019). Land use and land cover changes such as agricultural expansion and increased human population contribute immensely to the increase in breeding sites and the formation of habitat for mosquito species (Paul *et al*., 2018; Fornace *et al.,* 2021). Furthermore, climate change such as temperature extremes, rainfall, and relative humidity are major ecological factors which have a devastating effect on the environment, thereby influencing the abundance and diversity of mosquito species (Hasnana *et al*., 2016; Wilke *et al*., 2019; Ebube *et al.,* 2021). For example in South Korea from 2015 to 2020: an observational study reported that *C. pipiens* was the most common mosquito species in the urban region while mosquitoes of the genus *Ae* (*Ochlerotatus*) were the most common in the rural region (Lim *et al*., 2021). Mosquito abundance reached a maximum at 23.5 °C for *Cx. pipiens* and 26.4 °C for *Ae. vexans*. They further said that exposure to extremely high temperatures reduced the abundance of *Cx. pipiens* mosquitoes to a greater extent than that of *Anopheles* sp. (Lim *et al.,* 2021). In Ekiti State, Nigeria, temperature and rainfall were highly correlated with the abundance of mosquito vectors. It was observed that relative humidity of at least 50- 55 % prolong mosquito survival. The rainy season (March to October) recorded the highest number of mosquito vectors collection with the peak in the months of July and August while the lowest collection was in the month of February when (Simon-Oke and Olofintoye, 2015).

There have been reports of mosquito species diversity and abundance across Nigeria. In a study in Lagos State, five (5) species belonging to 3 genera were collected and identified as *An. gambiae* complex*, An. funestus* complex*, C. quinquefasciatus, Ae. aegypti,* and *Aedes albopictus. Culex quinquefasciatus* was the most abundant followed by *Ae, aegypti*, *An. gambiae* s.l. and *Ae. albopictus* (Fagbohun *et al.,* 2020). Among 6,195 adult mosquitoes collected in a farm situated in Ibadan western Nigeria, 16 species belonging to 5 genera were morphologically identified. *Culex quinquefasciatus* constituted the most abundant mosquito, representing 46.49 % of all mosquitoes encountered (Victor *et al.,* 2017). In another study in Delta State, adult mosquitoes that were separated into three

genera: *Anopheles*, *Aedes* and *Culex* were identified up to the species level. *Culex quinquefasciatus* was found to be the most abundant followed by *Ae. aegypti*. *Culex nebulosus* was the least abundant species (Onodua *et al.,* 2020). In the Omi reservoir irrigation project, Yagba West Local Government Area, Kogi State, north-central Nigeria, the three most common species mosquito identified were *An. gambiae*, *An. funestus* and *C. quinquefasciatus* (Ebube *et al.,* 2018). Comparing the two collection methods used, the Pyrethrum spray sheet had a greater number of mosquitoes than those with the Human Landing Catch method.

In Anambra East Local Government Area of Anambra State, four *Anopheles* species: *An. gambiae* s., *An. funestus* group, *An. moucheti* and *An. nili* were identified Egbuche *et al.,* 2021). In that study, the abundance of *Anopheles* mosquitoes was higher in Igbariam followed by Aguleri and Nsugbe. In Awka and Environs, mosquito species collected and identified were *C. quinquefasciatus*, *An. gambiae*, *and An. funestus*, *Ae. albopictus*, *Ae. aegypti* and *Ae. bromeliae*, with *C. quinquefasciatus* being the most abundant (Irikannu and Ogbonna 2021).

The most recent work by Izuka (2022) in the students hostels on mosquito abundance and diversity in the University community reported 6 mosquito species: *A. gambiae*, *A. funestus, Ae. aegypti, Ae. africanus, Ae. albopictus and C. quiquefasciatus* were identified, with *A. gambiae* being the most abundant. Hence, this study aimed to investigate the species composition of mosquitoes, the abundance and diversity of mosquito species in the Faculty of Science complex in the Nnamdi Azikiwe University community where there is thick vegetation, pools of standing water and freshwater bodies ideal as breeding sites for mosquitoes. This study will give a broader view and wider coverage of the diversity and abundance of mosquitoes in the study area from the beginning of the rainy season to the middle of the season.

## Materials and methods

### Study Sites

Nnamdi Azikiwe University is located in Awka, Awka-south L.G.A, Anambra state. The coordinates of Awka where the study area is located is 6.2220° N, 7.0821° E (www.latlong.net). The school is located in the tropical rainforest zone, although it has derived savannah vegetation. The temperature ranges from 270$^{o}$C to 300$^{o}$C between June and December but rises to 320$^{o}$C – 340$^{o}$C between January and April, with the last few

months of the dry season marked by intense heat. It has a relative humidity of 70 % reaching 80 % during the rainy season and an annual rainfall of about 2000mm (Iloeje, 2001). There are ground collections of stagnant water due to rainfall in the rainy season and the side gutters are heavily filled with stagnant waste water from student activities. The area was divided into two collection sites for convenience: site 1 started from the Faculty of Biosciences office complex down to the Zoological garden while Site 2 covered the uncompleted building complex at the centre of Science Village down to the Bioscience Auditorium (Figure 1).

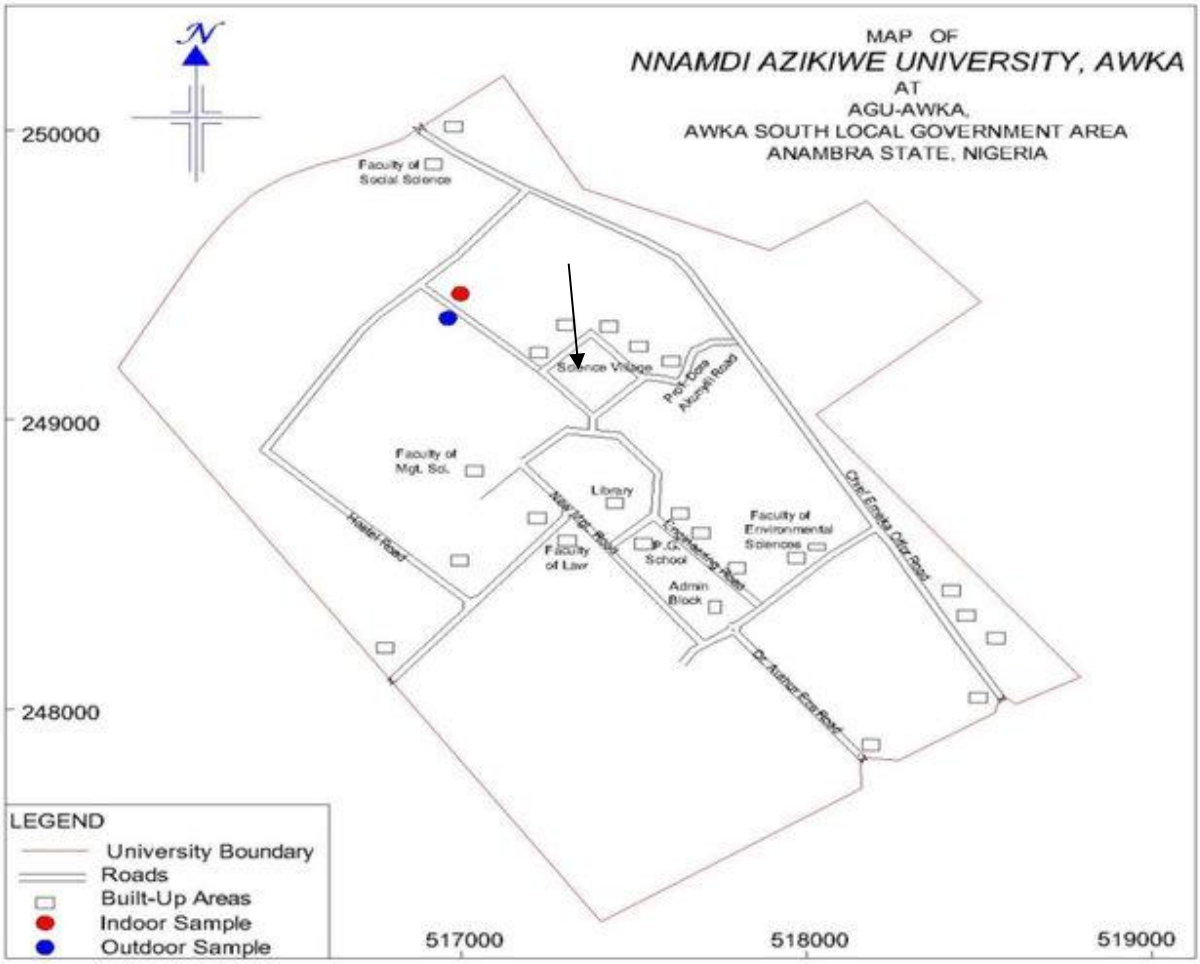


**Figure 1: Map of Nnamdi Azikiwe University showing Science Village.**

Source: Abajue & Ewuim, (2018).

Ethical consideration and certificate was obtained from the Nnamdi Azikiwe University Animal Research Ethics Committee with reference number NAU/AREC/2023/00028.

**Sample Collection**

Four methods were employed to collect samples and they were: Egg collection (with the use of an ovitrap), light trap, human landing catch and knock-down method (Spray sheet collection method).

**Ovitrap**

This trap was used for mosquito egg collection. Ten ovipositor containers of 300ml capacity each were placed in two different sampling sites. These locations were points within a 1.5km radius as such, only two ovitraps were used for sampling each site. All ovitraps were layered with white coloured ribbon as a substrate on the inside, according to the method described by Service (2012). The traps were labelled with code numbers representing each location after which, three-quarters of the ovitrap containers were filled with water. All the ovitraps were placed in suspected mosquito breeding sites for twenty-four hours in contrast with weekly collections observed in many studies due to time constraints.

**Light trap method**

Four WHO New Jersey light trap model 512 (one in each location) were used for the collection. Each light trap was hung about 1.5 to 2m above the ground and operated by 6-volt battery. Mosquitoes were attracted to the brightness of the light at night and they entered the hood of the trap where they got exposed to a strong downward air current produced by an electric motor fan. The mosquitoes were trapped in a funnel mesh screen.

**Knock-down Method (The Spray Sheet Collection Method)**

In spray–sheet collection, two spray team was employed to get a complete catch as possible; one student stood in the room of one of the uncompleted buildings in science village and sprayed the inside, while another sprayed outside the house, around the eaves and the inner walls that divide the room from the rest of the house, putting up a barrier of spray round all possible exits, the spraying was synchronized so that the eaves of air space above each wall was sprayed simultaneously from inside and outside. In each location, five rooms were randomly chosen and the collection was performed between the hours of 7. 00 pm and 9. 00 pm.

The floor surfaces of the room, as well as beds, and furniture were completely covered with white sheets. The windows and doors were closed and the eaves (openings) were blocked to prevent mosquitoes from escaping.

Then the aerosol (New Mortein powerGard® containing- Imiprothrin,) was used to flit the room and around the eaves outside the room, and then the room was closed for 10 -15 minutes. After 10 - 15 minutes, the sheets were carefully retrieved from the floor, starting from the door by lifting them at the four corners and moving them gently so that the mosquitoes would gather in the middle of the sheet. The mosquitoes were collected into a labelled Petri dish using forceps.

**The Human Landing Catch Method**

This was carried out in two different sampling sites. In each location, two student volunteers were recruited to carry out the mosquito collections. The catch was performed by immunized student volunteers. The volunteers were trained on sampling using human bait and given instructions on how to collect mosquitoes. The collectors stayed with both legs and arms exposed for the duration of the experiment. Any mosquito perching on the exposed part was caught before it was fed by inverting a small glass tube over it. All tubes containing mosquitoes were labelled to indicate the time of capture. The catch was performed at dusk between 17.00 and 19.00 hours as most specie has biting peak after sunset.

**Identification of the mosquitoes**

Collected mosquitoes were placed in sample tubes and preserved in the fridge at 4°. Preliminary identification of samples (eggs and adult mosquitoes) was done in the Zoology laboratory Nnamdi Azikiwe University using Google lenses and Maps. Samples were later taken to the laboratory of the National Arbovirus and Vector Research Centre Laboratory, Enugu for further identification and confirmation. The mosquitoes were identified morphologically through the use of microscopy.

**Statistical Analysis**

IBM SPSS statistical software (version 23) was used. The chi-square ($\chi 2$) test was used to compare the relative abundance of mosquitoes in the two chosen sampling sites of Science Village, Unizik, Awka. Level of significance was set at $p< 0.05$. The Shannon Weiner indices was used to determine the diversity of mosquito species using the formula $H = -å P_i(\ln P_i)$ where $P_i$ is the proportion of each species in the sample.

**Results**

A total of 440 mosquitoes belonging to 3 genera and 5 species were caught during the study. They are *C. quinquefasciatus, Ae.*

*Aegypti*, *A. gambiae sl*, *Ae. albopictus* and *Ae. Luteocephalus* (Table 1). The result of the relative abundance of mosquitoes collected in the two sites sampled showed that *C. quinquefasciatus* had the highest relative abundance (43.18 %) followed by *Ae. aegypti* (25.23 %), *A. gambiae sl* (19.09 %), *Ae. albopictus* (12.27) while *Ae. luteocephalus* (0.23 %) had the least. Site 1 had significantly higher number of mosquitoes (62.50%) than site 2 (37.50%) ($p<0.05$).

**Table 1: Species identification and Relative Abundance of Mosquitoes in the Study Area.**

| Species of mosquitoes | Site 1 | Site 2 | Total |
|---|---|---|---|
| *An. gambiae sl* | 67(24.36) | 17(10.30) | 84(19.09) |
| *C. quinquefasciatus* | 135(49.09) | 55(33.33) | 190(43.18) |
| *Ae. Aegypti* | 48(17.45) | 63(38.18) | 111(25.23) |
| *Ae. Albopictus* | 24(8.73) | 30(18.18) | 54(12.27) |
| *Ae. Luteocephalus* | 1(0.36) | 0(0.00) | 1(0.23) |
| **Total** | **275(62.5)** | **165(37.5)** | **440(100)** |

$\chi 2 = 42.282$; df = 4; P = 0.00*

The relative abundance of mosquitoes collected with the four sampling techniques in the study sites showed that the mosquitoes collected using light trap 188(42.73 %) were highest while the least was collected using human landing catch 29(6.59 %) (Table 2). There was significant difference between the relative abundance of the various species of mosquitoes in sites 1 and 2 based on the techniques used ($p<0.05$).

**Table 2: Relative Abundance of Mosquitoes Collected using different techniques.**

| Techniques | Site 1 (%) | Site 2 (%) | Total (%) |
|---|---|---|---|
| Light trap | 156(56.73) | 32 (19.39) | 188(42.73) |
| Spray sheet collection | 46(16.73) | 40(24.24) | 86(19.55) |

| | | | |
|---|---|---|---|
| Ovitrap collection | 58(21.09) | 79(47.88) | 137(31.14) |
| Human Landing Catch | 15(5.45) | 14(8.48) | 29(6.59) |

$\chi 2 = 61.823$; df = 3; P=0.00*

The Shannon Weiner indices of mosquito species from site 1 and site 2 revealed that mosquito diversity was higher in site 1 (1.2779) than in site 2 (1.2313) (Figure 2).

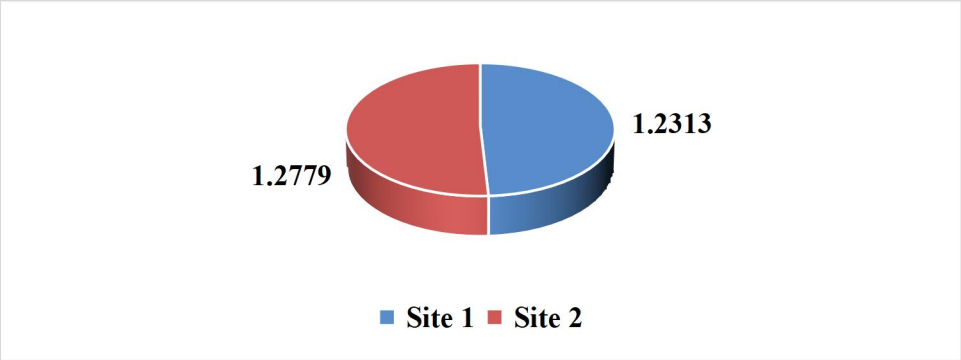


**Figure 2: Shannon Weiner Diversity of Mosquitoes in Sites 1 and 2**

Furthermore, the Simpson's dominance indices of mosquitoes in site 1 and site 2 shown in Figure 3 revealed that the Simpson's dominance in site 1 (0.3384) was higher than that of site 2 (0.3006).

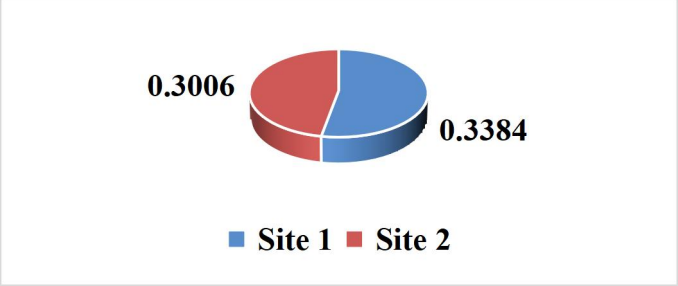


**Figure 3: Simpson's Dominance of mosquitoes in Sites 1 and 2**

Also, in Figure 4 the Margalef species richness of mosquitoes in site 1 and site 2 show that the mosquito species richness in site 1 (0.7122) was higher than that of site 2 (0.5876).

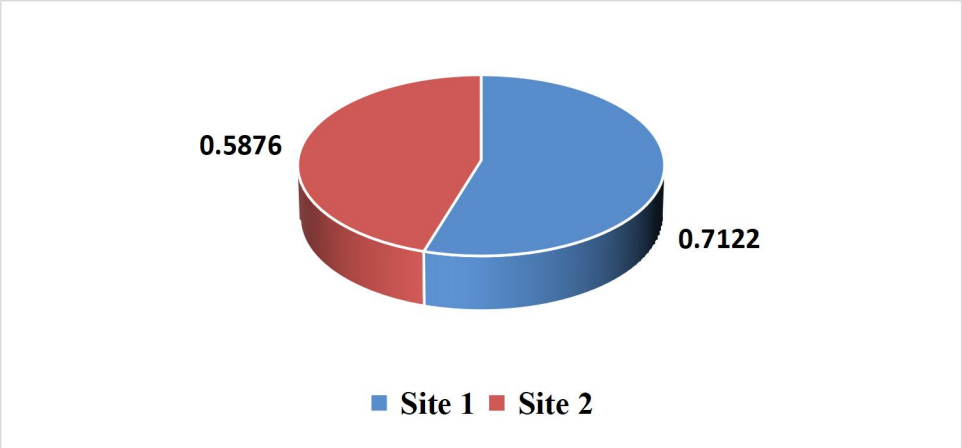


**Figure 4: Margalef Species richness of mosquitoes in Sites 1 and 2**

**Discussion**

Mosquito-borne diseases remain a major public health problem in Nigeria and their transmission is becoming frequent daily due to the widespread of mosquitoes as a result of increased breeding sites. The presence of the five species of mosquitoes found in this study is an indication that the climatic and environmental condition of the science village is conducive to support their breeding, development and survival. The relatively high number of mosquitoes collected during the study period indicates the preponderance of breeding sites around the area. The most abundant mosquito species collected was *C. quinquefasciatus*. However, Izuka (2022) reported that *C. quiquefasciatus* was the second most abundant in the year 2022 in a study done in the male and female hostels of Nnamdi Azikiwe University, Awka. It may be as a result of the presence of stagnant water and groundwater collections that serve as breeding grounds. Similarly, Ifediba *et al.* (2021) had earlier reported that *C. quinquefasciatus* , with relative abundance of 46.70 %, was the most abundant in Awka and Environs, Anambra State, Nigeria. In Ughelli North Local Government Area of Delta State *C. quinquefasciatus* was found to be the most abundant followed by *Ae. Aegypti* while *C. nebulosus* was the least abundant species (Onodua, *et al.,* 2020). Also, in Shendam Local Government Area, Plateau State, North-Central Nigeria *C. quinquefasciatus* and *A. gambiae* were the most abundant species (Lapang *et al*., 2019).

On the other hand, there was low abundance of *Anopheles* sp. *Anopheles* species are of great public health importance because of the

endemic nature and burden of malaria in Nigeria. The need for blood by adult female mosquitoes to develop their eggs is one of the reasons that they have become successful vectors of tropical diseases (Marques *et al.,* 2018). Likewise, in Akure, Ondo State Nigeria, of the total larvae population of mosquitoes identified, 714 larvae belong to the genus *Aedes* while only 52 larvae belong to the genus *Anopheles* (Afolabi *et al.,* 2019). *Anopheles gambiae* was the third most abundant in Ohafia, Abia State, Nigeria in a study done by Onyekachi *et al*. (2018). The abundance of *Anopheles* species in the study area could be a result of environmental factors such as temperature, relative humidity, and precipitation, the presence of palm gardens/vegetables that hold a large volume of rainwater, widespread salt marshes, and irrigation ditches (Al-Thukair *et al*., 2023). In this study mosquitoes collected with light trap had the highest relative abundance while the least was collected using human landing catch. In a study of mosquito traps that can be used in place of human landing catches for mosquito surveillance, light traps captured more of *An. gambiae* s.l. than HLC (Eckert *et al.,* 2022). In another study done in the coastal habitat of Alameda County (California, USA), a New Jersey Light Trap fitted with an incandescent bulb caught more female mosquitoes than the one fitted with an LED bulb, but the difference was not significant (Alemayehu *et al.,* 2020).

In this study, Simpson's dominance in site 1 was higher than that of site 2, the Shannon Weiner indices range from and the Margalef species richness of mosquitoes show that the mosquito species richness in site was also higher than that of site. In a study in Lagos State, Simpson's index range from 0.6751 to 0.6926 for all the sampled locations while the Shannon index ranges from 1.187 to 1.242 (Ifeoluwa *et al.,* 2020). In Southeast Nigeria *C. quinquefasciatus* had the highest Shannon-Wiener diversity index and Simpson's dominance index (0.495) (Irikannu, *et al*., 2023).

**Conclusion and Recommendations**

The relatively high density of mosquitoes encountered in this study is a source of threat to the students and staff and, therefore, is of public health concern. The high percentage of *C. quinquefasciatus* mosquitoes also encountered exposes the students to mosquito-borne diseases being transmitted by them which they have little or no natural resistance to and consequently affects their academic performance and life in general for a reasonable period of time. Strong emphasis should be laid on the importance of personal

protection and environmental hygiene in the University environment and the school management should make it a policy which every student should abide by

**Acknowledgement:**

We sincerely acknowledge the contributions of the management and staff of the National Arbovirus and Vector Research Centre Laboratory, Enugu who helped in the identification of the mosquitoes. Also, we thank the laboratory scientists in the Department of Zoology, Nnamdi Azikiwe University Awka for giving us access to the laboratory and the equipment.

**Conflict of Interest:** There was no conflict of interest.

**References**

Abajue M, Ewuim SC (2018): Chemical composition and Growth Rate of Blowfly Maggot from Poisoned Cadavers in Awka, Nigeria. Nig. Ent. 34, 123-132.

Afolabi OJ, Akinneye JO, Igiekhume AM (2019): Identification, abundance, and diversity of mosquitoes in Akure South Local Government Area, Ondo State, Nigeria. *J. Basic App. Zoo.* 80(1), 1-7.

Aliyu AA, Amadu L (2017): Urbanization, Cities, and Health: The Challenges to Nigeria – A Review. *Ann. Afric. Med.*, 16(4), 149-158.

Al-Thukair A, Jemal Y, Nzila A (2023): Influence of Climatic Factors on the Abundance and Profusion of Mosquitoes in Eastern Province, Saudi Arabia. IntechOpen. doi: 10.5772/intechopen.104615.

Arora AK, Sim C, Severson DW, and Kang DS (2022). Random Forest Analysis of Impact of Abiotic Factors on *Culex pipiens* and *Culex quinquefasciatus* Occurrence. *Front. Ecol. and Evol.*, *9*, 773360. https://doi.org/10.3389/fevo.2021.773360

Bartholomay LC, Waterhouse RM, Mayhew GF, Campbell CL, Michel K, Zou Z, Ramirez JL, Das S, Alvarez K, Arensburger P, Bryant B, Chapman SB, Dong Y, Erickson SM, Parakrama Karunaratne HP, Kokoza V, Kodira CD, Pignatelli P, Shin SW, . . . Muskavitch AT (2010). Pathogenomics of Culex quinquefasciatus and meta-analysis of infection responses to diverse pathogens. *Sci.*, *330*(6000), 88. https://doi.org/10.1126/science.1193162

Breedlove B and Arguin PM (2017). Haematophagous Endeavours, Fact and

Fancy. *Emerg. Infect. Dis.*, 23(8), 1436-1437. https://doi.org/10.3201/eid2308.AC2308.

Alemayehu D, Barretto M, Busam J, Haas-Stapleton E, Sette J and Wieland M (2020). Proceedings and Papers of the Mosquito and Vector Control Association of California. 88, 169.

Available: www. latlong.net Awka, Nigeria. Accessed 10th April 2024.

Diallo D, Diagne CT, Buenemann M, Ba Y, Dia I, Faye O (2018): Biodiversity pattern of mosquitoes in south-eastern Senegal, epidemiological implication in arbovirus and malaria transmission. *J. Med. Entomol*. 56, 453–63.

Ebube CA, Onyinye M, Ukpai1, Carmelita CO, Ube OPI, Onyekachi E, Chidiogo CN (2018): Distribution and seasonal abundance of Anopheline mosquitoes and their association with rainfall around irrigation and non-irrigation areas in Nigeria. Cuad. de Invest. UNED, 10, 2.

Eckert J, Oladipupo S, Wang Y, Jiang S, Patil V, McKenize B, Lobo N and Zohdy S (2022). Which trap is best? Alternatives to human landing catches for malaria vector surveillance: a meta-analysis. Research Article, https://doi.org/10.21203/rs.3.rs-1236441/v1

Egbuche CM, Onyido AE, Umeanaeto PU, Nwankwo EN, Omah IF, Ukonze CB. Okeke JJ, Ezihe CK, Irikannu KC, Aniekwe MI, Ogbodo JC, Enyinnaya JO (2020): Anopheles species composition and some climatic factors that influence their survival and population abundance in Anambra East LGA, Anambra State, Nigeria. *Nig. J. Parasit.* 41, 2.

Egbuche C, Okwubanego C, Omah I, Odoh V, Obi C, Dashar T, Egbobe J, Olisakwe S, Okafor T, Nwankwo J and Ezaka E (2021). Mosquito fauna of Anambra East LGA, Anambra state, Nigeria. J. Entomol. Zool. Stud., 9. 32-39. 10.22271/j.ento.2021.v9.i4a.8767.

Fagbohun IK, Idowu ET, Awolola TS, Otubanjo OA (2020): Seasonal abundance and larval habitats characterization of mosquito species in Lagos State, Nigeria. *Sci. Afri. 10*, e00656.

Fornace KM, Diaz AV, Lines J, Drakeley C J (2021): Achieving global malaria eradication in changing landscapes. *Malar. J.* 20, 69.

Ghosh SK, Podder D, Panja AK, Mukherjee S (2020): In target areas where human mosquito-borne diseases are diagnosed, the inclusion of the pre-adult mosquito aquatic niches parameters will improve the integrated mosquito control program. *PLoS Neg. Trop. Dis.* 14, 8.

Hasnana A, CheDoma N, Rostya H, Say Tyong C (2016): Quantifying the distribution and abundance of *Aedes* mosquitoes in Dengue Risk Areas of Sha Alam Selango. *Proc. Soc. Behave. Sci*. 234, 154-163.

Hawkes FM, Hopkins RJ. (2022). The mosquito: An introduction, In: Hall M, Tamïr D, editors. Mosquitopia: The Place of Pests in a Healthy World. Routledge, New York p. 463.

https://www.latlong.net › Countries › Nigeria › Cities. Where is Awka, Nigeria on Map Latitude and Longitude Coordinates. Accessed 17th April, 2024.

Ifediba V, Anthony CO, Kindness CI, Chibumma IN, Confidence UO, Rose LN, and Chinwendu SO (2021): Relative abundance and diversity of man-biting mosquito species before and after indoor residual spraying programme in Awka and Environs, Anambra State, Nigeria. *T r e n d. Entomol.* 17, 58-66.

Ifeoluwa KF, Emmanuel TI, Taiwo SA, Olubunmi AO (2020): Seasonal abundance and larval habitats characterization of mosquito species in Lagos State, Nigeria. Sci. Afr. 10, e00656.

Iloeje NP (2001). A new geography of Nigeria, a new revisited edition. Longman Nigeria p. l

Irikannu K. and Ogbonna, C. (2021). Relative abundance and diversity of man-biting mosquito species before and after indoor residual spraying programme in Awka and Environs, Anambra State, Nigeria. *T r e n d s i n Entomology*, 17. 57- 67.

Irikannu KC, Onyido AE, Ogaraku JC, Umeanaeto PU, Nzeukwu CI, Obiefule IE, Aniefuna CO, Elosiuba NV Onwuachusi GL (2023): Seasonal Distribution and Diversity of Mosquito Species in a Rainforest Community of Southeast Nigeria. *The Bioscient. J.* 11(1), 71-80.

Izuka FC (2022): Preliminary Study on the Ecology and Diversity of Mosquito Species in Nnamdi Azikiwe University Hostels, Awka, Anambra State. *Acta Scient. Vet. Sci*. 4(7), 11-16.

Lapang PM, Ombugadu A, Ishaya M, Mafuyai M J, Njila HL, Nkup CD Mwansat GS (2019): Abundance and Diversity of Mosquito Species Larvae in Shendam LGA, Plateau State, North Central Nigeria: A Panacea for Vector Control. *J. Zool. Res.* 3(3), 25-33.

Lim AY, Cheong HK, Chung Y, Sim K. and Kim JH (2021): Mosquito abundance in relation to extremely high temperatures in urban and rural areas of Incheon Metropolitan City, South Korea from 2015 to 2020: an observational study. *Parasit. Vecs.* 14, 559. https://doi.org/10.1186/s13071-021-05071-z

Marques J, Cardoso JCR, Felix RC, Santana RAG, Guerra MDGB, Power D & Silveira H. (2018): Fresh-blood-free diet for rearing malaria mosquito vectors. *Sci reports*, 8(1), 17807. https://doi.org/10.1038/s41598-018-35886-3

Onodua E, Odo PE Egwunyenga AO (2020): Mosquito Species Abundance, Distribution and Diversity in Ughelli North Local Government Area, Delta State, Nigeria. *Nig. Ann. Pure App. Sc.* 3, 42 – 51.

Onyekachi E, Carmelita CO, Ebube CA, Collins NE (2018): Distribution and abundance of mosquito larvae in Ohafia, Abia State, Nigeria. Cuad. de Inves. UNED 10(2), 379-385.

Paul P, Kangalawe RYM Mboera LEG (2018): Land-use patterns and their implication on malaria transmission in Kilosa District, Tanzania. *Trop. Dis. Travel. Med. Vaccines* 4, 6.

SIMON-OKE IA and Olofintoye LK (2015). The Effect of Climatic Factors on the Distribution and Abundance of Mosquito Vectors in Ekiti State. *Journal of Biology, Agriculture and Healthcare*, 5(9), 2224-3208.

Timothy CW (2019). Dutton, Penguin Random House, New York, NY, p. 35

Valentine MJ, Murdock CC, Kelly PJ (2019): Sylvatic cycles of arboviruses in non human primates. Parasit.Vect.12, 463.

Victor OA, Adekunle AJ, Tahiru IK, David OO (2017): Influence of Meteorological Variables on Diversity and Abundance of Mosquito Vectors in Two Livestock Farms in Ibadan,

Nigeria: Public Health Implications. *J. Mosquit. Res.*7 (9), 70.

Wilke ABB, Chase C, Vasquez C, Carvajal A, Medina J, Petrie WD, Beier JC (2019): Urbanization creates diverse aquatic habitats for immature mosquitoes in urban areas. *Scit. Reports Nat. Res*. 9 (15335), 112.