INTL J BONOROWO WETLANDS
Volume 14, Number 2, December 2024
Pages: 57-65

P-ISSN: 2775-8052
E-ISSN: 2775-8044
DOI: 10.13057/bonorowo/w140201

Morphological identification of mosquito species in Takur Adu'a and Yakasai, Dutse Local Government Area, Jigawa State, Nigeria

SANI ADO UMAR[1,♥], RAMGOPAL DHAKAR[1], HAMIMA SURAJ USMAN[2], MUSTAPHA SULAIMAN[3], MUBARAK SA'IDU[1], MADANIYYU SULAIMAN YAHAYA[4], AHMAD SADI SHITU[1], HABIB MUMAMMAD USMAN[5]

[1]Department of Life Science, Mewar University. NH - 48 Gangrar Chittorgarh, Rajasthan-312901, India. Tel.: +91-1471-285451/52, ♥email: saniadoumar@gmail.com
[2]Department of Biological Science, Federal University Dutse. Ibrahim Aliyu Way Bye-Pass, Dutse, Nigeria
[3]Department of Chemistry, Mewar University. NH - 48 Gangrar Chittorgarh, Rajasthan-312901, India
[4]Department of Mechanical Engineering, Mewar University. NH - 48 Gangrar Chittorgarh, Rajasthan-312901, India
[5]Department of Electrical Engineering, Mewar University. NH - 48 Gangrar Chittorgarh, Rajasthan-312901, India

Manuscript received: 20 August 2024. Revision accepted: 30 October 2024.

Abstract. *Umar SA, Dhakar R, Usman HS, Sulaiman M, Sa'idu M, Yahaya MS, Shitu AS, Usman HM. 2024. Morphological identification of mosquito species in Takur Adu'a and Yakasai, Dutse Local Government Area, Jigawa State, Nigeria. Intl J Bonorowo Wetlands 14: 57-65.* Mosquitoes, major vectors for various diseases, pose significant public health challenges worldwide. This study focuses on identifying and analyzing mosquito species in Takur Adu'a and Yakasai Areas of Jigawa State, Nigeria. Located in Northwestern Nigeria with Dutse as its capital, Jigawa State borders Kano, Katsina, Bauchi, Yobe, and the Zinder Region in Niger, facilitating cross-border trade. The major tribes are Hausa, Fulani, and Kanuri. Mosquito collection was conducted early in the morning using a prepared environment and spraying method. Morphological identification of differentiating species of mosquito are by palps, proboscis, wing patterns, body shape, and resting positions. In Takur Adu'a and Yakasai, a total of 449 mosquitoes were collected, 278 from Takur Adu'a and 171 from Yakasai. *Aedes* species included 21 females and 29 males; *Culex* had 82 females and 52 males; *Anopheles* had 35 females and 24 males; *Anopheles gambiae* had 7 females and 4 males; and non *A. gambiae* had 8 females and 16 males. *Culex* mosquitoes were the most dominant, followed by *Aedes* and *Anopheles*, with 71.2% being fed, indicating significant feeding activity and potential disease transmission. In Yakasai, Aedes species included 17 females and 12 males, *Culex* had 42 females and 50 males, *Anopheles* had 12 females and 16 males, *A. gambiae* had 8 females and 6 males, and non *A. gambiae* had 5 females and 3 males. The study identify only morphospecies but *A. gambiae* and non *A. gambiae* are different morphospecies but in the same genus. *Culex* was the most prevalent species, with 57.9% fed, highlighting a substantial risk of disease transmission. The study also assessed respondents' knowledge of mosquito bite prevention, finding significant awareness levels, though gaps remained, and necessitating targeted educational campaigns. Identifying multiple mosquito genera and species emphasizes the value of molecular methods for mosquito identification. The findings reveal a dominant presence of *Culex* mosquitoes and a high percentage of fed mosquitoes, indicating significant disease transmission risks. Continuous education and effective vector control strategies are crucial to mitigate health risks in Jigawa State.

Keywords: Blood-feeding insect, mosquito classifications, physical characterization, vector-borne illness

INTRODUCTION

Mosquitoes are regarded as one of humanity's biggest enemies, because of the tremendous misery and fatalities brought on by the diseases they spread. They are essential to the epidemiology of important public health insect-borne diseases, particularly in regions with a variety of lakes and rivers that facilitate their reproduction. Mosquitoes are a nuisance when they bite and can spread infectious diseases due to the range of water settings in which they can breed (Girard et al. 2021). The female *Anopheles* mosquito is the cause of malaria (Girard et al. 2021). Because of their widespread distribution, ability to transmit illness, variety, and ongoing infection, mosquitoes are the primary carriers of several illnesses, such as dengue fever, malaria, and the Zika Virus (Magalhaes et al. 2019). Many species prefer habitats with vegetation, while some breed in open, sunlit pools, and a few species use tree holes or the lower parts of the leaves of particular trees. Numerous factors, such as temperature of the water, movements, cover of vegetation, source of water, and depth, impact the development and dissemination of mosquito larvae in aquatic surroundings (Medeiros-Sousa et al. 2020). Nutrition also has a significant impact on the reproductive abilities of female mosquitoes and their larval growth, suggesting that deficiency in food during both adult and larval periods could influence their ability for reproduction (Dittmer and Gabrieli 2020). Since mosquitoes begin their lives as eggs, the procedures of laying eggs, larval growth, as well as other developing processes that occur in mosquito environments are crucial in determining the abundance and distribution of mosquitoes (Dittmer and Gabrieli 2020). Since mosquitos actively seek acceptable environments instead of haphazardly occupying them, collecting larval mosquitoes aids in estimating mosquito needs for site selection and survival. The developmental progress of growing adults is influenced by the selection of habitat, which dictates distribution patterns, density, development time, body size, and survival (Djihinto et al. 2022).

Traditional mosquito prevention methods include indirect capturing using Ultra-Violet (UV) light and direct poisoning with insecticidal sprays and repellents. However, continued use of these techniques may result in insecticide tolerance and have a negative impact on the natural world and human well-being (Kitching 2020). According to (Rolff et al. 2019), mosquito species are holometabolic insects that go through aquatic immature phases (larvae and pupae) before emerging as terrestrial adults. The intestinal epithelial is essential to the physiology and function of mosquitoes as adults, which differ physically from larvae (Hixson et al. 2021). Widespread malaria is caused by a number of mosquito species, including *Aedes*, *Culex*, *Anopheles*, and *Mansonia* (Santi et al. 2021). While *Culex* mosquitoes are frequent transmitters of diseases like West Nile Virus, *Aedes* mosquitoes are significant arbovirus vectors of chikungunya, rift vally fever and Mayaro virus (Velu et al. 2021). Although a few investigations have documented the virome for individual mosquitoes, research has attempted to sequence the virome of these genera (Shi et al. 2019).

In Jigawa State, Nigeria, the identification of mosquito species and their participation in malaria transmission has been the subject of numerous studies. Jigawa State is a state in northwest Nigeria. It is bordered to the west by Kano and Katsina, to the east by Bauchi, to the northeast by Yobe, and the north by an international boundary with the Zinder Region of Niger. This arrangement facilitates cross-border trade. Major tribes, including the Hausa, Fulani, and Kanuri, live in the state with Dutse as its capital. Investigators have mapped the distribution of mosquito species and studied their activity and breeding patterns in local governments in Jigawa State and nearby states like Kano, Katsina, and Bauchi. The results of these investigations have provided important information regarding the types of mosquitoes that are common in various areas (Chukwuekezie et al. 2020). *Anopheles* mosquitoes, the main malaria vectors, are quite prevalent in Kano, particularly in peri-urban and rural areas with standing water. The extensive *Aedes* mosquito population in urban areas of Katsina suggested possible dangers for illnesses other than malaria, like dengue fever. According to Shi et al. (2019), Bauchi's research revealed that *Culex* mosquitoes, which are abundant in densely populated areas and thrive in contaminated water bodies, are a significant factor in the spread of filariasis and malaria.

This study aims to determine the types of mosquitoes that are present in the Takur Adu'a and Yakasai Regions of Jigawa State's Dutse Local Government Area, Nigeria and evaluate their contribution to the spread of disease. The study highlights the necessity of ongoing education, successful vector control methods, and creative solutions to lower the health concerns brought on by mosquito populations. By gaining an understanding of the distribution and behavior of mosquito species in Takur Adu'a and Yakasai, this research can help create targeted interventions to lessen the effect of mosquito-borne diseases in Jigawa State.

MATERIALS AND METHODS

Study area

Jigawa State is one of the 36 states that constitute the Federal Republic of Nigeria, it is a state of central northern Nigeria with Dutse as the state capital. It’s located in the northwestern part of the country. Kano and Katsina states shared a border with Jigawa to the west, Bauchi to the east, and Yobe to the northeast. To the north, Jigawa shared an international border with the Zindar Region in the Republic of Niger, which is a unique opportunity for cross-border trading activities. The government readily took advantage of this by initiating and establishing a trade zone at the border town of Maigatari to the country of Niger; Hausa, Fulani, and Kanuri are the major tribes in the state. Dutse; latitude and longitude 12.4382° N, 8.6161° E.

Sample collection

All the equipment was gathered, the homes where the PSC would be conducted were identified, the head of the household was notified, and permissions were received, ideally the day before collection; samples were collected at different sites in both Takur Adu’a and Yakasai Areas. Materials such as Forceps, Petri dish, White sheet, Hand glove, Pyrethrum Spray Catch (PSC) have been used for sample collection. PSC should have been conducted early in the morning, approximately 5 am to 8 am. The house was prepared early in the morning, with all occupants and animals having remained outside. Exposed food and drinking water were covered, and any water pots that could not be moved were covered. White sheets (fabric) were spread over the entire floor, over the bed, and over furniture; all windows and doors were closed. The surfaces that mosquitoes may have been resting on, including the walls and ceiling, were sprayed (Pryce et al. 2022).

After the entire room has been sprayed, the operator immediately leaves the house and ensures the door remains closed for 10 minutes while waiting for the mosquitoes to be eradicated. Therefore, to contain the mosquitoes, the door was closed, starting from the doorway, and the sheets were taken one at a time from the corners. Each mosquito was quickly placed in a petri dish (Figure 1) until processed and stored long-term (Montoya et al. 2022).

Morphological identification of mosquitoes

The keys of Gillies and Coetzee (2019) were used for the identification of *Anopheles* species, while the identification key of Gilleth (2015) was used for *Culex* identification and Aedes mosquitoes. Mosquitoes were identified morphologically by using a microscope; male mosquitoes are identified by their feathery antennae and beard, while female ones are identified by the absence of feathery antennae and beard (Figure 2). *Anopheles* mosquitoes were identified by the palp, which is as long as the proboscis and pointed, and by the number, length, and arrangement of the dark and pale scales in small blocks on the veins of the wings. Male and female *Anopheles* mosquitoes were ide ntified by examination of antennae, in which those with feathery (plumose) appearance are males and those with only short and inconspicuous antennal hairs are females (Figure 2) (Supriyono et al. 2022).

The fed and unfed mosquitoes were identified under a microscope. Fed mosquitoes were identified by observing their stomachs; the stomach of the fed mosquito was red due to the presence of blood, while the unfed mosquito's stomach was white due to the absence of blood (Figure 3). Most mosquitoes that feed on blood are females. They need the nutrients from blood to produce eggs.

Culex mosquitoes have blunt abdomens, and their wings are usually clear without spots (Kang et al. 2020). Their body is usually brownish, and the palps (sensory organs near the mouthparts) are shorter than the proboscis (elongated mouthpart). The larvae rest parallel to the water surface; *Aedes* mosquitoes are known for their striking black and white markings on the body and legs. They have a pointed abdomen and their wings are also clear (Figure 2). *Aedes* mosquitoes are typically smaller and have shorter palps compared to the proboscis. They often have a more aggressive appearance and are commonly associated with daytime biting (Tallon et al. 2019). *Anopheles* mosquitoes, particularly *Anopheles gambiae*, are distinguishable by their palps, which are as long as their proboscis (Supriyono et al. 2022). Their wings often have dark and pale spots on the veins, and they have slender bodies compared to *Culex* and *Aedes*. When at rest, their bodies form an angle with the surface they are resting on rather than lying flat. Their larvae lie parallel to the water surface, but they have a unique head-down position (Figure 1). Non *A. gambiae* mosquitoes share many features with *A. gambiae*; both species their wings that often have dark and pale spots on the veins, and they have more slender body in corresponding to other species. The main difference between *A. gambiae* and non *A. gambiae* is the egg-laying pattern; the mosquito's life cycle starts from egg to adult (Figure 4).

Figure 1. Sample collection of mosquitoes

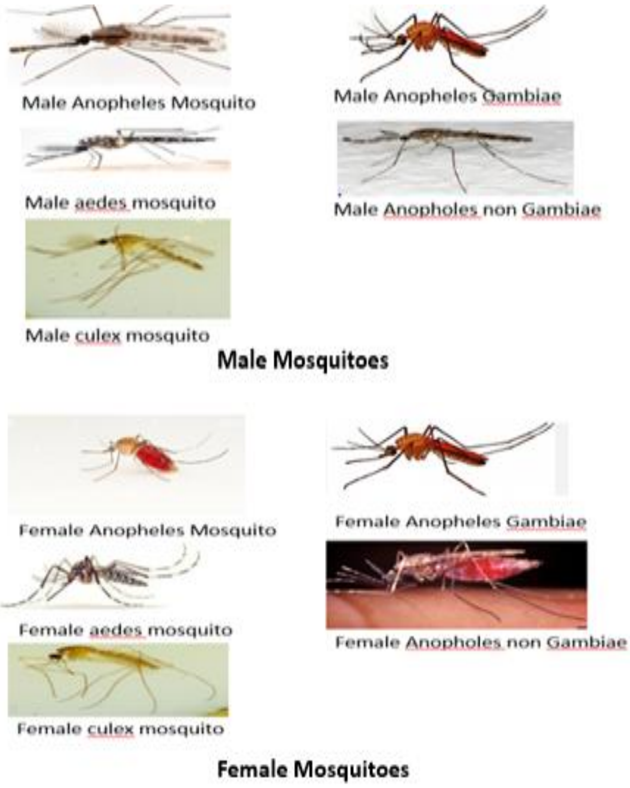

Figure 2. Male and female morphological identification of mosquito species

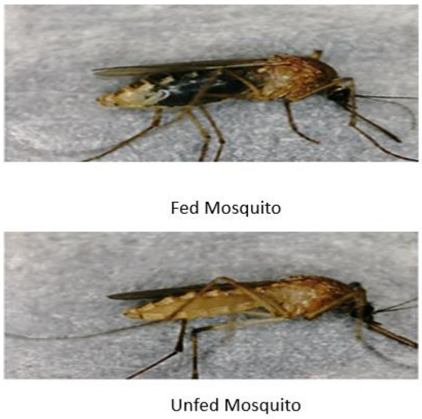

Figure 3. Fed and unfed mosquito

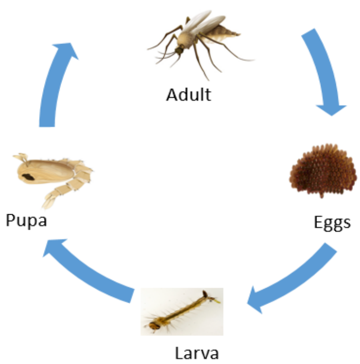

Figure 4. Mosquito life cycle

The main features to look for are the wing patterns, body shape, and resting positions. Male and female *Anopheles* mosquitoes can be differentiated based on their antennae; those with feathery antennae are male, while those with short antennae are female (Coetzee 2020). *Culex* has clear wings and a blunt abdomen, distinctive black and white markings, and a pointed abdomen. The *A. gambiae* has spotted wings and long palps, while non *A. gambiae* species have dark and pale spots on the veins (Namgay et al. 2020).

In order to gather information on the methods employed by individuals to prevent mosquito bites, a structured questionnaire was designed and administered to the respondents. The primary question asked was: "What method do you use to prevent mosquito bites?" Five possible preventive measures were presented as options for the respondents to choose from: (i) Use of bed nets, (ii) Use of mosquito repellent, (iii) Use of insecticide, (iv) Use of screens on windows and doors, (v) Use of fans. Respondents were instructed to select one or more of the options that they practiced regularly. The questionnaire was distributed to a sample population of individuals from the Takur adu'a and Yakasai area of Jigawa State, and responses were recorded for further analysis.

RESULTS AND DISCUSSION

This study aimed at identifying mosquito species in two selected areas, Takur Adu'a and Yakasai. These areas were chosen due to their environmental conditions—numerous drainages, farming activities, and sewage systems—which create ideal breeding grounds for mosquitoes, leading to a higher population density. A total of 449 mosquito samples were collected, with 278 samples from Takur Adu'a and 171 from Yakasai. This sampling effort reflects the researchers' intent to gather a comprehensive representation of mosquito species in these regions. The significant number of samples enables a robust analysis of the mosquito population and allows for more accurate identification of species, which is crucial in understanding potential health risks in the community, especially in relation to mosquito-borne diseases. The differences in sample sizes between the two areas may indicate varying environmental factors that influence mosquito breeding, such as water sources, human activities, and waste management.

Discussion

In Takur Adu'a and Yakasai Areas, 449 mosquitoes' species were collected; 278 were collected from Takur Adu'a, and 171 were collected and morphologically classified from Jigawa State's Yakasai Region. Table 1 shows the frequency and proportion of several mosquito species, broken down by sex, that are found in the Takur Adu'a Area. *Aedes, Culex, Anopheles, A. gambiae,* and non *A. gambiae* are among the species that were observed; mosquitoes were collected at three sites in Takur Adu'a, among which 94 mosquitoes were collected from site A, 114 from site B, and 70 from site C. There were 50 mosquitoes altogether, consisting of 21 females and 29 males, belonging to the *Aedes* species. This signifies an observable and impactful occurrence in the surrounding area, augmenting the total count of mosquitoes. A stable breeding population may be indicated by the reasonably balanced ratio of females to males of *Aedes* mosquitoes (O'Leary and Adelman 2020). The greatest frequency was found in *Culex* mosquitoes, with 82 females and 52 males totaling 134 individuals. This dominance implies that the most common species of mosquitoes in the area are *Culex* mosquitoes. Since female mosquitoes are largely responsible for biting and spreading illnesses, the higher number of females compared to males may have repercussions for disease transmission (Xia et al. 2021). There were 24 male and 35 female mosquitoes in the *Anopheles* species. Considering that many *Anopheles* mosquitoes are malaria vectors, this species is vital to public health awareness (Djihinto et al. 2022). There may be a risk of malaria transmission due to the slightly increased number of females (Sumner et al. 2021). There were 7 female and 4 male *A. gambiae* mosquitoes in all. The *A. gambiae*, which is well-known for its effectiveness in spreading malaria, is present but in very small numbers (Ahadji-Dabla et al. 2019). It may be required to implement ongoing control and monitoring procedures to stop possible outbreaks. Finally, there were a total of 24 species in the non *A. gambiae* category, comprising 8 females and 16 males. In comparison to other species, there may be a distinct pattern in the population dynamics or breeding behavior indicated by the greater proportion of males.

This study revealed that *Aedes* and *Anopheles* mosquitoes are the next most common species in the Takur Adu'a Area, after *Culex* mosquitoes. The information emphasizes how crucial it is to concentrate on *Culex* control strategies while also taking into account *Anopheles* species—particularly *A. gambiae*—and their implications for public health awareness. The distribution by gender shows that there are more females than males in each species, highlighting the possibility of disease transmission and the urgent need for immediate, focused vector control measures. Table 1 also gives the Takur Adu'a Areas fed and unfed mosquito frequency and percentage of occurrence. The information makes a distinction between mosquitoes that have been fed (fed blood) and those that have not (unfed blood). Fed and unfed mosquitoes were collected and identified from the three sites: site A 76 mosquitoes were fed; site B, 58, and site C, 64 mosquitoes were identified; unfed mosquitoes from site A were 18, and site B, 56 and 6 from site C.

Table 1 shows that 198 mosquitoes, or 71.2% of the entire mosquito population measured, were noted as fed. There is likely a significant amount of host-seeking and feeding activity in the area based on the high percentage of fed mosquitoes. Given that female mosquitoes are frequently the ones who transmit viruses through their bites, the prevalence of such a high percentage of fed insects plays a major role in the possible transmission of diseases carried by mosquitoes. However, 80 mosquitoes, or 28.8% of the overall population, were found to be unfed.

Even while this percentage is lower than that of fed mosquitoes, it nevertheless indicates a sizable component of insects that have not yet consumed blood. If these unfed mosquitoes get sick after feeding, they may aggressively seek out humans, increasing the risk of bites and disease transmission (Shaw et al. 2020).

Table 1. Frequency and percentage of occurrence of the mosquito species in Takur Adu'a Area, Jigawa State, Nigeria

Species	*Aedes*	*Culex*	*Anopheles*	*Anopheles gambiae*	Non *Anopheles gambiae*
Female	21	82	35	7	8
Male	29	52	24	4	16
Total	50	134	59	11	24

Species	Sites of collection			
	A	B	C	Total
Aedes	14	26	10	50
Culex	52	47	35	134
Anopheles	17	24	18	59
Anopheles gambiae	3	6	2	11
Non *Anopheles gambiae*	8	11	5	24
Total	94	114	70	278

Frequency and percentage of occurrence of fed and unfed mosquitoes in Takur Adu'a Area

Species	Frequency	Percentage (%)
Fed	198	71.2
Unfed	80	28.8
Total	278	100

Species	Collection site	Frequency	Percentage (%)
Fed	Site A	76	27.3
	Site B	58	20.9
	Site C	64	23.0
Unfed	Site A	18	6.5
	Site B	56	20.1
	Site C	6	2.2
Total	3	278	100

Table 2. Frequency and percentage of occurrence of the mosquito species in the Yakasai Area, Jigawa State, Nigeria

Species	*Aedes*	*Culex*	*Anopheles*	*Anopheles gambiae*	Non *Anopheles gambiae*
Female	17	42	12	8	5
Male	12	50	16	6	3
Total	29	92	28	14	8

Species	Sites of collection			
	A	B	C	Total
Aedes	11	8	10	29
Culex	38	27	27	92
Anopheles	9	12	7	28
Anopheles gambiae	4	7	3	14
Non *Anopheles gambiae*	3	4	1	8
Total	65	58	48	171

Frequency and percentage of occurrence of fed and unfed mosquitoes in Yakasai Area

Species	Frequency	Percentage (%)
Fed	99	57.9
Unfed	72	42.1
Total	171	100

Species	Collection site	Frequency	Percentage (%)
Fed	Site A	38	22.2
	Site B	27	15.8
	Site C	34	19.9
Unfed	Site A	27	15.8
	Site B	31	18.1
	Site C	14	8.2
Total	3	171	100

The study showed that 278 mosquitoes were scanned across the Takur Adu'a region, with the majority found to be fed. This indicates the presence of large vectors and the risk of spreading diseases such as dengue fever, malaria, and other mosquito-borne diseases. Hence, public health officials, researchers, and policymakers must take the lead in monitoring and managing mosquito populations in these areas. By reducing the number of feeding mosquitoes, we can effectively manage and minimize the health hazards associated with mosquito bites.

Table 2 presents the frequency and proportion of several mosquito species, broken down by sex, that are found in Yakasai Area. *Aedes*, *Culex*, *Anopheles*, *A. gambiae*, and non *A. gambiae* are among the species that were found. In Yakasai Area, mosquitoes were collected at three sites: site A, 65 mosquitoes were collected from all species; site B, 58, and site C, 48 mosquitoes were collected from all species.

There were a total of 29 mosquitoes, comprising 12 male and 17 female members of the *Aedes* species. Although not the most common species, this mosquito species makes up quite a large portion of the local mosquito population. According to Gouveia-Oliveira and Pedersen (2020), the generally balanced ratio of males to females points to a stable population dynamic. This stability can have significant consequences for the spread of disease, as a balanced ratio means more potential carriers for diseases like dengue fever and Zika. *Aedes* mosquitoes are known to carry these diseases. The most frequent mosquito species was *Culex*, with 42 females and 50 males totaling 92 individuals. This suggests that the most common species in Yakasai Region is *Culex*. The slightly larger male-to-female ratio may have an impact on population dynamics and total breeding. Because *Culex* mosquitoes are important carriers of diseases, including filariasis and the West Nile Virus, monitoring and control of this species is essential. There were 12 female and 16 male *Anopheles* mosquitoes in the species. This species is important from the standpoint of public health because *Anopheles* mosquitoes are the main carriers of malaria. The greater proportion of males than females may indicate a shift in the population's structure or recent environmental changes that have an impact on mosquito breeding habits. There were 8 female and 6 male *A. gambiae* mosquitoes in total. The *A. gambiae* is present in relatively small quantities, but because of how well it spreads malaria, it is important. The nearly equal proportion of men and females points to a stable population, which calls for ongoing monitoring and preventative efforts to lower the risk of malaria. There were 3 males and 5 females in the non *A. gambiae* group, for a total of 8 mosquitoes. The fact that there are fewer non *A. gambiae* mosquitoes than other species shows that they are the least common. They should not be disregarded, though, as they may nevertheless raise the risk of mosquito-borne illness in general.

Table 3. Distribution of respondents based on their knowledge of practices for mosquito bite prevention in Takur Adu'a and Yakasai Area of Jigawa State, Nigeria

Responses	**Frequency**	**Percentage (%)**
Bed net	30	42.9
Use of repellent	10	14.3
Use of insecticides	15	21.4
Use of screens in windows and doors	10	14.3
Use of fan	5	7.1
Total	70	100

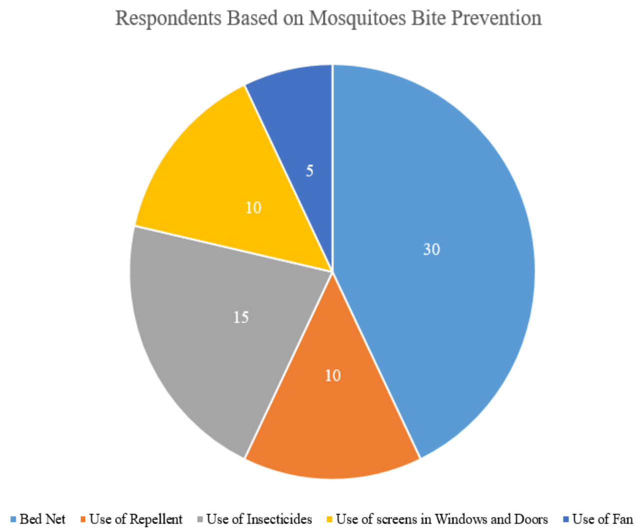

Figure 5. Respondents based on mosquitoes bite prevention

Aedes and *Anopheles* mosquitoes are the next most common species in Yakasai Region, behind *Culex* mosquitoes. According to the research, there are different mosquito populations, which can have different effects on the spread of disease. The prevalence of *Anopheles* and *A. gambiae* highlights the significance of malaria prevention methods, whereas the greater number of *Culex* mosquitoes indicates a focus on controlling this species. The distribution of genders among species emphasizes the necessity of focused interventions to control the feeding and breeding habits of female mosquitoes, which are principally in charge of spreading disease (Dahalan et al. 2019).

Table 2 also gives the number and percentage of fed and unfed mosquitoes that are present in Yakasai Area. The information distinguishes between mosquitoes that have been fed (fed) and unfed (unfed) blood meals. In Yakasai Area, fed and unfed mosquitoes were collected from the three sites; in site A, 38 mosquitoes were identified as fed under a microscope, 27 from site B, and 34 from site C, and there are 27 unfed mosquitoes from site A, 31 from site B, and 14 mosquitoes from site C, from the all species.

Table 2 shows that 99 mosquitoes, or 57.9% of the total mosquito population measured, were noted as fed. The aforementioned suggests that a significant proportion of mosquitoes in the Yakasai Region have exhibited host-seeking and feeding behaviors. Since fed female mosquitoes are the main carriers of mosquito-borne illnesses like dengue, Zika, and malaria, the high percentage of fed mosquitoes is alarming. The higher risk of disease transmission in the area indicated by this high proportion calls for the implementation of appropriate vector control and public health initiatives (Shaw et al. 2020). However, 72 mosquitoes, or 42.1% of the overall population, were found to be malnourished. Even while this percentage is lower than that of fed mosquitoes, it nevertheless indicates a sizable component of insects that have not yet consumed blood. Since these unfed mosquitoes are probably actively looking for victims, if they get infected after feeding, there may be a higher chance of bites and subsequent disease spread.

The 171 mosquitoes in Yakasai Area were surveyed. According to the data, a significant proportion of the mosquito population is feeding, which emphasizes the necessity of focused mosquito control efforts. Reducing the number of feeding mosquitoes through interventions including insecticide-treated nets, indoor residual spraying, and environmental management could greatly decrease the risk of disease transmission. Furthermore, it is critical to monitor and manage the population of fed mosquitoes to stop them from spreading disease after feeding (Jones et al. 2020). The results of this study are of paramount importance, as they highlight how crucial it is to implement comprehensive mosquito control measures in the Yakasai Region to maintain public health.

Table 3 and Figure 5 show the respondents' distribution according to their understanding of preventative measures against mosquito bites. The population's knowledge and protective measures against mosquito bites are reflected in the data, which is important in reducing diseases spread by mosquitoes. The table divides the respondents into two groups: those who know how to prevent mosquito bites and those who don't. The statistics showed that a sizable percentage of responders had information regarding preventing mosquito bites. This suggests that people are generally well-informed, which is encouraging for public health programs. In order to effectively avoid mosquito bites and the spread of disease, knowledgeable people are more likely to adopt preventative measures, including using insect repellent, donning protective clothes, and placing screens on windows and doors (Duval et al. 2023). However, it also shows that some of the respondents were ignorant of precautions against mosquito bites. This awareness gap is concerning because those who are unaware of preventive measures have a higher risk of contracting diseases linked to mosquito bites. This emphasizes the need for focused educational efforts and environmental outreach initiatives to increase public awareness and educate the public about practical methods to prevent mosquito bites. These initiatives might involve distributing educational materials, setting up workshops, and using media outlets to spread knowledge. The information also emphasizes the significance of ongoing instruction and reinforcement of preventative measures against mosquito bites. It is important to ensure that these techniques are applied continuously, even by qualified individuals. In order to encourage long-term behavioral change and assist the populace in implementing and upholding efficient preventative measures, public health officials and community leaders should collaborate (Monroe et al. 2021). The data shows that respondents have a relatively high level of knowledge regarding mosquito bite prevention, which is positive news for public health initiatives. However, addressing knowledge gaps in some populations is still important. As researchers, our role in implementing and improving educational programs and encouraging the regular use of preventative measures is crucial in reducing the prevalence of mosquito-borne diseases and improving public health in the region.

In Takur Adu'a and Yakasai locations, the analysis of the three tables offers a thorough summary of mosquito species distribution, feeding habits, and public awareness of mosquito bite avoidance. The great danger of mosquito-borne disease transmission can be seen from the large number of *Culex* mosquitoes in both areas and the high proportion of insects they feed on. Although there are still knowledge gaps, the substantial awareness of mosquito bite avoidance techniques among respondents is encouraging. This emphasizes the need for focused teaching programs to reduce the harm caused by the spread of mosquito populations. Moreover, ongoing public health education plays a crucial role in maintaining community welfare and reducing the prevalence of mosquito-borne diseases; effective vector control measures are also crucial (Suárez et al. 2020).

This study findings validate previous research that emphasizes the significant role of mosquito-borne diseases in global public health. Molecular identification methods, as outlined by Fall et al. (2021), are highly effective in detecting mosquito species that may be challenging to identify through morphological taxonomy. Fall et al. (2021) in his study collected 11,873 larvae and 4,843 adult *Culicine* mosquitoes from the sampling sites. Fourteen species from three genera—*Aedes, Culex,* and *Mansonia*—were identified, including *Anopheles theileri*, *Culex mimeticus*, *Culex pipiens*, and *A. gambiae*. These results are consistent with the findings of this work.

In conclusion, the findings of the Jigawa State study offer vital information about mosquito species identification, their function in the spread of malaria, and practical preventative measures. Numerous mosquito species are significantly present, especially *Culex* and *Anopheles*, which are known to carry diseases like malaria. The higher risk of disease transmission in Takur Adu'a and Yakasai is highlighted by the high percentage of fed mosquitoes, which highlights the active host-seeking and feeding activity of female mosquitoes. The *A. gambiae*, the main malaria vector, could be distinguished from other mosquito species using the morphological identification techniques that were used. In line with earlier studies, the study also proved the usefulness of molecular techniques for mosquito identification, highlighting the significance of precise species identification in public health initiatives. Although there are still information gaps, the general public's awareness of mosquito bite avoidance measures is typically high, highlighting the necessity for ongoing education programs. Efficient vector control tactics, like insecticide-treated nets, indoor residual spraying, and environmental management, are critical for lowering the number of mosquitoes carrying food and lowering the chance of disease spread. Conclusively, this research offers significant insights into the identification of mosquito species, their function in the transmission of malaria, and strategies for averting mosquito-borne illnesses. The results highlight the need for focused vector control strategies and ongoing public health education to shield Jigawa State communities from the serious health hazards associated with large mosquito populations.

ACKNOWLEDGEMENTS

We want to thank the Department of Biological Science, a Federal University Dutse, Nigeria, for providing adequate facilities and materials to conduct this research.

REFERENCES

Ahadji-Dabla K, Amoudji AD, Nyamador SW, Apétogbo GY, Chabi J, Glitho IA, Ketoh GK. 2019. High levels of knockdown resistance in *Anopheles coluzzii* and *Anopheles gambiae* (Diptera: Culicidae), major malaria vectors in Togo, West Africa: A 2011 monitoring report. J Med Entomol 56: 1159-1164. DOI: 10.1093/jme/tjz030.

Chukwuekezie O, Nwosu E, Nwangwu U, Dogunro F, Onwude C, Agashi N, Ezihe E, Anioke C, Anokwu S, Eloy E, Attah P, Orizu F, Ewo S, Okoronkwo A, Joseph A, Ikeakor I, Haruna S, Gnanguénon V. 2020. Resistance status of *Anopheles gambiae* (s.l.) to four commonly used insecticides for malaria vector control in South-East Nigeria. Parasites Vectors 13: 152. DOI: 10.1186/s13071-020-04027-z.

Coetzee M. 2020. Key to the females of Afrotropical *Anopheles* mosquitoes (Diptera: Culicidae). Malar J 19: 70. DOI: 10.1186/s12936-020-3144-9.

Dahalan F, Churcher T, Windbichler N, Lawniczak M. 2019. The male mosquito contribution towards malaria transmission: Mating influences the *Anopheles* female midgut transcriptome and increases female susceptibility to human malaria parasites. PLoS Pathog 15 (11): e1008063. DOI: 10.1371/journal.ppat.1008063.

Dittmer J, Gabrieli P. 2020. Transstadial metabolic priming mediated by larval nutrition in female *Aedes albopictus* mosquitoes. J Insect Physiol 123: 104053. DOI: 10.1016/j.jinsphys.2020.104053.

Djihinto O, Medjigbodo A, Gangbadja A, Saizonou H, Lagnika H, Nanmede D, Djossou L, Bohounton R, Sovegnon P, Fanou M, Agonhossou R, Akoton R, Moussé W, Djogbénou L. 2022. Malaria-transmitting vectors microbiota: overview and interactions with *Anopheles* mosquito biology. Front Microbiol 13: 891573. DOI: 10.3389/fmicb.2022.891573.

Duval P, Aschan-Leygonie C, Moro C. 2023. A review of knowledge, attitudes, and practices regarding mosquitoes and mosquito-borne infectious diseases in nonendemic regions. Front Public Health 11: 1239874. DOI: 10.3389/fpubh.2023.1239874.

Fall F, Laroche M, Bossin H, Musso D, Parola P. 2021. Performance of MALDI-TOF mass spectrometry to determine the sex of mosquitoes and identify specific colonies from French Polynesia. Am J Trop Med Hyg 104 (5): 1907-1916. DOI: 10.4269/ajtmh.20-0031.

Gilleth 2015. Mosquito species diversity and distribution in three riverine communities in Taraba State, North-Eastern Nigeria. IOSR J Pharm Biol Sci 12 (2): 21-28. DOI: 10.9790/3008-1202032128.

Gillies MT, Coetzee M. 2019. A supplement to the Anophelinae of Africa South of the Sahara (Afrotropical region). South African Institute for Medical Research, Johannesburg.

Girard M, Martin E, Vallon L, Raquin V, Bellet C, Rozier Y, Desouhant E, Hay A, Luis P, Moro C, Minard G. 2021. Microorganisms associated with mosquito oviposition sites: implications for habitat selection and insect life histories. Microorganisms 9 (8): 1589. DOI: 10.3390/microorganisms9081589.

Gouveia-Oliveira R, Pedersen A. 2020. Higher variability in the number of sexual partners in males can contribute to a higher prevalence of sexually transmitted diseases in females. J Theor Biol 261: 100-106. DOI: 10.1016/j.jtbi.2009.06.028.

Hixson B, Taracena ML, Buchon N. 2021. Midgut epithelial dynamics are central to mosquitoes' physiology and fitness, and to the transmission of vector-borne disease. Front Cell Infect Microbiol 11: 653156. DOI: 10.3389/fcimb.2021.653156.

Jones RT, Ant TH, Cameron MM, Logan JG. 2020. Novel control strategies for mosquito-borne diseases. Philos Trans R Soc B Biol Sci 378: 0802. DOI: 10.1098/rstb.2019.0802.

Kang D, Kim S, Cotten M, Sim C. 2020. Transcript assembly and quantification by RNA-Seq reveals significant differences in gene expression and genetic variants in mosquitoes of the *Culex pipiens* (Diptera: Culicidae) complex. J Med Entomol 58: 139-145. DOI: 10.1093/jme/tjaa167.

Kitching 2020. Biological Control of Mosquito Vectors: Past, Present, and Future. Insects, 7 040052.

Magalhaes T, Bergren N, Bennett S, Borland E, Hartman D, Lymperopoulos K, Sayre R, Borlee B, Campbell C, Foy B, Olson K, Blair C, Black W, Kading R. 2019. Induction of RNA interference to block Zika Virus replication and transmission in the mosquito *Aedes aegypti*. Insect Biochem Mol Biol 111: 103169. DOI: 10.1016/j.ibmb.2019.05.004.

Medeiros-Sousa A, Oliveira-Christe R, Camargo A, Scinachi C, Milani G, Urbinatti P, Natal D, Ceretti-Junior W, Marrelli M. 2020. Influence of water's physical and chemical parameters on mosquito (Diptera: Culicidae) assemblages in larval habitats in urban parks of São Paulo, Brazil. Acta Trop 205: 105-394. DOI: 10.1016/j.actatropica.2020.105394.

Monroe A, Olapeju B, Moore S, Hunter G, Merritt A, Okumu F, Babalola S. 2021. Improving malaria control by understanding human behaviour. Bull World Health Organ 99: 837-839. DOI: 10.2471/blt.20.285369.

Montoya LF, Alafo C, Martí-Soler H, Máquina M, Comiche K, Cuamba I, Munguambe K, Cator L, Aide P, Galatas B, Cuamba N, Marrenjo D, Saúte F, Paaijmans KP. 2022. Overlaying human and mosquito behavioral data to estimate residual exposure to host-seeking mosquitoes and the protection of bednets in a malaria elimination setting where indoor residual spraying and nets were deployed together. PLoS ONE 17 (9): e0270882. DOI: 10.1371/journal.pone.0270882.

Namgay R, Pemo D, Wangdi T, Phanitchakun T, Harbach RE, Somboon P. 2020. Molecular and morphological evidence for sibling species within *Anopheles* (*Anopheles*) lindesayi Giles (Diptera: Culicidae) in Bhutan. Acta Trop 207: 105455. DOI: 10.1016/j.actatropica.2020.105455.

O'Leary S, Adelman Z. 2020. CRISPR/Cas9 knockout of female-biased genes *AeAct-4* or *myo-fem* in *Ae. aegypti* results in a flightless phenotype in female, but not male mosquitoes. PLoS Negl Trop Dis 14 (12): e0008971. DOI: 10.1371/journal.pntd.0008971.

Pryce J, Medley N, Choi L. 2022. Indoor residual spraying for preventing malaria in communities using insecticide-treated nets. Cochrane Database Syst Rev 1: CD012688. DOI: 10.1002/14651858.CD012688.pub3.

Rolff J, Johnston PR, Reynolds S. 2019. Complete metamorphosis of insects. Philos Trans R Soc B Biol Sci 374: 1783. DOI: 10.1098/rstb.2019.0063.

Santi V, Khaireh B, Chiniard T, Pradines B, Taudon N, Larréché S, Mohamed A, Laval F, Berger F, Gala F, Mokrane M, Benoît N, Malan L, Abdi A, Briolant S. 2021. Role of *Anopheles stephensi* mosquitoes in malaria outbreak, Djibouti, 2019. Emerg Infect Dis 27: 1697-1700. DOI: 10.3201/eid2706.204557.

Shaw R, Holmdahl I, Itoe M, Werling K, Marquette M, Paton D, Singh N, Buckee C, Childs L, Catteruccia F. 2020. Multiple blood feeding in mosquitoes shortens the *Plasmodium falciparum* incubation period and increases malaria transmission potential. bioRxiv 16 (12): e991356. DOI: 10.1101/2020.03.24.991356.

Shi C, Beller L, Deboutte W, Yinda KC, Delang L, Vega-Rúa A, Failloux AB, Matthijnssens J. 2019. Stable distinct core eukaryotic viromes in different mosquito species from Guadeloupe, using single mosquito viral metagenomics. Microbiome 7: 121. DOI: 10.1186/s40168-019-0734-2.

Suárez G, Udiani O, Allan B, Price C, Ryan S, Lofgren E, Coman A, Stone C, Gallos L, Fefferman N. 2020. A generic arboviral model framework for exploring trade-offs between vector control and environmental concerns. J Theor Biol 490: 110-161. DOI: 10.1016/j.jtbi.2020.110161.

Sumner K, Mangeni J, Obala A, Freedman E, Abel L, Meshnick S, Edwards J, Pence B, Prudhomme-O’Meara W, Taylor S. 2021. Impact of asymptomatic *Plasmodium falciparum* infection on the risk of subsequent symptomatic malaria in a longitudinal cohort in Kenya. eLife 10: e68812. DOI: 10.7554/eLife.68812.

Supriyono S, Soviana S, Novianto D, Musyaffa MF, Tan S, Hadi UK. 2022. Morphological characteristic of malaria vector *Anopheles aconitus* (Family: Culicidae) revealed by advanced light and scanning electron microscope. Biodiversitas 23: 3546-3552. DOI: 10.13057/biodiv/d230730.

Tallon AK, Hill SR, Ignell R. 2019. Sex and age modulate antennal chemosensory-related genes linked to the onset in the yellow-fever mosquito, *Aedes aegypti*. Sci Rep 9: 43. DOI: 10.1038/s41598-018-36550-6.

Velu RM, Kwenda G, Libonda L et al. 2021. Mosquito-borne viral pathogens detected in Zambia: A systematic review. Pathogens 10 (8): 1007. DOI: 10.3390/pathogens10081007.

Xia S, Ury J, Powell J. 2021. Increasing effectiveness of genetically modifying mosquito populations: Risk assessment of releasing blood-fed females. Am J Trop Med Hyg 104: 1895-1906. DOI: 10.4269/ajtmh.19-0729.