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Evaluation of Occurrence and Population Variations of *Culex quinquefasciatus* Mosquitoes in Selected Areas of Jigawa State, Northwest Nigeria

Kamoru A. Adeniyi[1], Oluwaseun Adegbola Adesoye[2,3], Abubakar A. Sadiq[4], Tasiu Shuaibu[1], Muzammil B. Mustapha[1], Yusuf Lamidi[5], Adedapo Adeogun[3], Israel Akinsete[6], Blessing A. Ezeonuegbu[7], Callistus A. Akinleye[8] and Oluwatoyin A. Oyeniran[9]

[1]Department of Biological Sciences, Federal University Dutse Jigawa State, Nigeria.
[2]Department of Biological Sciences, University of Abuja, FCT, Nigeria
[3]Molecular Entomology and Vector Control Unit, Nigerian Institute of Medical Research, Yaba, Lagos, Nigeria.
[4]Deparment of Biological Sciences, Sule Lamido University, Kafin Hausa, Jigawa State, Nigeria
5Department of Microbiology, Prince Abubakar Audu University, Anyigba, Kogi State, Nigeria
[6]Department of Animal Biology, Federal University of Technology, Minna, Nigeria.
[7]Deparment of Microbiology Technology, School of Science Laboratory Technology, University of Port Harcourt, Nigeria
[8]Department of Community Medicine, Osun State University, Osogbo, Nigeria
[9]Department of Medical Microbiology and Parasitology, Osun State University Teaching Hospital, Osogbo, Nigeria

Corresponding Author: oluwaseun.adesoye@uniabuja.edu.ng

ABSTRACT

Culex quinquefasciatus ecology and breeding sites, as well as the physical and chemical properties of their habitats are valid information to vector control. Thus, this study aimed to assess the occurrence and population size of *Cx. quinquefasciatus* mosquitoes that are captured in Jigawa State, northwest Nigeria. The dipping standard sampling method was employed for larval collection during the period from August to October 2023. Collected larvae were reared to adult stage and identified as *Culex quinquefasciatus.* Data obtained was analysed using SPSS version 20.0 and Analysis of Variance was employed to assess statistical difference. *Culex* mosquito were found in all breeding sites identified. The average number of identified males in Mai-lolo were 233.50±1.10 (12.40%) while that of female in the same location were 203.10±2.10 (7.76%). At Mai-alkama breeding sites the mean number of male mosquitoes were 264.22±2.00 (14.40%) which is significantly higher (ANOVA: $P = 0.3220$) than the values obtained in GRA (94.30±3.00) location. Notably, mean values of female *Cx. quinquefasciatus* Mosquitoes (281.00±0.00) in locations that includes Mai-rakumi is significantly higher (ANOVA: $P = 0.2120$) than the male (236.30±1.11) mosquitoes in the same location. *Cx. quinquefasciatus* is found to be abundant therefore, it is recommended that breeding habitats identified be eradicated and efforts to sustain public health campaigns on vector control management should be encouraged across the study location.

Keywords: *Cx. quinquefasciatus,* Breeding site, mosquito vector, lymphatic filariasis, mosquito larvae.

INTRODUCTION

Culex (*Cx.*), a genus of mosquitoes commonly regarded as common house mosquitoes, serves as the primary vector responsible for transmitting viruses associated with West Nile fever, St. Louis encephalitis, and Japanese encephalitis (Oduola *et al.,* 2017; Adesoye *et* *al.,* 2023). Additionally, these mosquitoes play a role in spreading viral diseases among birds and horses. Beyond viral transmission, *Culex* mosquitoes are implicated in the transmission of parasitic diseases, such as lymphatic filariasis, and bacterial diseases, including tularemia (Oduola *et al.,* 2017). *Culex* mosquitoes exhibits a global distribution, being found in tropical and temperate regions worldwide, excluding extremely northern latitudes. This group of mosquitoes are characterized by their nocturnal feeding habits, targeting both humans and animals. They can be found in diverse environments, both indoors and outdoors, contributing to their potential impact on public health across various geographic areas (Soto and Delang, 2023).

Some of the identified species within the *Culex* genus include: *Cx. pipiens, Cx. tarsalis, Cx. tritaeniorhynchus, Cx. nigripalpus, Cx. modestus* (Gorris *et al.,* 2021). Notably, *Cx. quinquefasciatus* is one of the most popular species within the *Culex* genera and it has been considered as one of the most important vectors of public health importance across the globe. This is because it transmits Zika virus, lymphatic filariasis, West Nile virus, St. Louis encephalitis virus, eastern equine encephalitis virus, and western equine encephalitis virus across different regions of the World (Moser *et al.,* 2023). and most importantly transmits lymphatic filariasis and West Nile virus in sub-Saharan Africa including Nigeria (Uttah *et al.,* 2013; Lupenza *et al.,* 2021; Omotayo *et al.,* 2022).

The tropical infection known as lymphatic filariasis (LF) is caused by nematodes, or thread-like worms, that live in human lymphatic capillaries and are frequently disregarded or neglected. There are three kinds of lymphatic parasites known to infect humans: *Brugia timori*, *Wuchereria bancrofti*, and *Brugia malayi* (Fimbo *et al.,* 2021). *Wuchereria bancrofti*, on the other hand, can only infect and reproduce within human cells, which serve as its exclusive host, and has been linked to 90% of human cases. Despite various interventions, there are still around 882 million people in 44 countries that are at risk from lymphatic filariasis globally (Hussaini *et al.,* 2020; Amanyi-Enegela *et al.,* 2022). Nigeria is one of the more than 70 countries in sub-Saharan Africa where lymphatic filariasis is endemic, placing an estimated 512 million people at risk of contracting the disease in the region with 28 million cases reported each year (Amanyi-Enegela *et al.,* 2022).

Mosquito vector control has been recommended as a tactic of minimizing transmission of lymphatic filariasis (Fimbo *et al.,* 2021). People may be protected from infection through mosquito bites by taking precautions such wearing personal protective equipment, indoor residual spraying, or nets impregnated with insecticide and most importantly, larviciding (Olagundoye and Adesoye, 2023; Davis *et al.,* 2021). In the past, vector control has helped eradicate lymphatic filariasis in certain situations when other preventive treatment failed or not available (Okorie *et al.,* 2013; Fimbo *et al.,* 2021).

In Nigeria, study which spans all geopolitical zones, Okorie *et al.* (2023) collated data on the prevalence, clinical symptoms, and entomological features of LF in 2013. Their study indicated that LF is present in 19 States (including Jigawa State) across all six geopolitical zones of the country. Amanyi-Enegela *et al.* (2022) examined the efforts made in the Federal Capital Territory of Abuja, Nigeria, to eradicate lymphatic filariasis which was considered to be target-based and significant in a recent study.

In order to support the effectiveness of potential vector control methods in Nigeria, it becomes vital to comprehend the preferred larval habitats of *Cx. quinquefasciatus*, their distribution in the habitat, as well as the physico-chemical properties of such habitats in a particular environment. Thus, the purpose of this study is to assess the population size of *Cx. quinquefasciatus* mosquitoes that are captured in Jigawa State, northwest Nigeria.

MATERIALS AND METHODS

Study Area

The research was conducted in the town of Biram, which has been renamed Hadejia. Hadejia is a Hausa town located in the eastern part of Jigawa State, in northern Nigeria. In 2006, the population was approximately 105,628 (Zungum *et al.*, 2019). Positioned between latitude $12^0 26' 6^0$N and longitude $10^0 3' 10^0$E, Hadejia falls within a typical Sudan savannah zone, experiencing average temperature and annual rainfall ranges from 15.86-38 °C and 491-1186 millimeters respectively (Adeniyi *et al.,* 2023). The town's primary economic activities revolve around crop farming and animal rearing, with a significant portion of the population engaged in trading, fishing, and various services, including civil service. Hadejia is situated to the north of the Hadejia River and upstream from the Hadejia-Nguru wetlands. It holds international ecological significance as an environmentally sensitive zone (Kutama *et al.,* 2016) (Figure 1).

Identification of Mosquitoes Larval Habitat/Breeding Sites

The identification of mosquitoes' larval habitat was done by regular observation of the natural breeding sites and collection of water samples to examine the mosquitoes larvae presence, these breeding sites (habitats) are grouped into gutters, septic tanks, ground pools (puddles), abandoned containers, used wheel-tires, drainages, ponds, river pets, plodded area etc. in the study as shown in Figure 2. Identified breeding sites were classified into permanent temporary and semi-permanent types (Mattah *et al*., 2017; Onyido *et al.*2019,).

Larvae Collection

The Dipping sampling method, as outlined by Lapang *et al.* (2019), was employed for larval collection during the period from August to October 2023. Collections were conducted thrice a week during the early hours of the day, typically between 6:30 and 9:00 am. The dipper was carefully lowered at a 45° angle to minimize water disturbance, allowing larvae to flow into it. Subsequently, the dipper was raised gently to prevent water spillage, and the number of mosquito larvae per dip was estimated.

Collected larvae were then transferred into plastic containers to facilitate their movement between different habitats within the selected local governments. Twenty dips were made in each examined habitat type to capture various mosquito larvae. The larvae were sourced from gutters, ponds, rice fields, potholes, and drainages. Following collection, the larvae were transported to the Insectary Department of Biological Sciences at Federal University Dutse.

Rearing of Larvae to Adults in the Insectary

The rearing of mosquito larvae into adults within the insectary adhered to the procedures outlined by Adesoye *et al.,* (2023B) and Adesoye *et al.* (2023C). The process unfolded as follows: initially, larvae gathered from the field were placed into white plastic containers, filled to two-thirds of their capacity with non-chlorinated distilled water. The container opening was covered with untreated mosquito netting, featuring a small hole at the center sealed with dry cotton wool until adult mosquitoes emerged. To nourish the larvae, yeast tablets were utilized. Ten grams of yeast were dissolved in 50ml of distilled water, and a 10% sugar solution was prepared. Daily

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feeding continued until pupae emerged. Pupae emerged after 7 days and adults after 3-4 days. To confine the adults within the container, mosquito netting was applied. Upon mosquito emergence, they were transferred to a mosquito rearing cage using an aspirator. Using a teaspoon, 2ml of the sugar solution was applied onto the cotton wool inserted through the mosquito net, dampening it as a food source for emerging adults according to a procedure described by Adesoye *et al.,* (2023C). This feeding process was repeated every two days with fresh cotton wool. The feeding regimen persisted for 5 days. The adult mosquitoes that emerged were collected using mouth aspirator and subsequently identified.

Latitude/Longitude 12° 26' 6° N/10° 3' 10° E! Time zone: UTC+1! Currency

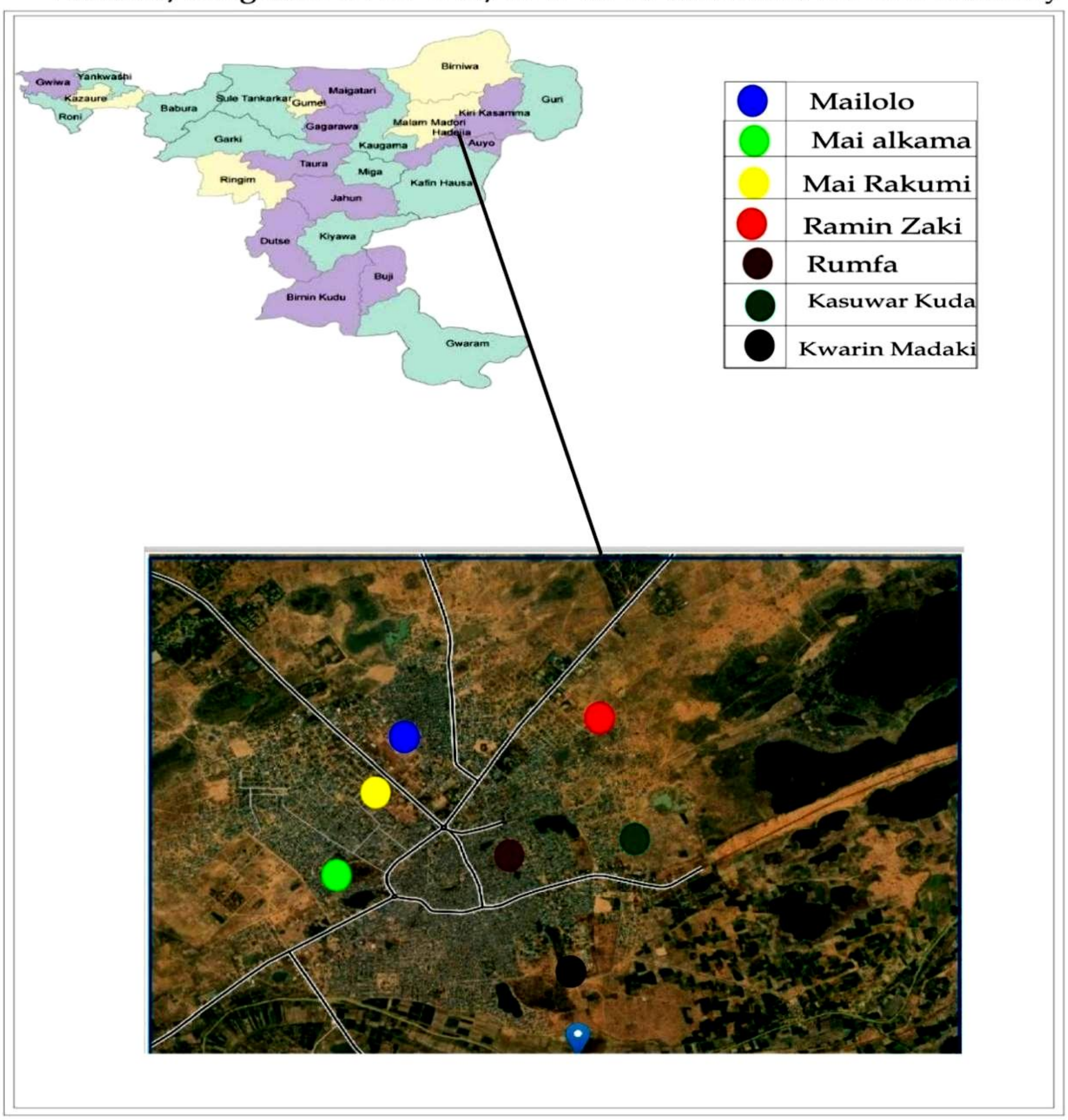

Figure 1: Map of Hadejia Showing the Breeding Sites of Mosquitoes

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Figure 2: Identified mosquito breeding sites in Hadejia metropolis, Jigawa State, Northwest Nigeria.

Key: A-Stream, **B**- Abandoned wheel-tires, **C**- Swamp, **D**- Drainage, **F**- River

Identification of Mosquitoes Species

The Morphological identification of *Culex* and other mosquito group species was done using a describe method by Kayedi *et al.* (2020). Adult *Culex* mosquitoes that emerged were put into the refrigerator for 20 hours at 4^{o}C. *Cx. quinquefasciatus* were identified, after which the male and female were separated by their morphological features as the body colour, nature of the antennae, palps and the marking on the thorax. Also, prior to the identification, the male mosquitoes were differentiated from females using the hairy nature of antennae, and the length of the palps (Mattah *et al.,* 2017).

Data Analysis

The larvae gathered were quantified in mean and presented in tables utilizing the Statistical Package for Social Sciences (SPSS version 20.0, Inc., Chicago, IL, United State of America, USA) and Graph Prism Statistical software (Prism, GraphPad Software, San Diego, CA, USA). To assess differences in larval numbers across various breeding sites, One-way Analysis of Variance (ANOVA) at 95% (P = 0.05) was employed.

RESULTS

Table 1 shows locations, coordinates and corresponding economic status of different mosquito breeding sites in the study area. Garko, Mai-lolo, Mai-alkama among others were among places where larvae were collected.

Table 1: Anthropogenic activities at different breeding sites of *Culex* mosquitoes in Hadejia metropolis, Jigawa State

Serial number	Locations	Anthropogenic activities	GPS coordinates
1	GRA	Urban settlement	Latitude: 11.707347; Longitude :9.3593980
2	Garko	Business site	Latitude:11.72230; Longitude:9.366.206
3	Mai – lolo	Semi-urban	Latitude: 11.693505; Longitude: 9.3295450
4	Mai –alkama	Farming	Latitude: 11.7061980; Longitude: 9.359870
5	Mai-rakumi	Semi-urban	Latitude: 11.693338; Longitude:9.320943
6	Raminzaki	Car wash site	Latitude:11.71343; Longitude:9.361995
7	Rumfa	Urban site	Latitude: 11.6851910; Longitude: 9.351644
8	Kasuwarkuda	Urban site	Latitude: 11.594291; Longitude: 9.261544
9	Kwarinmadaki	Urban site	Latitude :11.714130; Longitude:9.362884

Abbreviations: GRA Government Reserved area.

There are other genera of mosquitoes such as *Anopheles* and *Aedes* co-breeding with *Culex* in every site identified in the present study, however, emphasis is principally laid on *Culex* mosquitoes. A mean total of 4,523±1.42 (100%) *Culex* larvae were sampled and identified. Of this samples, breeding sites in Raminzaki has the highest (680.30±1.10) which is significantly higher (ANOVA: *P* = 0.0020) than the lowest sample size collected from Government Reserved area (GRA) (265.10±1.00). However, samples collected from Raminzaki is not significantly (ANOVA: *P* = 0.06450) different from samples from Mai-rakumi (617.25±2.11) and Mai-alkama (670.10±2.20). Generally, samples collected from urban centers are quite minimal and majority of them are not significantly different from each other (Table 2).

Table 2: Distribution of *Culex* larvae collected across all breeding sites in Hadejia metropolis, Jigawa State

S/N	Location	Mean Number of *Culex* larvae collected	Rate (%) of occurrence
1	Mai-lolo	439.11±1.51b	9.70
2	Mai-alkama	671.10±2.20c	14.83
3	Mai-rakumi	617.25±2.11c	13.62
4	Garko	517.10±1.42b	11.43
5	Raminzaki	680.30±1.10c	15.03
6	Rimfa	469.23±1.51b	10.36
7	Kwarinmadaki	466.11±2.20b	10.30
8	Kasuwarkuda	496. 20±1.50b	10.96
9	GRA	265.10±1.00a	5.85
Total		4,523±1.42	100

Subscripts with different alphabets along the column are significantly different at $P<0.05$; Abbreviations: GRA Government Reserved area.

Table 3 shows the sex distribution of male and female *Culex* mosquitoes reared from larvae collected from different breeding sites. The average number of identified males in Mai-lolo were 233.50±1.10 (12.40%) while that of female in the same location were 203.10±2.10 (7.76%). At Mai-alkama breeding sites the mean number of male mosquitoes were

264.22±2.00 (14.40%) which is significantly higher (ANOVA: P = 0.3220) than the values obtained in GRA (94.30±3.00) location. Notably, mean values of female *Cx. quinquefasciatus* Mosquitoes (281.00±0.00) in locations that includes Mai-rakumi is significantly higher (ANOVA: P = 0.2120) than the male (236.30±1.11) mosquitoes in the same location.

Table 3: Distribution of Male and Female *Cx quinquefasciatus* Mosquitoes across locations of Breeding Sites

Species of interest	Breeding locations	Mean number of males	Rate (%) number of males	Mean number of females	Rate (%) number of males	Total (%)
Culex quinquefasciatus	Mai-lolo	233.50±1.10b	12.40	203.10±2.10b	7.76	439 (9.70)
	Mai-alkama	264.22±2.00c	14.40	348.30±1.11c	13.28	671 (14.83)
	Mai-rakumi	236.30±1.11b	12.45	281.00±0.00c	10.69	617 (13.62)
	Garko	266.33±2.23c	14.14	308.10±0.13c	11.72	517 (11.43)
	Raminzaki	288.10±0.13c	15.25	391.10±1.21c	14.88	680 (15.03)
	Rumfa	156.20±2.11a	8.18	314.33±2.23c	11.95	469 (10.36)
	Kwarinmadaki	182.00±0.00a	9.60	284.00±0.00c	12.40	466 (10.30)
	Kasuwar kuda	171.10±1.10c	8.97	326.20±2.11c	12.40	496 (10.96)
	GRA	94.30±3.00a	4.96	171.23±3.00a	6.51	265 (5.85)
	Total	1,795	41.90	2,628	58.10	4,523 (100)

Subscripts with different alphabets along the column are significantly different at P<0.05; Abbreviations: GRA Government Reserved Area.

Raminzaki has the highest number of females of *Culex* mosquitoes, 391.10±1.21(14.88%), followed by Mai-alkama breeding sites which have 348.30±1.11 females *Culex* mosquito while the least was breeding sites in GRA with mean value of 171.23±3.00 (6.51%) females *Cx. quinquefasciatus* mosquitoes.

Table 4 shows the average number of *Culex quinquefasciatus* mosquito larvae per dip collection across different identified breeding sites. The least average number of *Cx. quinqunfastus* larvae were collected at GRA per dip while there was no significant different (ANOVA: P = 0.05910) in samples collected from Mai-alkama (32.11±2.20) and Mai-rakumi (31.80±1.40), and other breeding sites in the present study.

The characteristic and some physico-chemical parameters of the breeding sites are as presented in the Table 5. The characteristics of these sites varies from one to another. Mai-lolo location which contain ditches, gutters and run-off has a permanent type of water site, man- made and has dark coloration with an average temperature of 28 ^{o}C and pH of 8.5. Mai-alkama has majorly temporary type of water for mosquito breeding. Organ of these water sites are river with clear water coloration, the temperature of 15 ^{o}C. Mai-rakumi has permanent water bodies and the nature of water is ditch and man-made with a dark colour having average temperature of 16 ^{o}C. GRA comprises of semi-permanent and man-made mosquitoes breeding sites, the nature of water is ditch, gutters and is clear with average temperature of 28 ^{o}C.

Table 4: Average number of *Cx. quinquefasciatus* samples collected per dip across all breeding sites.

S/N	Breeding sites	Mean number of *Cx. quinquefasciatus* per dip (N=20)
1	Mai-lolo	27.70±3.10a
2	Mai-alkama	32.11±2.20a
3	Mai-rakumi	31.80±1.40a
4	Garko	30.23±3.10a
5	Raminzaki	26.91±3.10a
6	Rumfa	27.52±3.10a
7	Kwarinmadaki	24.94±3.10b
8	Kasuwarkuda	27.50±3.10a
9	GRA	17.11±3.10b

Subscripts with different alphabets along the column are significantly different at $P<0.05$; Abbreviations: GRA (Government Reserved area), N= Number of dips.

Table 5: Characteristic of the *Culex* mosquito breeding site in Hadejia metropolis, Jigawa State

S/N	Breeding Sites	Breeding site type	Origin of Water	Nature of Water	Water colour	Average temperature	pH
1	Mai-lolo	Temporary	Man Made	Swamp	Dark	28°C	8.5
2	Mai-alkama	Permanent	Natural	Rivers	Clear	15°C	7.2
3	Mai-rakumi	Temporary	Man-made	Puddle	Dark	16°C	7.9
4	Garko	Permanent	Man Made	Used containers	Dark	15°C	8.6
5	Raminzaki	Permanent	Man Made	Ditch	Polluted	30°C	7.5
6	Rumfa	Permanent	Man-made	Ditch	Polluted	14°C	7.8
7	Kwarinmadaki	Permanent	Natural	Stream	Dark	25°C	8.1
8	Kasuwarkuda	Permanent	Natural	Ditch	Turbid	16°C	7.6
9	GRA	Temporary	Man-made	Drainage	Clear	28°C	7.8

Abbreviations: GRA Government Reserved Area.

Table 6 shows existing forms and frequency of breeding sites in the study locations. With only consideration of breeding sites that are positive for *Culex* mosquitoes, breeding sites existed naturally has the least number 6(7.31) as oppose to 34(41.46) breeding sites that are created through human activities. Only 73% breeding sites are *Culex* positive from abandoned wheel-tires whereas 100% of breeding sites created as a result of ditches and abandoned containers are positive for the mosquito group and the remaining for other mosquito groups such as *Anopheles* and *Aedes* groups in the present study.

Table 6: Diversity and Occurrence rate of *Culex* Mosquito Breeding Sites in Hadejia Metropolis, Jigawa State

Breeding site groups	Type of breeding Site		Origin of water		% Total
	Permanent N(%)	Temporary N(%)	Natural N(%)	Man-made N(%)	
Rivers/Streams	4(100)	0(0)	4(100)	0(0)	
Puddles	5(30)	4(60)	0(0)	9(90)	
Abandoned containers	0(0)	7(100)	0(0)	7(100)	
Used wheel-tires	8(73)	0(0)	0(0)	8(73)	
Drainages	5(32)	2(20)	0(0)	7(52)	
Ditches	3(10)	1(100)	2(50)	1(100)	
Swamps	0(0)	1 (100)	0(0)	0(0)	
Others	0(0)	2 (100)	0(0)	2(100)	

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No. of habitat (N = 82)	25	17	6	34	
% of Total	30.42	20.73	7.31	41.46	**100**

DISCUSSION

Various forms of breeding sites were positive for *Culex* mosquitoes in more in up to 9 locations in present study. This explains the adaptive properties of this mosquito group to various aquatic habitat. However, results from the present study indicated less than 100 % of the mosquitoes collected in some breeding sites were of *Culex* group. While various mosquito species exhibit preferences for specific breeding sites (Liu *et al.,* 2019; Adeniyi *et al.,* 2024), the present study reveals that *Culex* mosquitoes cohabit with other mosquito genera in diverse proportions across all identified breeding habitats. This finding aligns with Emidi *et al.* (2017)'s report, which documented the coexistence of *Anopheles* and *Culex* mosquito larvae in breeding sites within a rural area of Tanzania. Therefore, the present study substantiates Emidi *et al.* (2017)'s study and earlier observations in Ethiopia (Dejenie *et al.,* 2011), indicating that mosquitoes from different genera can coexist in breeding sites despite variations in their breeding ecology. This outcome suggests that, despite preferences for breeding sites, mosquitoes belonging to different genera can tolerate a wide range of physico-chemical properties in water habitats.

Locations situated around water and carwash (such as Raminzaki) exhibited the highest larval collection, followed by Garko, located in a spacious business area. This can be attributed to the ease of water accumulation in the form of puddles, ditches, and drainages due to these human activities, thus promoting mosquito breeding (Hamza *et al.,* 2016; Omotayo *et al.,* 2022). Residual water in drainages and ditches often provides suitable habitats for mosquito breeding. Conversely, the GRA, characterized by higher sanitation levels, an urban setting, improved lifestyle, and a higher standard of living, showed the lowest mosquito collection percentage. Additionally, increased levels of water and air pollution resulting from the use of chemicals in industries and households may have contributed to the mosquito count in the GRA, being an urban settlement (Tudi *et al.,* 2021).

However, locations like Mai-lola may eventually experience an increase in mosquito numbers. This is because human populations tend to migrate from rural to urban areas, and population growth is occurring at an unprecedented rate nowadays. This situation has led to overcrowded urbanization and an augmented population of vectors, subsequently causing a rise in diseases such as lymphatic filariasis and other mosquito-borne illnesses (Debrah *et al.,* 2021; Tsegaye *et al.,* 2023 Adeniyi *et al.,* 2024).

Man-made habitat pooled the highest proportion of *Culex* mosquito collected in the presented study. This is similar to the report of Nchoutpouen *et al.* (2019). Their study showed that highest mean larval vector was collected from man-made pool (1.0 larvae/dip). These reports have great public health implication because the larger the mosquito larval collected the higher the human biting rate in such environment (Debrah *et al.,* 2021). This will in-turn increases the incident rate of mosquito-borne diseases. Furthermore, larval breeding location such as Raminzaki, Kasuwar kuda and Rumfa are noteworthy for highest number of female *Cx. quinquefasciatus* mosquitoes found therein and, this implies that transmission rate of lymphatic filariasis could be higher around such places. This is because female mosquitoes are the exclusively the principal mosquito vectors because of their blood feeding habit (Liu *et al.,* 2019).

CONCLUSION

This research findings suggest a significant prevalence of *Culex quinquefasciatus* mosquito larvae in Hadejia metropolis. Various factors, including irrigation farming, open gutters and drainage, optimum temperature, and the nature of water waste, contribute to creating suitable breeding sites for this vector species. *Culex quinquefasciatus* is a recognized carrier of lymphatic filariasis, one of the Neglected Tropical Diseases. This disease predominantly affects economically disadvantaged individuals residing in both rural and urban areas who are more susceptible to mosquito bites. Consequently, it is recommended that identified breeding habitats be eradicated, and efforts to sustain public health campaigns on vector control management should be encouraged in the study area.

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