Article

Species composition, abundance and diversity of mosquitoes (Culicidae: Diptera) larvae in Qua'an-Pan Local Government Area, Plateau State, Nigeria

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Abstract

Mosquitoes (Diptera: Culicidae) are vectors of emerging arthropod-borne infections of medical and zoonotic importance. They undergo complete metamorphosis and breed in different habitat types. We conducted this study to investigate the composition, abundance and diversity of mosquito species in Qua'an-Pan Local Government Area (LGA), North Central Nigeria. The aquatic mosquito species' immature stages from the selected communities were surveyed between February 2020 and January 2021, from the late dry season through the early rainy season of 2020 and from the late rainy season to the late dry season. A total of 4186 (47.19%) Anopheline and 4685 (52.81%) Culicine larvae were collected. 3518 (47.36%) Anopheline and 3910 (52.64%) Culicine emerged to adult. 13 mosquito species were identified, 6 *Anopheles,* 4 *Culex,* 2 *Aedes* and 1 *Mansonia* species. There were 26 *Anopheles,* 73 *Culex* and 25 *Aedes* unidentified species. *Culex quinquefasciatus* (33.21 %) and *Anopheles gambiae* (22.25%) were the dominant species, whereas *Aedes hirsitus* (0.16 %) was the least abundant. There was a significant difference in Anophelesspecies abundance (P<0.05) while *Culex* species abundance did not differ significantly (P>0.05). The study reveals that the breeding index (BI) of mosquito species was 62.77% while the diversity level of emerged mosquito species was approximately 2. The study shows a rich species composition and diversity of mosquitoes and presents a high risk of mosquito-borne diseases transmission to the inhabitants of Qua'an-pan LGA. This public threat may be attributed to anthropogenic alteration of the ecosystem.

Keywords mosquito species composition; abundance; diversity; habitat types.

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1 Introduction

Mosquitoes (Diptera; family Culicidae) are vectors of several emerging arthropod-borne infections of medical and zoonotic importance (Umeanaeto et al., 2017). The female mosquitoes are hematophagous (blood feeders) in nature and take blood meal every 2-3 days for egg maturation after mating (CDC, 2024). Mosquitoes, especially gravid females, might travel a distance of 300km in a 9-hour flight at night in search of food and mates. *Anopheles* mosquitoes travel distances of 700m-1.5km and not more than 2km in a day (ILSI Research Foundation, 2016; Huestis et al., 2019). After blood digestion and egg maturation, the female mosquito finds a suitable oviposition site: the sequence of activities from when the mosquito acquires a blood meal to when it lays its eggs is called the gonotrophic cycle (Ferede, 2022). However, the life cycle of mosquitoes is directly influenced by high temperatures associated with high humidity and high precipitation, which favours mosquito larval development and survival, prolongs adult life, and increases the overall mosquito population (Ezeakacha and Yee, 2019; Cator, 2020; Couper, 2021).

The quest for blood meal makes mosquitoes the most medically important group of insects as this increases their potential for disease pathogens transmission (Ferede, 2022). In addition to disease transmission, mosquitoes also constitute a nuisance in the environment as their bite often leaves undesired itch and may interfere with sleep (Li et al., 2021).However, only a few of the identified 3,614 mosquito species (Harbach, 2022) are actual vectors of various arboviral and parasitic pathogensresponsible for infecting millions ofindividuals and resulting in mortalityparticularly in tropical and subtropical regions. In sub-Saharan Africa, over 630,000 deaths posed by mosquito-borne diseases have been recorded (WHO, 2015). These diseases negatively impact the economy, medical, and social well-being of the populace, and they need to be treated urgently (WHO, 2018).

Mosquito communities are influenced by landscape alteration, which affects the richness and abundance of their populations. Such changes could be key determinants for future arboviral outbreaks, especially in rural settlements where sylvatic vector species could be established in anthropic environments (Almeida et al., 2023; da Silver and Vieira, 2022). Some practices, such as deforestation and agricultural activities, could influence the local vector species population, which could, in turn, increase the incidence of human cases of zoonotic malaria caused by *Plasmodium knowlesi* (Byrne et al., 2021). Furthermore, anthropogenic activities such as the creation of puddles for washing, drinking sources, mining, irrigation farming, and road construction aimed at improving the livelihood of the common people have resulted in the creation of more breeding habitats for the mosquito species. The citing of these habitats around human dwellings has enhanced the rate of transmission of diseases by these mosquitoes (Lapang et al., 2019). Additionally, changes in the climatic condition of a place resulting from variations in ecological factors over time (e.g., rainfall, temperature,and relative humidity)contribute to making the environment suitable for the breeding of these vectors, resulting in their increased abundance and diversity (Hasnana et al., 2016; Wilke et al., 2019; David et al., 2021).

The aquatic environments in which these mosquitoes breed are also influenced by several factors, which include turbidity, salinity, degree and size of water permanence, sunlit, shade, presence of emergent/ submerged/floating vegetation, presence of predators, and distance to human habitation (Getachew et al., 2020). The nature of the water body as well, whether natural or artificial, also serves to provide a suitable environment which supports mosquito oviposition, larval development and emergence of adult mosquitoes. Furthermore, the shady low woodlands or Savannah grasslands are well suited for resting, swarming and mating (Mbanzulu et al., 2020) of the adult mosquitoes. Therefore, understanding the abundance of mosquito species in a place as well as determining the factors such as environmental and climatic, which are key drivers for larval abundance or species richness is crucial to identifying suitable habitats for the proliferation of the vectors as well as risk factors suitable for disease transmission (Estallo et al.,2018).

2 Materials and Methods

2.1 Study site

This study was conducted in thirteen selected communities namely Aningo, Dokan-kasuwa, Kwang, Miket, Doemak, Kwalla, Namu, Kwande, Kurgwi, Mangoro-uku, Maraba-damshin, Langkaku, Sabon-gida, Tim, Pandam, Bwall and Bakin-ciyawa in Qua'an-pan LGA Plateau State, North-Central Nigeria (Fig. 1). The source of livelihood for the inhabitants of the area is mainly agriculture. Located in the lowland part of Plateau state, Qua’an-pan is characterized by high rainfall, relative humidity and temperature. These factors make the environment suitable for mosquito breeding (Mwansat et al., 2019; Nanvyat et al., 2017).

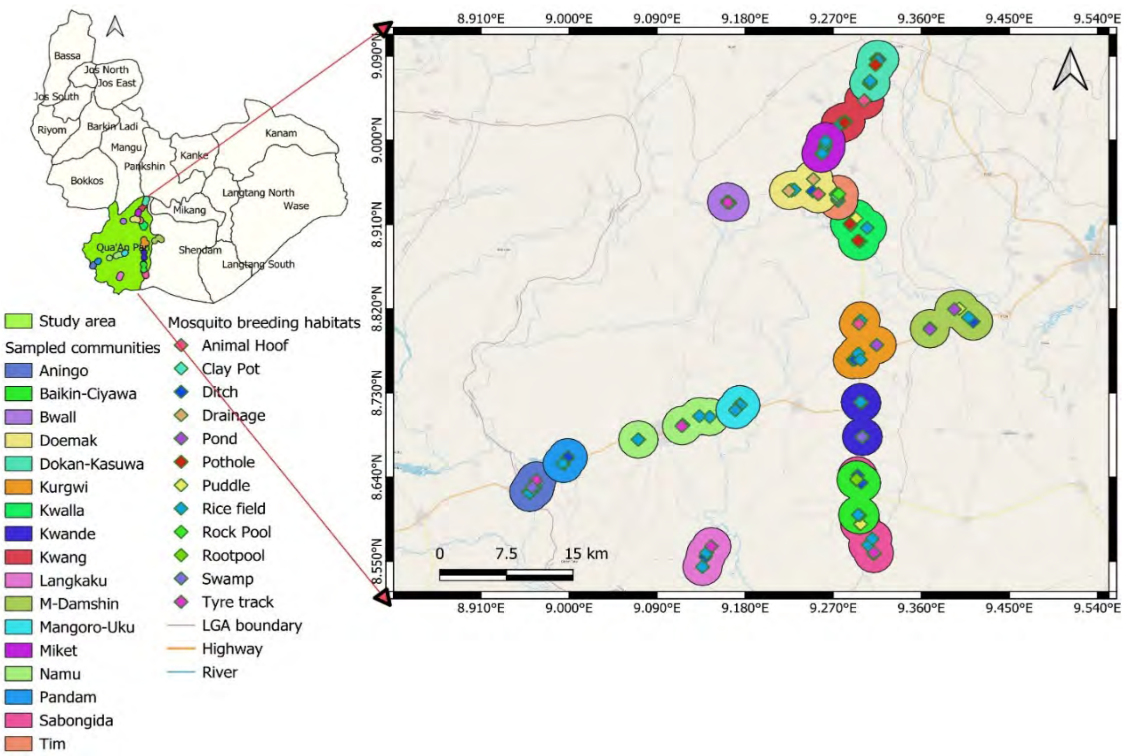

Fig. 1 Map of Plateau State, showing location of sample collection (Generated using QGIS version 3.40.1).

2.2 Mosquito larval sampling

The mosquito breeding sites positive for Culicidae were surveyed, and 35 sampling points were encountered and visited monthly for the period of 12 months during the late dry season (February 2020 to March 2020), early rainy season (April 2020 to June 2020), late rainy season (July 2020 to October 2020) and early dry season (November 2020 to January 2021). The aquatic stages of the mosquito were collected between the periods of 8:00 am-3:00 pm. Larvae were collected using the dipping technique. Two types of dippers were used in this study. One was a standard dipper or soup ladle with a capacity of 100-350ml, while the second dipper was improvised as described by Emidi et al. (2017) and used for sampling in smaller collections of water. Larvae were identified by their characteristic horizontal lying position (anopheline) or by their characteristic slanting position (culicine) in the water. The dipper was skimmed through the water at an angle of 45^0 to enable the larvae to flow into the dipper. The number of larvae collected per dip was estimated and transferred into a small plastic tub (30 ml) to facilitate movement in the field. In very small habitats where the dip could not be used, a 5ml graduated pipette was used instead. For each habitat sampled, ten (10) dip samples were taken. Meanwhile, in smaller habitats such as animal hoof-prints, collections from several similar habitats were pooled together to make up the required sample volume. Samples from the field were conveyed in labeledJerry cans to the insectary.

2.3 Breeding of mosquito larvae

Mosquito rearing was done in cages arranged and marked according to sampled communities and breeding habitats. The mosquito larvae collected were distributed into small rubber tubs containing water from the field and kept in the cages. After the larvae had been acclimatized to the new environment, yeast was first introduced into the water before ground biscuits. The introduction of yeast was to enhance the growth of zooplankton, phytoplankton and other organisms to enrich the medium and also support larval growth and development (Coon et al., 2017; Souza et al., 2019; Steyn et al., 2016). Crushed biscuit was used to feed the larvae twice a day to supplement the nutrient requirement of the habitat so as to reduce competition and cannibalism among the larvae.

2.4 Mosquito species identification

Identification of emerged adult mosquitoes was done under a dissecting microscope with the aid of standard mosquito identification keys (Coetzee, 2020; Kent, 2006).

2.5 Data analysis

Statistical analysis of all data collected was done on R Console software version 4.0.2. Mosquito larval abundance between identified groups as well as the abundance of emerged adults in relation to species was compared using Pearson's Chi-square test. While the mean Culicine and Anopheline abundance was compared using t-test. Furthermore, ANOVA test was performed to ascertain if there was a significant difference in larval abundance in relation to habitat types and the distance between breeding sites and the nearest house. Results were considered significant at $P < 0.05$.

2.6 Species diversity

The diversity of mosquito species was determined using the Shannon-Wiener diversity index, according to Zach Bobbitt (2021):

$$H' = -\sum_{i=1}^{s} (Pi)\,(\ln Pi)$$

where:

pi = proportions of individual species

I = Total number of samples

∑ = Summation

lnpi = natural logarithm of the proportion

H = Shannon diversity

The Shannon-Wiener diversity index ranges from 0 – 5, with an index value between 0 and 2.4 indicating low species diversity and 2.5 to 5 indicating high species diversity.

2.7 Breeding Index (BI)

The risk Index was computed based on the Formula by Bashar et al. (2016):

$$\text{Breeding index (BI)} = \frac{\text{Number of positive sites}}{\text{total number of sites inspected}} \times 100$$

When the breeding index is above 5% in an area, it indicates a high risk of mosquito-borne disease transmission.

3 Results

Our result showed that there were more culicine (4685, 52.81%) compared to anopheline (4186, 47.18%) in Qua'an-Pan Local Government Area, although, there was no significant difference ($p > 0.05$) in the abundance of the two mosquito families encountered (Table 1).

Table 1 Composition of Culicidae larvae collected from breeding sites in Qua'an-Pan LGA.

Group	No. collected (%)
Anopheline	4186 (47.18)
Culicine	4685 (52.81)
Total	8871

$\chi^2 = 0.32399$, df = 1, P = 0.5692.

Seven (7) *Anopheles* species were encountered in this study, out of which *Anopheles gambiae* (22.25%) followed by *Anopheles funestus* (16.01%) were the dominant species encountered. There were other unidentified *Anopheles* speciesencountered in the study as well which encountered for 0.34% of the collection (Table 2). Among the Culicines, three (3) mosquito genera were encountered: *Culex, Aedes* and *Mansonia.* Five (5) *Culex* species were encountered of which *Culex quinquefasciatus* (33.21) was the most abundant species. Two (2) *Aedes* species were identified in the study with *Aedes aegypti* (7.63%) as the most abundant species, where as only *Mansonia uniformis* (0.24%) was identified in the genus, *Mansonia* (Table 2). Overall, Chi square test shows that there is a significant difference ($p < 0.001$) in the abundance of the different mosquito species encountered in the study.

Table 2 Checklist of emerged adult mosquitoes in Qua'an-Pan LGA.

Subfamily	Genus	Species	Number	% Composition
Anophelinae	*Anopheles*	*Anopheles rufipes*	101	1.36
		Anopheles pretoriensis	79	0.96
		Anopheles funestus	1189	16.01
		Anopheles gambiae	1653	22.25
		Anopheles coustani	367	4.94
		Anopheles maculipalpis	112	1.51
		Anopheles species	26	0.34
Culicinae	*Culex*	*Culex antenatus*	203	2.73
		Culex bitaeniorhynchus	438	5.9
		Culex quinquefasciatus	2467	33.21
		Culex univitatus	107	1.44
		Culex species	73	0.98
	Aedes	*Aedes aegypti*	567	7.63
		Aedes hirsutus	12	0.16
		Aedes species	25	0.34
	Mansonia	*Mansonia uniformis*	18	0.24
			7428	100

$\chi^2 = 16162$, df = 15, P < 0.0001.

Larval abundance across the sampled communities showed that Dokan-Kasuwa followed by Aningo encountered for the majority of larvae collected in the study (17.9% and 9.16% respectively). The least number of larvae was however encountered in Kwang (3.71%). Statistical test shows that there is a significant difference ($p < 0.001$) in the number of mosquito larvae encountered in the different communities sampled (Table 3).

Table 3 Larval mosquito abundance across sampled communities in Qua'an-Pan LGA, Plateau State.

Community	No. of Anopheline (%)	No. of Culicine (%)	TotalNo. Collected (%)
Aningo	593 (14.17)	220 (4.70)	813 (9.16)
Baikin-Ciyawa	118 (2.82)	290 (6.16)	408 (4.60)
Bwall	328 (7.84)	297 (6.34)	625 (7.05)
Doemak	271 (6.47)	403 (8.60)	674 (7.60)
Dokan-Kasuwa	1036 (24.75)	552 (11.78)	1588 (17.90)
Kurgwi	221 (5.28)	343 (7.32)	564 (6.36)
Kwalla	206 (4.92)	579 (12.36)	785 (8.85)
Kwande	137 (3.27)	310 (6.62)	447 (5.04)
Kwang	132 (3.15)	197 (4.20)	329 (3.71)
Langkaku	70 (1.67)	87 (1.86)	157 (1.77)
Mangoro-uku	64 (1.53)	65 (1.39)	129 (1.45)
Mararaba-Damshin	52 (1.24)	81 (1.73)	133 (1.50)
Miket	396 (9.46)	273 (5.83)	669 (7.54)
Namu	76 (1.82)	162 (3.46)	238 (2.68)
Pandam	145 (3.46)	214 (4.57)	359 (4.05)
Sabongida	143 (3.42)	143 (3.05)	286 (3.22)
Tim	198 (4.73)	469 (10.01)	667 (7.52)
Total (%)	4186 (47.19)	4685 (52.81)	8871

Comparison of pooled mosquito larval abundance across communities: $\chi^2 = 3882.7$, df = 16, $P < 0.0001$.
Comparison of Anopheline larval abundance across communities: $\chi^2 = 3945.8$, df = 16, $P < 0.0001$.
Comparison of Culicine larval abundance across communities: $\chi^2 = 1414.5$, df = 16, $P < 0.0001$.

The overall result obtained from this study (Fig. 2) showed that larval mosquito abundance differed significantly ($p < 0.05$) across sampled habitats. When considered individually, the Anophelines, which are vectors of malaria and lymphatic filariasis, did not differ significantly ($p > 0.05$, Fig. 3) in terms of abundance across habitat types. However, the Culicines, which are vectors of filariasis and arboviruses, showed a significant variation in species abundance across habitat types ($p < 0.05$, Fig. 4).

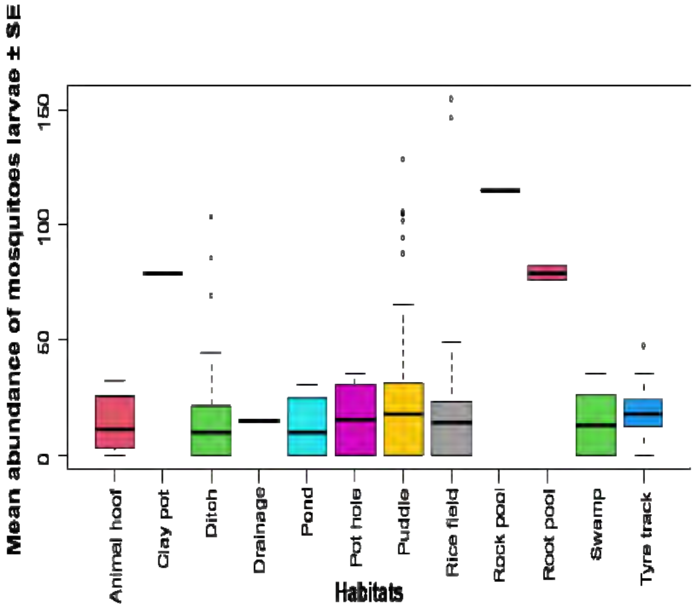

Fig. 2 Mean abundance of mosquito larvae in relation to habitat types(F511 =4.383, Adjusted R2 = 0.006564, P = 0.03679).

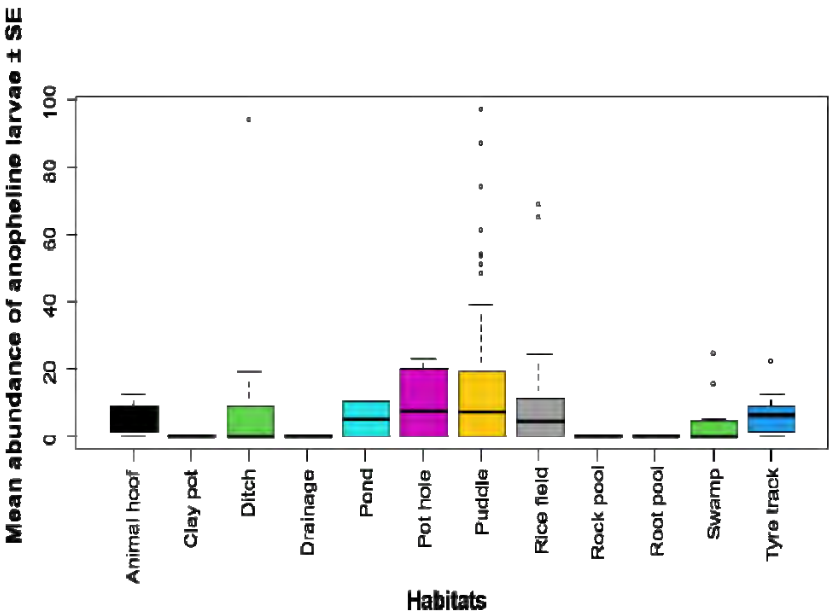

Fig. 3 Mean abundance of anopheline larvae in relation to habitat types(F511 = 1.62, Adjusted R2 = 0.00121, P = 0.2036).

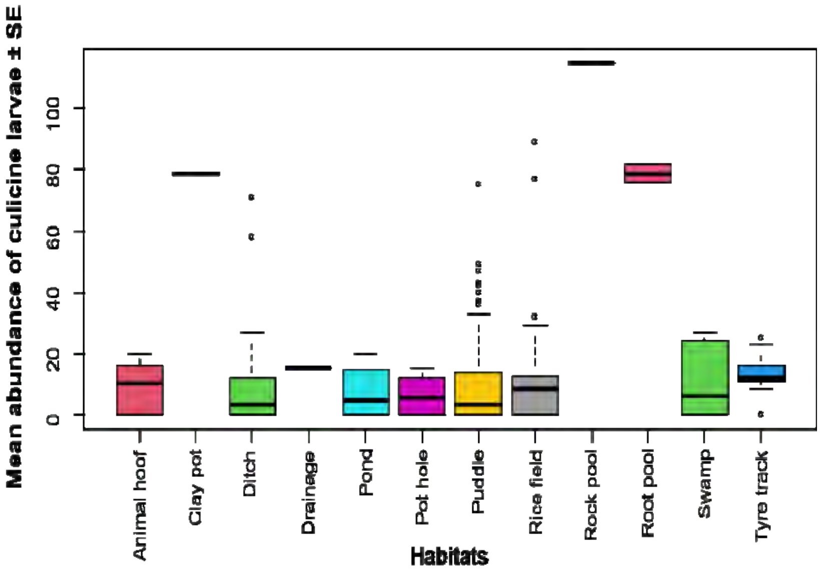

Fig. 4 Mean abundance of culicine larvae in relation to habitat types(F511 = 4.504, Adjusted R2 = 0.006797, P = 0.0343sn).

Overall, larval abundance did not differ significantly ($p > 0.05$, Fig. 5) across the seasons. However, while *Anopheles* larval abundance varied significantly ($p < 0.05$, Fig. 6) across all seasons, *Culex* larval abundance showed no significant variation ($p > 0.05$, Fig. 7) across the seasons studied.

It was observed that the distance of mosquito breeding sites from the nearest house had no significant effect on larval abundance ($p > 0.05$) (Fig. 8).

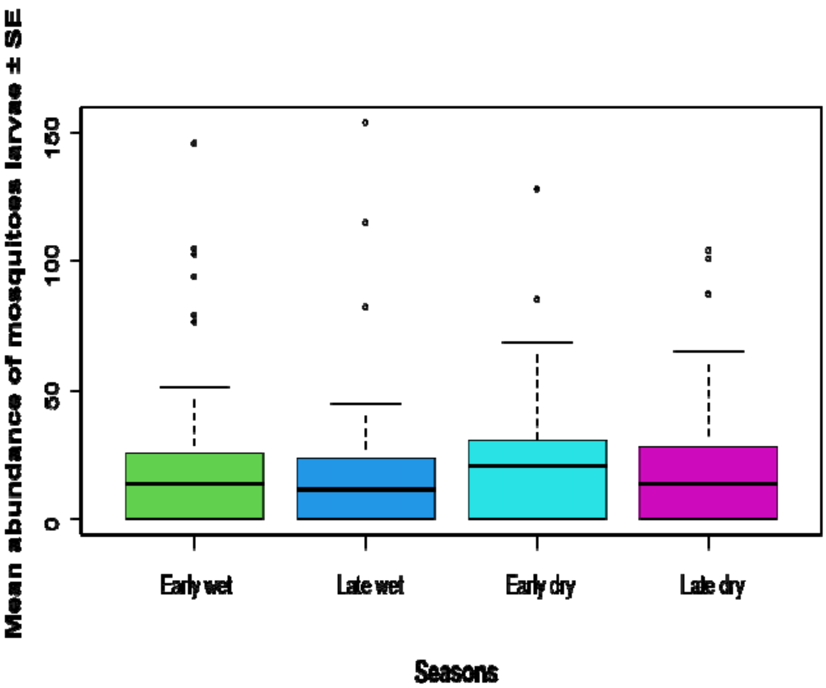

Fig. 5 Mean abundance of mosquito larvae in relation to seasons(F_{509} =1.61, Adjusted R^2=0.003559, P =0.1862)

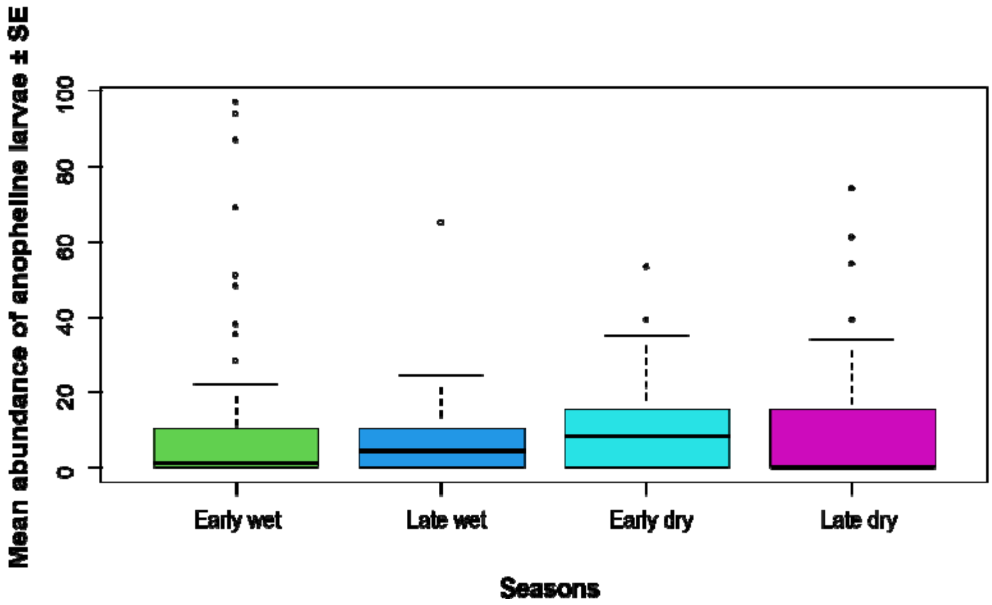

Fig. 6 Mean abundance of anopheline larvae in relation to seasons(F509 = 2.824, Adjusted R2 =0.01058, P = 0.03823).

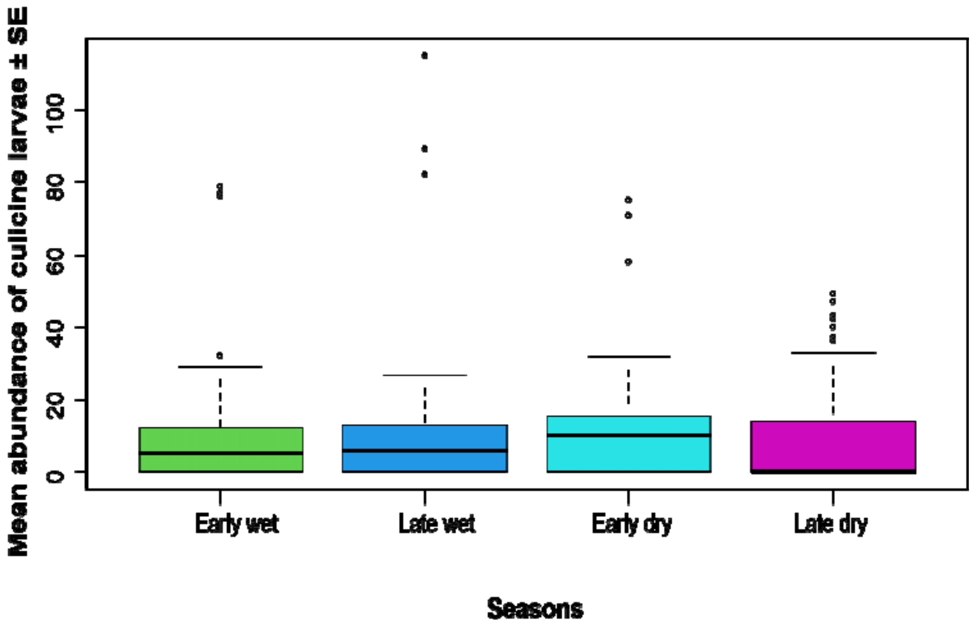

Fig. 7 Mean abundance of culicine larvae in relation to seasons(F509 = 0.4959, Adjusted R2= -0.002962, P = 0.6853ns).

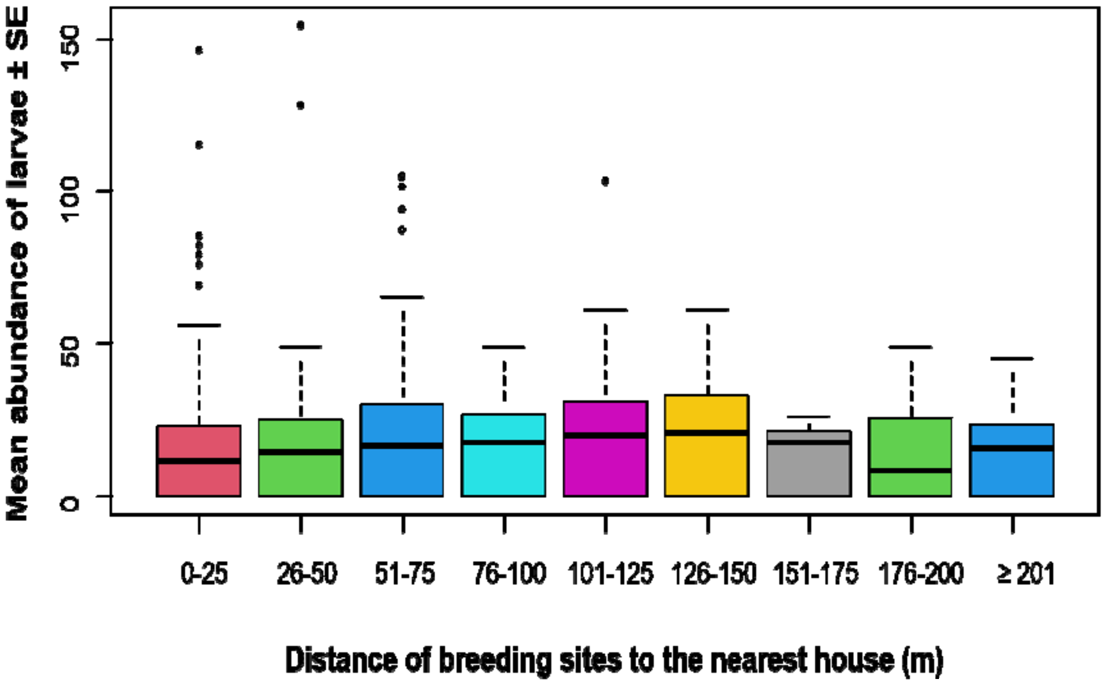

Fig. 8 Mean abundance of mosquito larvae in relation to distance to the nearest house(F_{511} = 1.292, Adjusted R^2 = 0.000569, P = 0.2563^{ns}).

Overall, the diversity of mosquito species in the study area was relatively low (H´ = 1.94448; Table 4).

Table 4 Diversity level of emerged adult mosquitoes.

Species	Number	Pi	ln(Pi)	Pi*ln(Pi)
Anopheles coustani	367	0.049408	-3.00765	-0.1486
Anopheles funestus	1189	0.16007	-1.83214	-0.29327
Anopheles gambiae	1653	0.222536	-1.50266	-0.3344
Anopheles pretoriensis	79	0.010635	-4.54356	-0.04832
Anopheles maculipalpis	112	0.015078	-4.19451	-0.06325
Anopheles rufipes	101	0.013597	-4.29789	-0.05844
Anopheles species	26	0.0035	-5.65492	-0.01979
Culex antenatus	203	0.027329	-3.59981	-0.09838
Culex bitaeniorhynchus	438	0.058966	-2.83079	-0.16692
Culex quinquefasciatus	2467	0.332122	-1.10225	-0.36608
Culex univitatus	107	0.014405	-4.24018	-0.06108
Culex species	73	0.009828	-4.62255	-0.04543
Aedes aegypti	567	0.076333	-2.57265	-0.19638
Aedes hirsutus	12	0.001616	-6.42811	-0.01038
Aedes species	25	0.003366	-5.69414	-0.01916
Mansonia uniformis	18	0.002423	-6.02264	-0.01459
Total	7428			-1.94448
H´ = 1.9448				

The breeding index (BI) for potential breeding sites in Qua'an-Pan LGA was 62.77%, as shown in Table 5. Productive habitats are the habitat types that have at least one larva, while unproductive habitat types have no larvae at all. Table 6 shows that out of the 513 habitat types surveyed, 322 productive habitat types and 191 unproductive habitat types were recorded.

Table 5 Breeding index of collected mosquitoes across breeding sites in Qua'an-Pan LGA, Plateau State.

Status of breeding site	No.	BI
Sites with larvae	322	62.77%
Sites without larvae	191	
Total No. of sites surveyed	513	

4 Discussion

To design a suitable and sustainable vector control strategy which targets the aquatic stages ofthe mosquitoes, it is pertinent to understand the spatial extent of these larvae and the factors which favour their abundance. In this study, we encountered a total of 8871 Culicidae larvae from twelve habitat types in Qua'an-Pan LGA of Plateau State. This is made up of 4186 (47.19%) Anopheline and 4685 (52.81%) Culicine larvae, with 3518 (47.36%) Anopheline emerging as adults while 3910 (52.64%) Culicine emerged to adults. This finding corroborates the work of Amawulu et al. (2020), who reported a high abundance of *Culex quinquefasciatus* followed by *Anopheles gambiae* in the study location. Similar to this study also, Gbaye et al. (2017) observed that there were more *Cx. quinquefasciatus* in Idanre and Ese Odo areas in Ondo State, Southwestern, Nigeria. While Omoregie et al. (2019) noted that*Cx. quinquefasciatus* followed by *An. Gambiae*were more abundant in their study. Our finding is also in line with the earlier observation by Lapang et al. (2019) that the most abundant mosquito species in Shendam LGA of Plateau State was *Culex quinquefasciatus* followed by *Anopheles gambiae*. However, our finding is in disagreement with that by Emidi et al. (2017), who worked on a similar project in Tanzania and reported a high abundance of *Anopheles gambiae* compared to *Culex quinquefasciatus.* Furthermore, Afolabi et al. (2019) found that *Aedes aegypti* compared to *Cx. quinquefasciatus* and *An. gambiae*, was the most abundant mosquito species in their study, which is contrary to the result of this study.

In this study, it was observed that mosquito larvae abundance was dependent on the breeding habitat type. Other studies have also reported significant variation in the abundance of of mosquito species (Wilke et al., 2019). This is further corroborated by the work of Afolabi et al. (2019), who found that the *Culex* group was significantly more abundant than other mosquito genera, with *Culex andersoni*as the most abundant mosquito species. The most productive habitat types recorded in this study include puddles, followed by Potholes, swamps, Animal hoofs, ponds, Tyre tracks, Rice fields and ditches, while Clay Pots, Drainage, Rockpools and Root pools were less productive. This indicates that the breeding sites encountered support the proliferation of vector species. Similar to our finding, Grech et al. (2020) also reported the following productive habitat types: artificial ponds, natural ponds, drainage, ditches, and swamps. Dida et al. (2015) in their study recorded that open drainage, puddles, and hoof-prints were found to contain a considerable number of mosquito larvae together with other predatory organisms. Similar work was conducted by Olusi et al. (2021), who reported that River bed, River edges, Pond beds, Animal spoors, Concrete gutters, Canals, abandoned tyres, potholes, Gutters, Tyre tracks, abandoned containers and Rain pools are productive habitats for *Anopheles* mosquitoes which is also similar to the finding by Elmalih et al. (2018) in Sudan. Dida et al. (2018) encountered the following habitats with*Anopheles*mosquitoes' larvae, which are within human dwellings: river bed, pond bed, spoors/foot tracks canal and gutter which was similar to the earlier report by Getachew et al. (2020). More so, Novianto et al. (2021) reported that *Aedes albopictus* were breeding in the containers (trash cans and buckets) they encountered in their study. Similarly, Afolabi et al. (2019) also reported a high density of mosquito species breeding in peri-domestic containers: cans, plastics, and Styrofoam, in their study. Our finding, however, disagrees with this work due to the fact that recycling of resources such as metals, plastics and cans has been too demanding, as it has become the source of livelihood to some people, thereby reducing the number of these man-made habitats within the human environment.

In this study, it is worth noting thatthe composition, and relative abundance and diversity of mosquito species obtained from this study are of public health concern as their presence shows that the inhabitants were exposed to the potential bites and nuisance of these mosquitoes, and possibly a high risk of disease transmission. The high abundance of immature mosquito stages is attributed to high rainfall patterns, which help create a productive breeding sites for the mosquitoes. In tropical and subtropical regions, rainfall affects the seasonal variation of most mosquito species abundance by creating temporary breeding habitats which contribute to the surge in population density of some vector species and an increase in disease transmission. Swamp and puddles are the most productive habitat types obtained in the study area. Mosquito population densities vary with seasons due to fluctuations in productive breeding sites (Getachew et al., 2020). Understanding mosquito larval breeding sites characteristics can provide information that could be used to develop effective control strategies against mosquito species (Amawulu et al., 2020).

The complexities in mosquito ecology can be reflected in how mosquito abundance and seasonal occurrence could change over time in the same site. The seasonal variation in mosquito abundance in this study did not vary significantly, although a higher abundance of mosquito larvae was observed in the early dry season. Suggesting that mosquito larvae breeding is favoured all year round. This finding corroborates the report of another study (Magombedze et al., 2018) which found that *An. gambiae* and *An. arabiensis*are more succesful during the dry season. Similarly, Ondibaet al. (2019) observed that most mosquito species thrive well during the dry season, even though they also observed that larval abundance did not vary significantly across the rainy and dry season months. Our results, however, contrasts the finding of Mattahet al. (2017), that higher numbers of Anopheline larvae were recorded during the wet season as against what was recorded in the dry season. It is also in contrast with the finding of Smith et al. (2018), who conducted a study in a malaria-endemic region and discovered that the indoor resting density of *Anopheles* mosquitoes was significantly higher during the rainy season than in the dry season. Species-wise, a significant association was observed between *Anopheles* mosquito abundance and season, though early and late dry seasons show higher abundance. This result agrees with the findings of Tantely et al. (2016) and Zogo et al. (2019), who also reported significant *Anopheles* mosquito larvae abundance during the dry season as against the rainy season. In this study the *Anopheles* species encountered are mostly vectors of the malaria parasite: *An. gambiae* s. s., *An. Arabiensis* and *An. funestus* found in the Afro-tropical region. According to Getachew et al. (2020), as the breeding habitats of the *Anopheles* species dries up in the dry season, these vectors could migrate several kilometersto find other suitable breeding habitats. As a result, most malarial transmission within this period was vectored by immigrant mosquitoes that must have flew in from several kilometers away.

The number of productive mosquito breeding habitats as well as their proximity to human habitation where they can access blood meal is a measure of adult mosquito density (Tsegaye et al., 2023). It was observed in this study that the distances 101-125m and 126-150m had the highest abundance of mosquito immature stages, suggesting that distance to the nearest house was a significant determinant of mosquito species abundance. This indicates that the environment favours thebreeding success of the mosquitoes, and the inhabitants of the communities are prone to disease transmission. In a study by Mathania et al. (2020), they noted that mosquitoes prefer habitats with clean water at distances within the range of 10–100 m from the nearest house. This suggests that proximity to human habitation could influence larval abundance, thus increasing the potential for indoor vector density (Hawaria et al., 2020). Other authors, such as Tsegaye et al. (2023), have also made similar observations. Oniya et al. (2019) noted that distances ranging between 0.5-300m between the breeding sites and human residence, is within the flight range of the vectors and hence, can allow for effective transmission of mosquito-borne diseases within the area. The wind borne migration of mosquito species is a driving force in shaping the epidemiology of many diseases transmitted by these vectors; this new aspect of vector and mosquito-borne-pathogens ecology should be given more attention in predicting disease spread as well as in planning disease control strategies (Yaro et al., 2022).

The high breeding index recorded in this study is an indication that there is a high risk of mosquito-borne infectious disease transmission in the area. In an earlier work,Lapang et al. (2019), also recorded very high breeding index values over the threshold value of 5.00 for Anopheline (16.06) and Culicine (25.76) mosquitoes. This finding suggests a likelihood of multiple transmissions of mosquito-borne diseases amongst the populace from the two vector groups. In another study, Ferede et al. (2018) had recorded very high breeding indices for *Aedes aegypti* (container index = 32.9; house index = 25.5, and Breteau index = 48.4), the main vector of dengue and other arboviral infections, suggesting also a high potential risk for arboviral disease transmission.

Although, the species diversity index in this study was low, it is similar to that reported early by Ombugaduet al.(2020), who recorded low species diversity of ($H' \approx 1.0$) in a study conducted in student hostels of the Federal University, Lafia. It also conformed with the finding by Lapang et al. (2019) in a study conducted in Shendam LGA, Plateau State Similarly to the present finding also is the report byIrikannuet al. (2023), who had a relatively low diversity of 0.107. The low diversity of mosquito species obtained in our study could be due to the continued application of pesticides and herbicides by farmers to control pests, which have a negative effect on the mosquitoes and their ecology.

Understanding the breeding ecology and behavioural pattern of mosquito species is imperative in the implementation of an optimal vector control system. The composition of mosquito species encountered from this study are of public health concern because their availability in the study area showed that the inhabitants were exposed to the potential bites and nuisance of these mosquitoes, and possibly a heightened risk of disease transmission. The high abundance of immature stages of mosquitoes obtained was attributed to high rainfall patterns, which helped create a productive breeding habitat for the mosquito. Swamp and puddles are the most productive habitats obtained in this study. The productivity of mosquito larvae from different habitat types is heterogeneous, hence the diversity and density of larvae in all the habitat encountered. This is an indication that the area is a focal zone for mosquito-borne disease transmission and calls for an urgent need for intervention through periodic surveillance, evaluation, and implementation of vector control strategy, as all these will drastically reduce the population of mosquito species and the disease burden in the study area.

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