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Spatial distribution of mosquitoes (Diptera: Culicidae) population in different larval habitats in urban environment in Makurdi, North-Central Nigeria

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Abstract
Characteristics of mosquito larval habitats are vital in determining whether they can survive and successfully complete their developmental stages. Data on the ecological factors affecting mosquito density and abundance of their breeding sites can possibly be helpful in implementing larval management programs. Soup ladle dipper (0.105L capacity) and rope-fastened plastic jars were used to obtain larval mosquitoes from breeding receptacles. Fully developed larvae were preserved with 70% ethanol while lower instar larvae were nurtured on baker's yeast diet. Temperature, pH, EC and TDS were determined with HANNA HI 98129PH/EC/TS/Temp meter. Ethanol (70%) preserved larvae were identified with pictorial taxonomic keys. The relationship between larval abundance and physicochemical parameters was assessed using Pearson's correlation. Differences in physicochemical properties among habitat types were determined using ANOVA. A total of 4641 mosquito larvae consisting of 22 species distributed in 3 genera were collected from 11 breeding habitats. They are, 165(3.6%) *Ae. aegypti*, 777(16.7%) *Ae. africanus*, 28(0.6%) *Ae. domesticus*, 47(1%) *Ae. centrapunctatus*, 104(2.2%) *Ae. cumminsi*, 35(0.8%) *Ae. fraseri*, 45(1%) *Ae. keniensis*, 27(0.6%) *Ae. pulchrithorax*, 108(2.3%) *Ae. simpsoni*, 2129(45.9%) *Ae. vittatus*, 67(1.4%) *An. gambiae* s.l., 24(0.5%) *Cx. arbieeni*, 2(0.04%) *Cx. decens*, 212(4.6%) *Cx. duttoni*, 74(1.6%) *Cx. horridus*, 210(4.5%) *Cx. quinquefasciatus*, 73(1.6%) *Cx. macfiei*, 134(2.9%) *Cx. nebulosus*, 73(1.6%) *Cx. pipiens molestus*, 229(4.9%) *Cx. rubinotus*, 23(0.5%) *Cx. striatipes* and 57(1.2%) *Cx. tigripes*. *Aedes vittatus*, *Ae. africanus* and *Cx. rubinotus* had dominant densities. Mosquito larval occurrence was highest in discarded tyres followed by rock pools and electric poles. Highest larval density due to impact of human activities was recorded in concrete electric poles. Rock pools, discarded tyres, domesticated containers and electric poles differed significantly ($p<0.05$) with the abundance of mosquito larvae. Temperature, TDS and EC correlate significantly with the abundance of mosquito larvae. This study provides evidence on distinct breeding of mosquitoes in anthropic habitats focusing on water chemistry that might be implemented towards enhancing effective design for vector control strategies.

Keywords: Habitat diversity; relative abundance; public health implication; physicochemical parameters; human activities

Introduction
Mosquitoes are some of the organisms that seem to benefit from anthropogenic environmental change. The fast-growing urban population which occurs at a large scale create suitable breeding opportunities for mosquitoes increasing by then, mosquito borne disease transmission risk in urban settings [1]. Highly modified environments such as urban areas, provide some advantages for container breeding mosquitoes, especially via the greater availability of artificial larval habitats [2]. Immature mosquitoes can develop in a wide range of aquatic habitats or breeding places where female mosquitoes lay eggs, larvae grow and pupate, and adults emerge [3]. The great diversity of immature habitats forms a gradient from small and highly ephemeral to large and permanent natural and artificial fresh water bodies [4]. Moreover, ecosystem processes operating at different organization levels and temporal and spatial scales, regulate the patterns of productivity of mosquito larval habitats in a larger landscape context [5]. In Nigeria, mosquito borne diseases represent one of the major threats to public health whereby mosquitoes belonging to the genera *Anopheles*, *Aedes* and *Culex* have been associated with malaria, filariasis, dengue (DENV) and yellow fever (YFV).

Malaria is the most widespread mosquito borne disease in Nigeria where it is holoendemic. It accounts for >300,000 deaths from >20 million clinical cases annually with about 10-20% of the hospital admissions [6]. The threat of yellow fever outbreak still remains high [7, 8] and the extent of the dengue burden in Africa remains unknown, as does the true burden of yellow fever, though tens of thousands die annually in Africa [9], even with availability of an effective vaccine.

Distribution of disease-causing vectors and consequently the spread and occurrence of the human pathogen has been affected by various environmental factors like urbanization, increased exchanges and climatic change [10]. Some of the chemical properties of the larval habitat related to vegetation, pH, optimum temperature, concentration of ammonia, nitrate and sulphate have been found to affect the larval development and survival [11]. One of the most important determinants for maintenance of adult populations is the presence and quality of immature breeding habitats, and may have implications for adult abundance, affecting their temporal and spatial distribution [3]. Anthropological activities such as open drainage system, agricultural activities and littering of environments with various peri-domestic containers encourage the breeding of mosquitoes and consequently increase mosquito-borne diseases in the area. In addition to the anthropogenic habitats, there are natural water bodies scattered around most urban areas that can support mosquito breeding [12]. This makes potential larval habitats numerous and larval control seems a difficult option in mosquito control.

Over recent decades, human contact with mosquitoes has become more frequent as peri-urban suburbs expanded into previously undisturbed natural areas, thus providing a greater number and variety of mosquito breeding places than inner-city areas [13]. The propensity to ignore the importance of mosquito bionomics, sole dependence on insecticides for mosquito control and at the same time insufficient knowledge about their susceptibility status seem to be responsible for the failure of mosquito control programs in the city areas [14]. The adoption of integrated control programs mostly larviciding and elimination of larval habitats is now being canvassed. This becomes necessary as human activities associated with settlement, agriculture, and other environmental alterations have resulted in the proliferation of larval habitats [15]. For effective larval control, the type of habitat should be considered and most productive habitat type be given a priority in the mosquito abatement program. Indeed, information on the spatial distribution of mosquito breeding habitats is required to enable tracking and targeting hotspot areas where there is persistent presence of vector populations. Studies have been carried out on larval habitats of mosquitoes but substantial information regarding larval habitat preference, influence of physicochemical properties and anthropological impact on mosquito distribution have not been fully investigated to unravel its ecological undertones and its potential applicability in control. This study aimed at determination of anthropological and physicochemical influences on the spatial distribution of aquatic stages of mosquitoes in relation to density and diversity of natural and artificial container breeding mosquitoes.

Materials and Methods

Study Area

Makurdi is located at longitude (6°28'E) and latitude (7°14'N) of the Guinea savanna zone in North Central Nigeria. Makurdi is home to Benue State University and the Federal University of Agriculture. The State derived its name from the River Benue which is the second largest river in the country and the most outstanding geographic feature in the State. North-bank as one of the satellite towns derived its name due to transversion of Makurdi capital by the River Benue into the north and south banks [16]. North-bank is known with its clustered and unplanned settlement just few centimeters at the River bank but holds base for NASME barrack, 72 Division barrack, Federal Housing Estate, Federal Low-Cost Estate, Federal University of Agriculture, Makurdi and North-bank Market. Eight settlements were sampled for larval habitats of preimaginal mosquitoes which included; Asase, Federal University of Agriculture, Makurdi, Federal Housing Estate, Federal Low-Cost Estate, Ichwa, Katungu, Makurdi-Lafia Axis and Mission Ward. The capital is a city located along the Benue River and holds the base for the Nigerian Air Force’s MiG 21 and SEPECAT Jaguar aircraft squadrons. Benue State is the nation’s acclaimed food basket because of its rich agricultural produce which includes yams, rice, beans, cassava, potatoes, maize, soya beans, sorghum, millet and cocoyam. Agriculture is the mainstay of the economy, engaging over 75% of the state farming population. The State also boasts of one of the longest stretches of river systems in the country with great potential for a viable fishing industry, dry season farming through irrigation and for an inland water highway.

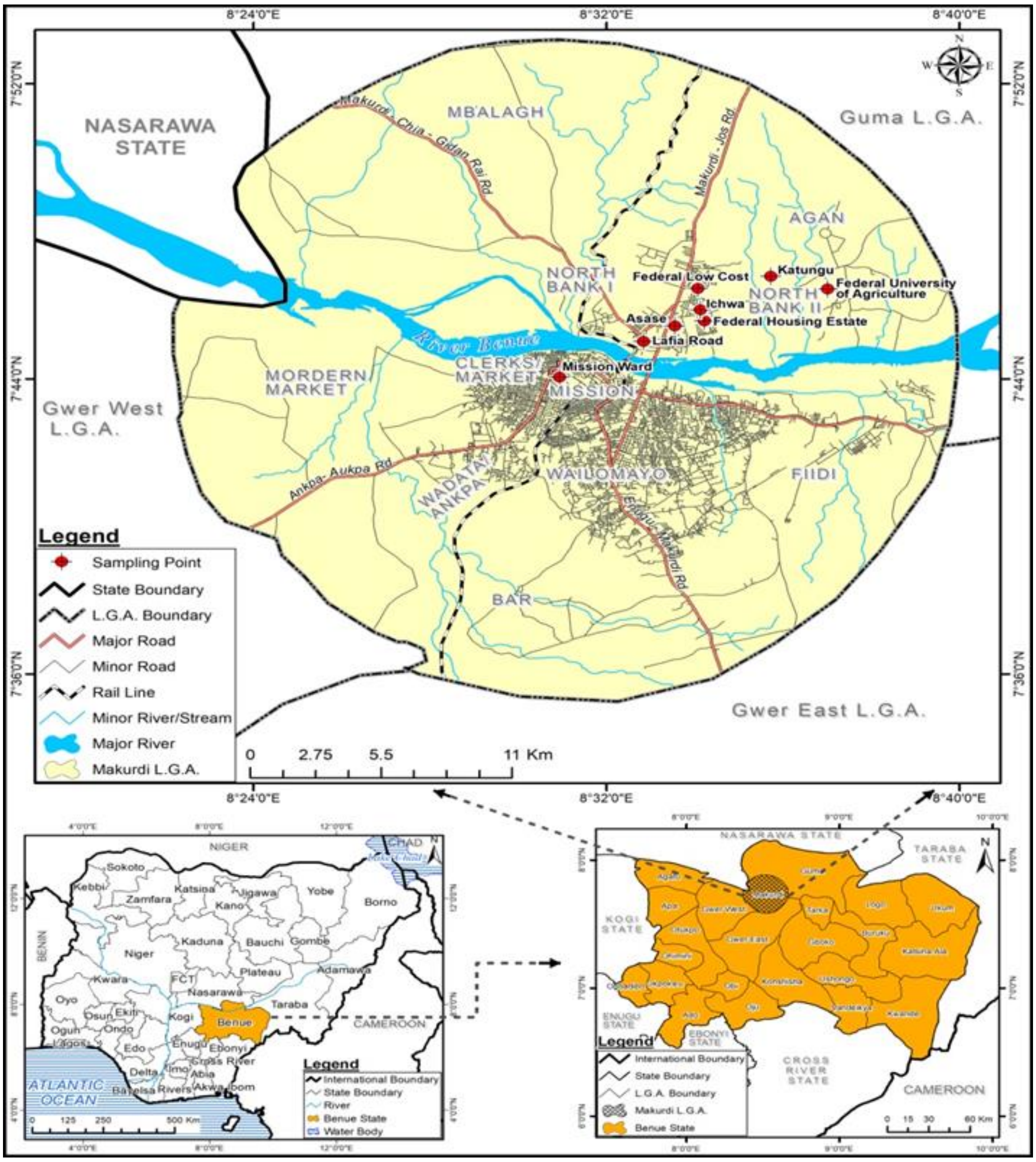

Fig 1: Map of Makurdi showing sampling points.

Larval Survey and Collection

Sampling for larval stages of mosquitoes was carried out fortnightly at eight study sites as much as access was permitted between June and October, 2015. In each study site, possible habitats of mosquitoes were surveyed for the presence of immature stages of mosquitoes ranging from large expanse of water such as abandoned well to small collections of natural habitats such as tree-holes. Collections were made at randomly selected potential breeding habitats in the study areas according to the methods of [17] and [18]. The collection was avoided immediately after heavy rain because at that time there was more possibility of the immature being washed out from their breeding places [19]. Ten dips of water in every other potential breeding habitats were obtained with a plastic soup ladle dipper (0.105L capacity) [20]. Plastic jar tighten with rope was used to collect water samples from wells, wider and dipper breeding sites. Water from each habitat was collected in a white plastic bowl and carefully observed for the presence of preimaginal mosquitoes. Anopheline and culicine larvae, in their fourth instars were concentrated and carefully picked with dropping pipette into a labeled specimen bottle and preserved in 70% ethanol. Larvae in their lower instars were nurtured to the fourth instars in labeled plastic bowls (11x5.5cm) on a diet of bakers' yeast [20] and subsequently preserved in 70% ethanol in appropriately labeled specimen bottles.

Physicochemical parameters

Water samples were analyzed for the following physicochemical parameters: Temperature, pH, electrical conductivity (µscm^{-1}) and total dissolved solid (ppm). The breeding water characteristics were determined with HANNA HI 98129PH/EC/TS/Temp meter [21].

Mosquito Species identification

All the mosquitoes collected were morphologically identified to the species taxon and counted under X10 magnification of a compound microscope. Anopheline mosquitoes were identified based on the pictorial keys of [22]. Culicine mosquitoes were identified based on the pictorial keys of [23].

Data analysis

The important quantitative analysis including relative abundance and larval density of mosquito species were determined according to [24]. Larval density of mosquitoes per pool is an expression of the total number of mosquito species collected divided by the corresponding total number of habitats examined.

Density was calculated by the equation: $\text{Density} = \frac{\text{Total number of mosquito species}}{\text{Total number of habitats examined}}$

Means and standard errors of physicochemical variables were calculated with Microsoft statistical tool pack. The relationship between larval abundance and physicochemical parameters was assessed using Pearson's correlation. Differences in physicochemical properties among habitat types were established using Analysis of variance (ANOVA). The IBM SPSS statistical package (SPSS Inc., Chicago) version 22 was employed for ANOVA and Pearson's correlation analyses. Least significant difference (LSD) was used to separate significantly differed means and significance was assigned at level of $p< 0.05$.

Results

A random entomological survey was conducted at eight study sites in North-bank, Makurdi for collection of mosquito larvae from different breeding habitats. Consistently, the number of mosquito larvae was relatively high at different study sites throughout the study period. Of 109 microhabitats examined, 4641 mosquito larvae were collected from 66 breeding receptacles (Table 1). Katungu had an overall highest larval density per pool with highest relative abundance of mosquito larvae. Federal University of Agriculture, Makurdi had the highest number of habitats examined but with least relative abundance of mosquito larvae. Highest number of mosquito larvae was recorded from Federal Housing Estate while Asase village had the least number of mosquito larvae with overall least larval density. The number of larval habitats fluctuated at Makurdi-Lafia Axis but constituted the second highest larval density per pool.

Table 1: Occurrence and larval densities of mosquito larvae

Localities	No. of habitats examined	No. of habitats positive (%)	No. of larvae collected (%)	Relative abundance of larvae	Larval No. per habitat (density)
Asase	9	3(2.75)	144(3.10)	48.0	16.0
Fuam	22	9(8.26)	372(8.01)	40.22	16.45
Fhe	15	9(8.26)	858(18.49)	95.33	57.20
Flce	12	10(9.17)	555(11.96)	55.50	46.25
Ichwa	19	10(9.17)	645(13.89)	64.50	33.95
Katungu	8	8(7.33)	828(17.84)	103.50	103.50
Lafia Road	7	6(5.50)	545(11.74)	90.83	77.86
Mission Ward	17	11(10.10)	694(14.95)	63.10	40.82
Total	109	66(60.55)	4641	70.17	42.49

Key: FUAM – Federal University of Agriculture, Makurdi; FHE – Federal Housing Estate; FLC – Federal Low-Cost Estate.

Eleven probable mosquito larval habitats which ranged from natural and artificial sources were observed for mosquito breeding. These included rock pools, discarded tyres, discarded containers, cesspools, abandoned well, potholes, farmland, rice farm, gutter, electric poles and tree holes. Discarded tyres were the most active habitats (30.4%) with highest larval abundance (Table 2). Rock pools were second most active habitats (22.6%) while abandoned wells had the least (0.8%) larval abundance. Concrete electric poles had higher abundance of *Ae. vittatus* than discarded tyres. Rice farm and tree holes were only habitats examined without mosquito larvae while blocked drainage had the highest diversity of mosquito larvae. *Aedes vittatus* and *Ae. africanus* were the most abundant species which occurred in rock pools, discarded tyres, domesticated containers and electric poles. Both species were least recorded in abandoned well and rock pools respectively. *Aedes centrapunctatus* and *Cx. decens* were the most restricted species encountered only in discarded tyres and gutters respectively. *Aedes vittatus* and *Ae. simpsoni* displayed a wide diversity of habitat, encountered in 6 of the 11 larval habitats sampled in this study. The abundance of *Aedes* mosquitoes were two folds the number of *Culex* mosquitoes. *Culex rubinotus*, *Cx. duttoni* and *Cx. quinquefasciatus* were the dominant *Culex* mosquitoes with higher larval abundance in discarded tyres, containers (discarded containers and domesticated containers) and rock pools respectively. *Culex quinquefasciatus* bred in rock pools and blocked drainage while *An. gambiae* s.l. bred in cesspools and potholes.

Table 3 shows physicochemical variables determined *in situ* with HANNA HI 98129PH/EC/TS/Temp meter at different larval breeding habitats. Temperature of the larval habitats recorded minimum of 23.2 ºC while extreme is 35.4 ºC. *Aedes vittatus* bred in larval habitats with wide range of temperature 23.2–35.4 and mean value of 29.55±4.53. *Cx. arbieeni* and *Cx. macfiei* were also found in larval habitats with extreme range of temperature 26.8–35.4 and 27.2–35.4 respectively with corresponding mean values of 29.8±20.09 and 30.66±15.10. *Aedes keniensis* had the overall least temperature range of 25.8–27.7 and mean value of 26.75±32.47. On average, the daily pH ranged from slight acidity to slight alkalinity. *Aedes vittatus* bred in pH media ranging from 6.40 (acidic) to 9.13 (alkaline) while *Cx. horridus* bred in pH media that is near neutral value (6.91). A near neutral to alkaline pH range (6.99–7.86) supported the breeding of *Cx. striatipes* while pH value of slight acidity to strong alkalinity supported the breeding of *Cx. macfiei* (6.99–8.09), *Cx. pipiens molestus* (6.99–8.65) and *Cx. rubinotus* (6.99–8.57). *Aedes centrapunctatus* and *Ae. cumminsi* were only mosquito species that thrived in pH medium with strong alkalinity range of 8.10-8.10 and 8.06-8.83 respectively. Of *Culex* mosquitoes, *Cx. duttoni* was found in larval habitats with the highest range of electrical conductivity and total dissolved solid of 198–1341μscm^{-1} and 98–672ppm respectively. *Aedes vittatus* bred in larval habitats with the highest range of electrical conductivity (38–1308μscm^{-1}) compared to other *Aedes* mosquitoes. Extreme range of total dissolved solid (55 – 269 ppm) and electrical conductivity (111–547μscm^{-1}) favoured the breeding of *Ae. domesticus*. Rock pools, discarded tyres, domesticated containers and electric poles differed significantly ($p<0.05$) with abundance of mosquito larvae. The proportion of *Ae. simpsoni* (2.3%) and *Ae. Vittatus* (48.7%) positively correlate with electrical conductiviy.

Temperature of the breeding habitats negatively correlate with abundance of *Ae. africanus* (16.7%), *Ae. simpsoni*, (2.3%), *A* *e. vittatus* (48.7%) and *Cx. quinquefasciatus* (4.5%). Total dissolved solid positively correlate with abundance of *Ae. cumminsi* (2.2%), *An. gambiae s.l* (1.4%) and *Cx. pipiens molestus* (1.6%). Anthropogenic activities that probably promote mosquito larval occurrence and abundance were searched and categorized into the following habitats: (i) Blocked drainage (ii) Construction site (iii) Farmland (iv) Concrete electric poles (v) Mechanic workshop (vi) Motor park (vii) Residential and (viii) Roadside (Table 4). A total of 3594 mosquito larvae were caught from 96 breeding habitats which resulted from impact of human activities. Out of the 96 breeding habitats, 53(55.2%) habitats were found with mosquito larvae and yielded an overall larval density of 37.4. Interestingly, discarded used vehicle tyres from mechanic workshops had the highest number of mosquito larvae followed by piled concrete electric poles. Residential areas were found with the highest number of mosquito breeding habitats while concrete electric poles which had the highest larval density were found with the least number of mosquito breeding habitats. The least number of mosquito larvae were recorded from farmland which also had the least larval density.

Table 2: Distribution of mosquito species in different types of larval habitats

	Types of breeding habitats											
Mosquito species	**RP**	**DT**	**DC**	**CP**	**AW**	**PH**	**FP**	**RF**	**BD**	**EP**	**TH**	**Total**
Ae. aegypti	24	0	133	0	0	0	0	0	0	6	0	165
Ae. africanus	31	428	157	0	0	0	0	0	0	161	0	777
Ae. centrapunctatus	0	47	0	0	0	0	0	0	0	0	0	47
Ae. cumminsi	13	0	0	13	0	0	0	0	0	78	0	104
Ae. domesticus	3	9	2	0	0	0	0	0	0	16	0	28
Ae. fraseri	0	26	4	0	0	0	0	0	1	4	0	35
Ae. keniensis	0	0	9	0	0	0	0	0	36	0	0	45
Ae. pulchrithorax	0	27	0	0	0	0	0	0	0	0	0	27
Ae. simpsoni	10	48	6	14	0	0	0	0	13	17	0	108
Ae. vittatus	966	356	0	294	2	0	0	0	0	511	0	2129
An. gambiae s.l.	0	0	0	28	0	39	0	0	0	0	0	67
Cx. arbieeni	0	0	0	0	0	0	8	0	16	0	0	24
Cx. decens	0	0	0	0	0	0	0	0	2	0	0	2
Cx. duttoni	0	0	198	0	0	0	14	0	0	0	0	212
Cx. horridus	0	0	5	0	54	0	0	0	15	0	0	74
Cx. macfiei	0	0	0	0	4	0	39	0	11	19	0	73
Cx. nebulosus	0	0	0	0	0	0	0	0	134	0	0	134
Cx. pipiens molestus	0	104	0	0	17	0	20	0	13	0	0	73
Cx. quiquefasciatus	141	0	0	0	0	0	0	0	69	0	0	210
Cx. rubinotus	0	173	0	0	10	0	0	0	46	0	0	229
Cx. striatipes	0	19	0	0	2	0	0	0	2	0	0	23
Cx. tigripes	0	32	10	0	0	0	0	0	6	9	0	57
Total *P-value*	1047 0.041*	1410 0.01*	517 0.00*	349 0.631ns	35 0.362ns	39 0.127ns	81 0.247ns	0 0.082ns	340 0.329ns	821 0.003*	0 0.316ns	4641

Key: ns - not significant, "*" - significant, RP – Rock pools; DT – Discarded tyres; DC – Discarded containers/Domesticated containers; CP – Cesspools; AW – Abandoned well; PH – Potholes; FP – Farm pools; RF – Rice fields; BD – Blocked drainage; EP – Electric poles; TH – Treehole

Table 3: Ranges (Mean±SE) of physicochemical variables of water utilized for breeding by mosquito species

	Physicochemical parameters			
Mosquito species	**Temperature (°C)**	**pH**	**Total Dissolved Solid (ppm)**	**Electrical Conductivity (μscm^{-1})**
Ae. aegypti	27.5 – 29.7 (28.9±16.19)	7.37 – 8.12 (7.73±4.32)	44 – 211 (117.75±74.79)	88 – 417 (233.25±148.13)
Ae. africanus	24.4 – 34.1 (29.26±6.11)	7.06 – 8.83 (7.8±1.64)	19 – 269 (77.96±19.81)	39 –547 (243.30±36.81)
Ae. centrapunctatus	29.4 – 29.4 (29.4±0.0)	8.10 – 8.10 (8.10±0.0)	73 – 73 (73±0.0)	147 – 147 (147±0.0)
Ae. cumminsi	23.2 – 34.1 (29.88±14.74)	8.06 – 8.83 (8.39±4.11)	71.15 (111±56.63)	145 – 305 (221±112.52)
Ae. domesticus	28.5 – 34.9 (30.95±17.36)	7.26 – 8.85 (7.97±4.47)	55 – 269 (115.75±82.54)	111 -547 (334.75±167.7)
Ae. fraseri	24.4 – 30.4 (27.7±10.33)	7.45 – 8.37 (7.91±3.48)	19 – 99 (66.17±33.40)	39 – 257 (133.33±67.19)
Ae. keniensis	25.8 – 27.7 (26.75±32.47)	7.50 – 7.82 (7.66±6.65)	18 – 229 (123.50±150.68)	38 – 459 (28.5±275.02)
Ae. pulchrithorax	29.1 – 29.1 (29.1±0.00)	7.93 – 7.93 (7.93±0.00)	34 – 34 (34±0.00)	71 – 71 (71±0.00)
Ae. simpsoni	23.2 – 33.4 (29.09±8.09)	7.26 – 8.83 (8.03±2.23)	19 – 269 (94.64±30.99)	89 -547 (192.14±62.91)
Ae. vittatus	23.2 – 35.4 (29.55±4.53)	6.40 – 9.13 (7.86±1.21)	18.66 (120.99±26.21)	38 – 1308 (243.30±52.40)
An. gambiae s.l.	29.80 – 33.0 (31.4±27.32)	7.71 – 8.70 (8.21±7.14)	45 – 108 (76.5±73.58)	92 – 217 (154.5±148.12)
Cx. arbieeni	26.8 – 35.4 (29.8 ±20.09)	7.86 – 8.09 (7.99±5.33)	99 – 252 (150.67±112.63)	199 – 502 (301±224.69)
Cx. decens	27.3 – 27.3 (27.3±0.0)	7.86 – 7.86 (7.86±0.0)	99 – 99 (99±0.0)	199 – 199 (199±0.0)
Cx. duttoni	26.8 – 34.4 (30.04±14.76)	7.69 – 8.02 (7.58±3.86)	98 – 672 (229.6±158.20)	198 – 1341 (459±305.774)
Cx. horridus	29.0 – 29.0 (29.0±0.0)	6.91 – 6.91 (6.91±0.0)	192 – 192 (192±0.0)	412 – 412 (412±0.0)
Cx. macfiei	27.2 – 35.4 (30.66±15.10)	6.99 – 8.09 (7.78±3.81)	98 – 252 (163.2±85.02)	199 – 502 (332.6±173.24)
Cx. nebulosus	27.2 – 27.7 (27.45±23.84)	7.82 – 7.86 (7.84±6.81)	99 – 229 (164±156.66)	199 – 459 (329±314.11)
Cx. pipiens molestus	27.2 – 34.3 (30.3±14.87)	6.99 – 8.65 (7.81±3.83)	33 – 192 (122.40±66.73)	67 – 412 (251.20±138.47)
Cx. quiquefasciatus	26.8 – 31.2 (28.65±16.05)	7.65 – 8.14 (7.92±4.43)	29 – 110 (84.75±50.95)	59 – 220 (170±102.09)
Cx. rubinotus	26.8 – 34.1 (29.77±13.46)	6.99 – 8.57 (7.85±3.47)	55 – 192 (119.67±57.10)	111 – 412 (245.17±117.64)
Cx. striatipes	27.2 – 31.20 (29.13±19.48)	6.99 – 7.86 (7.81±3.83)	99 – 192 (133.61±93.93)	199 – 420 (279.67±199.54)
Cx. tigripes	28.4 – 34.1 (30.83±11)	7.65 – 8.83 (8.05±3.02)	47 – 178 (92.75±37.62)	94 – 355 (186.88±75.64)

*. Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed),

Table 4: Anthropogenic influence on the occurrence and larval abundance of mosquito species

Human activity type	Number of habitats examined	Number (%) of habitats with mosquito	Number of larvae	Larval density
Blocked drainage	8	5(5.2)	310	38.8
Construction site	11	5(5.2)	204	18.5
Farmland	9	4(4.2)	42	4.7
Concrete electric poles	6	5(5.2)	821	136.8
Mechanic	14	11(11.5)	1386	99.0
Motor park	11	7(7.3)	255	23.2
Residential	29	13(13.5)	525	18.1
Roadside	8	3(3.1)	51	6.4
Total	96	53(55.2)	3594	37.4

Number of habitats with mosquito was expressed as the corresponding percentage of total number of habitats examined

Discussion

In this study, heterogenous distribution and significant preference for breeding especially *Ae. vittatus* and *Ae. africanus* which constituted the bulk of the mosquitoes collected in this survey suggest increasing susceptibility of humans to the yellow fever, dengue and probable Zika virus diseases. This study demonstrated that rock pools and discarded tyres were the most productive habitats which are temporary in nature and exist for a brief period of time in a year. The flattened architecture of the granite rock proffers its suitability for sun-drying of agricultural farm produce especially peeled cassava while large number of abandoned concrete electric poles supported the breeding of *Aedes vittatus*. These temporary habitats concurred with previous studies [25, 21, 26, 27] that reported stoney pools as the predominant and the most preferred breeding habitats of *Ae. vittatus*. Inherent amenability of *Ae. vittatus* in stoney pools and dominance of *Ae. africanus* in discarded tyres could not only signify increasing susceptibility of inhabitants to arboviruses but also the occurrence of its outbreak. *Aedes vittatus* is well known to be involved in peri-urban transmission of yellow fever in Nigeria [28] and has been indicted as a probable vector of dengue virus as evidenced by virus isolations [27] and principal zoophagic species of Zika virus [29]. Results demonstrated that both habitats contributed significantly on mosquito production and larval production is dependent upon temporary larval development sites. Previous study had revealed that the prime factor in the establishment of infection in a new focus is the presence of a suitable vector in densities capable of transmitting the infection [30]. However, possible lack of sylvatic amplifying host necessary in the transmission chain tend to have been the source of respite as the potential mosquito vectors are in abundance in the study area. Yellow fever outbreaks recently have plagued several northern States including Bauchi, Kano, Borno and Katsina States as reported by [8] and in southern and central part of Nigeria [31].

Although several mosquito species may coexist in the same aquatic habitats, evidence of differential habitat use has been documented [32, 33]. These habitats differed in their structural complexity in terms of water holding capacity, vegetation, amount of detritus and species composition. Natural breeding sites such as rock pools supported diverse number of *Aedes* mosquitoes which included *Ae. aegypti*, *Ae. africanus*, *Ae. cumminsi*, *Ae. domesticus*, *Ae. simpsoni*, *Ae. vittatus* and *Cx. quinquefasciatus*. Human habits resulting from use of rocky platforms and low-leveled inselbergs for drying of fermented cassava could cause off-load of organic materials within the small circumference of the rock pools, thereby altering breeding chemistry of the habitats. Factor such as the ability of *Cx. quinquefasciatus* to exploit human activities for breeding and self-perpetuation could explain the vector's adaptability in rock pools more than the suspected polluted breeding habitats such as drainages. High total dissolved solid and electrical conductivity could further buttress the preference of *Ae. vittatus* and *Cx. quinquefasciatus* for polluted breeding microhabitats. The occurrence of *Ae. vittatus* in discarded used tyres, domesticated containers, cesspools and abandoned electric poles proved the vector's anthropogenic-induced adaption to successfully invade. Results of this study seemed to support the reports of [34] and [33] that in most areas of its distribution, *Cx. quinquefasciatus* prefer habitats with turbid water caused by organic matter. More mosquito larvae were found in artificial habitats than natural temporary sources indicating the impact of human population for the proliferation of larval breeding habitats. Used motor vehicle tyres are one of the categories of artificial containers with distinct particularities. Despite the public health relevance of used tyres, there seems to be absence of environmental regulatory measures against discarding used tyres in the open in Nigeria as these containers were littered indiscriminately. This unwarranted negligence posed serious threat in mosquito abatement programs resulting to proliferation of diverse species of mosquitoes from used tyres in urban areas. This study witnessed dominance of arboviral vectors in used tyres despite the absence of two tyre-breeding mosquito species of cosmopolitan distribution, *Ae. aegypti* and the complex *Culex pipiens* which contrasted with [35, 36]. Results reaffirmed pre-eminence of *Ae. aegypti*, *Ae. africanus*, *Ae. domesticus* and *Ae. simpsoni* in water-holding containers within private human premises. The water quality as well as conditions of water containers seemed to contribute to their abundance as they opted for freshwater habitats with high total dissolved solid and electrical conductivity. Although *Ae. simpsoni* found in Nigeria seems to be non-man biting variants, *Ae. lilii* and *Ae. bromeliae*, the role of *Ae. simpsoni* was probably continued by *Ae. africanus* and *Ae. aegypti* which are found in large numbers in rural dwellings and forest fringes [28]. However, in terms of the mosquito species diversity, blocked drainages were found to be more congenial and stand to be model mosquito larval habitat in Makurdi. Sanitary problem which stems from dumping of domesticated wastes and spoiled farm produce within the drainage system had resulted to unintended consequences of abandoned water puddles supportive of wide spectrum of *Culex* mosquitoes especially *Cx. quinquefasciatus* and the urban differentiated form, *Cx. pipiens molestus* [37]. Although *Cx. tigripes* is non-blood sucker, selection of oviposition sites could depend on the presence of mosquito immatures in used tyres, discarded containers, electric poles and blocked drainages. Its colonization in artificial habitats could be influenced by the presence of prey species and structure of the habitat [38]. In addition to public health importance, *Culex* mosquitoes cause tremendous nocturnal discomfort and allergic responses due to its nuisance biting.

The relative abundance of *An. gambiae* s.l. in cesspools and potholes fashioned by heavy vehicles conveying materials at different construction sites within the University of Agriculture Main Bus Stop, South Core marked its preference for human and changes induced by human habitation. Its relative abundance in these habitats could likely be explained in part by the fact that the female species of *An. gambiae* s.l. preferentially select them for oviposition which is evidently demonstrated by the report of [10]. The abundance of *An. gambiae* s.l in cesspools and potholes seemed to support the reports of [39] that suggested the preference of *An. gambiae* is to turbid than clear water for oviposition. Its survival ability could also be that larval predation was less prevalent or non-existent in these temporal pools as opposed to large permanent habitats. The abundance of *Anopheles* immatures could maintain a stable malaria transmission among human population considering the students' population within the University. This species has been reported as the major malaria vector [40], the most endemic parasitic disease in the study area. [12] supported the view that shallow bodies of water increase the number of anopheline larval habitats in rural areas, but the absence of suitable habitats and increased water pollution generally inhibit the development of anopheline larvae in urban areas, resulting in fewer anopheline larval habitats. However, the study noted a common heavy application of herbicides in paddies; practice which could unwittingly repulse adult oviposition and as well make unfit rain-fed pools for larval development. Paddy habitats could as well be rendered less productive for Anophelines and other mosquito larvae resulting from the nature of soil and topography which do not allow formation of rain-fed pools. These observations contrasted with the work of [41] and [42] who reported rice fields as very productive habitats of mosquito larvae. Absence of mosquito immatures in tree-holes may be explained by the fact that structurally simple habitats such as tree-holes had less amount of resource to support mosquito population as has been noted in larval habitats like bamboo stumps [43, 38].

Water characteristics of breeding places are important for oviposition and development of mosquitoes. Changing these factors in larval habitats may create conditions favourable or unfavourable for mosquito biology [44]. Results of this study suggested that larval growth, development and survival was highest in water temperature between 23.2-35.4 ºC and was paramount for spatial distribution of mosquito larvae. This temperature range indicated that extreme exist but ideal for oviposition and development of the mosquito larvae. Temperature lower than 14–16 °C and higher than 30 °C reduces the rate of larval development of many species [45]. Both anopheline and culicine were negatively associated with temperature. This finding concurred with [46] who reported negative correlation between temperature and mosquito abundance. In contrast, [14] showed that both *Culex* and *Aedes* were not associated with water temperature. Temperature of the study locations as reported by [47] is usually high throughout the year due to constancy of isolation with the maximum of 32 °C and minimum of 26 °C. Variation observed in the present study may have been influenced by variables such as time of sampling and condition of the habitats. The pH of the breeding water in the present study ranged from 6.40 (acidic) to 9.13 (alkaline) and therefore could be important factor for breeding site selection and larval development. Breeding activity of *Aedes* species occurred within a narrow pH range of 7 – 8 except *Ae. vittatus* which bred in water with pH range of 6.40 – 9.13. Results seemed to support earlier studies by [48] who reported that *Aedes* species had an inclination for breeding in narrow pH range of 6 – 8. *Culex* species also showed preference for breeding within a narrow pH range of 7 – 8 except *Cx. horridus, Cx. macfiei, Cx. pipiens molestus*, *Cx. rubinotus* and *Cx. striatipes* that bred in pH with slight acidity. However, there was no relationship between pH and larval abundance which concurred with the reports of [3] and [49]. However, *Ae. aegypti* and *Ae. vittatus* showed their ability to proliferate in habitats with high total dissolved solid and electrical conductivity more than any other *Aedes* mosquitoes. Meanwhile, results displayed a positive relationship existed with the larval abundance of *Ae. vittatus*, *An. gambiae* s.l., *Cx. quinquefasciatus,* and *Cx. pipiens molestus* and total dissolved solid and electrical conductivity which could be important determinants that leverage their prolific breeding in artificial and natural temporary habitats.

Conclusion

This study revealed that anthropic activities had produced and supported diverse suitable habitats for mosquito breeding. Suitability of mosquito breeding and survival could potentially be driven by temperature, total dissolved solid and electrical conductivity as strong correlations confirms the influence of these parameters on the breeding activities of mosquitoes. There is need for a public education campaign to mitigate general mosquito nuisance and also to reduce the risk of a mosquito-borne disease outbreak.

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