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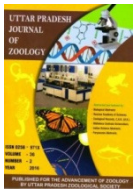

SEASONAL VARIATION IN DISTRIBUTION AND ABUNDANCE OF MOSQUITOES (DIPTERA: CULICIDAE) IN AKURE, NORTH LOCAL GOVERNMENT AREA, ONDO STATE, NIGERIA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between both authors. Author AOJ designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AOJ and AOC managed the analyses of the study. Author AOC managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The distribution and abundance of mosquito species in relation to seasons and habitats were studied between January, 2016 to December, 2017. One hundred and twenty sampling sites randomly distributed across six geographical locations of Akure North Local Government Area were sampled. The larvae collected were preserved in 70% ethanol and identified to species level. Evaluation of mosquito breeding sites revealed that concrete gutters harbored the largest number of mosquito larvae (1702) while the least number of mosquito larvae (127) was obtained from drum. Similarly, the highest relative abundance of mosquito larvae (98.44) was found in Shasha Market where 80% of the 20 sampled sites were positive for mosquito breeding. This abundance strongly correlated with highest temperature of 28°C, dissolved oxygen (7.69 mg/l), conductivity (85.25µs) and low alkaline (7.43). Meanwhile, the lowest relative abundance (20) correlated with lowest dissolved oxygen (6.55 mg/l) and relatively low temperature (27.48°C). Seasonal abundance of mosquito during the rainy season (88.80) was observed to be significantly higher than that of dry season (11.20). It was further observed that *Ae. irritans*, *Ae. durbanensis*, *Ae. metallicus*, *Ae. amaltheus*, *Ae. vittastus*, *Cx. stratipes*, *Cx. nebulosus*, *Cx. horridus*, *Cx. philipi*, *Cx. stellatus*, *Cx. macfei, Cx. pruina* and *An. gambiae* were completely absent in the study during the dry season. Even among the species that were present in both seasons with the exception of *Cx. arbeeni*, the percentage abundant was significantly higher in the rainy season than in the dry season. The persistent occurrence of *Aedes*, *Culex* and *Anopheles* species poses a serious epidemiological concern to the inhabitants of the study area since these mosquito genera are known vectors of diseases such as malaria, yellow fever and filariasis. Therefore, intensive vector control programs that are ecofriendly are recommended in order to reduce mosquito population and the prevalence of mosquito-borne diseases in the study area.

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Keywords: Season; abundance; physico-chemical parameters; *Culex.*

ABBREVIATIONS

Ae. = *Aedes*
Cx.= *Culex*
An.= *Anopheles*
Tx = *Toxorhynchites*

1. INTRODUCTION

Mosquitoes are cosmopolitan in distribution and found mostly in warm humid tropical countries of West and East Africa, Southeast Asia, the Caribbean and South America and Europe [1]. The only areas from which they are absent are Antartica and a few Islands due to the frozen nature of the areas. In Nigeria, mosquitoes are widely distributed throughout the country; the most common species belong to the genera *Anopheles, Culex* and *Aedes* [2,3]. Mosquitoes are responsible for the transmission of many medically important pathogens and parasites such as viruses, bacteria, protozoans and nematodes. The most notorious mosquito species which have been incriminated in the transmission of such disease like malaria (*Anopheles gambiae*, *An. arabiensis*), yellow fever (*Aedes aegypti*) and filariasis (*Anopheles gambiae* s.s and *Culex. quinquefasciatus*), have also been identified in Nigeria. Other diseases caused by mosquitoes include dengue fever, Chikungunya fever, encephalitis or filariasis [4,5,6,7]. Transmission can be mechanical such as mosquito transmitting *Myxoma* virus causing myxomatosis in rabbits or biological such as mosquito transmitting *Plasmodium* causing malaria in human. The latter is more complex because it involves an obligatory period of replication and/or development of the pathogen or parasite in the insect vector. Due to their blood-sucking behaviour, mosquitoes are able to acquire the pathogens or parasites from one vertebrate host and pass them to another, if the mosquito's ecology and physiology are appropriate for transmission. Highly efficient vectors have to be closely associated with the hosts and their longevity has to be sufficient enough to enable the pathogens/parasites to proliferate and/or to develop to the infective stages in the vector. For successful transmission, multiple blood-meals are necessary. For the vectorial capacity of mosquitoes to be achieved, gravid adult female mosquitoes must lay their eggs in aquatic habitats which are usually freshwater habitats where the developmental stages can develop into aerial adult. In the quest for water, mosquitoes exploit almost all types of lentic aquatic habitats for breeding [8]. Many species breed in both natural and artificial containers such as pools, gutters, coconut shells, tree holes, bamboo stumps, leaf axils, septic tanks etc. [9,10]. Some species prefer habitats with vegetation, some breed in open, sunlit pools while a few species breed in tree holes or the leaf axils of some plants [11]. The larvae of mosquitoes have been found to thrive in aquatic bodies such as fresh or salt water marshes, mangrove swamps, rice fields, grassy ditches, the edges of streams and rivers, and small temporary rain pools. Mosquitoes show preference to water with suitable pH, optimum temperature, dissolved oxygen, concentration of ammonia and nitrate [12].

Akure, the capital city of Ondo State is undergoing rapid urbanization of settlements in areas where only a scattered rural population existed formerly. This has resulted in some areas being densely populated. In such settings, organized sanitary facilities are usually poor; also sewage disposal depends largely upon the initiative of the individual resident. Where water supply is available, there may be drains, soakage pits, peridomestic run offs and pools of standing water. Domestic conditions like these are ideal as breeding sites of some common mosquitoes; such as *Culex quinquefasciatus* [13]. The construction of the surface run-off (gutters), the provision of open or partially covered soakage pits for houses and abandoned tyres are also likely to create good and active breeding sites for mosquitoes in urban settlements. The aim of this research is to identify different species of mosquitoes in Akure North Local Government Area.

2. MATERIALS AND METHODS

2.1 Study Area

A cross-sectional study was carried out in Akure North local Government Area of Ondo State from January, 2016 to December, 2017. The study area is located in the Southwestern geopolitical zone of Nigeria and bounded in the North by Ekiti and Kogi States, in the east by Edo State and in the south by the Atlantic Ocean. The state contains eighteen Local Government Areas in which Akure North is one of them. Akure North Local Government Area has its headquarters in the town of Iju/Itaogbolu. It has an area of 660 km^2 and a population of 131,587 at the 2006 census. The tropical climate of the Local Government is broadly of two seasons: rainy season (April-October) and dry season (November-March). Its temperature throughout the year ranges between 21°C – 29°C and humidity is relatively high. The Local Government has annual rainfall of about 1150 mm and it also

enjoys luxuriant vegetation with high forest zone.

One hundred and twenty (120) sampling sites consisting of 20 sites each from 6 locations were randomly selected within the study area. Six locations where the samples were collected include; Oba-Ile, Ijapo, Shasha, Owode, Igbatoro and Isinigbo (Fig. 1).

2.2 Water Sampling and Water Quality Parameters

Water samples were collected from different sampling sites, which includes the negative (absence of mosquito larva) and the positive (presence of mosquito larva) sampling sites. Parameters such as temperature and pH were measured in-situ with the use of a Hanna pH/Temp meter. The conductivity of the water was determined by using Conductivity meter while the amount of dissolved oxygen present in the water samples was determined in the Chemistry Laboratory, Federal University of Technology Akure.

2.3 Identification of Mosquitoes

Six towns (Isinigbo, Owode, Igbatoro, Ijapo, Oba-Ile and Shasha) were randomly selected within the study area and twenty sampling sites were sampled for mosquito larvae in each location. The one hundred and twenty sites selected across the locations were sampled with muslin cloths, dippers, aspirators, pipettes and plastic container. The habitats sampled include concrete gutters, abandoned tyres, peridomestic containers and stagnant pools. The larvae collected from each site were preserved separately in container containing 70% ethanol, and the larvae were transported to the Biology Laboratory of Federal University of Technology Akure for identification. The larvae were identified to species level using X20 dissecting microscope and guided by the morphological keys [14,15,16].

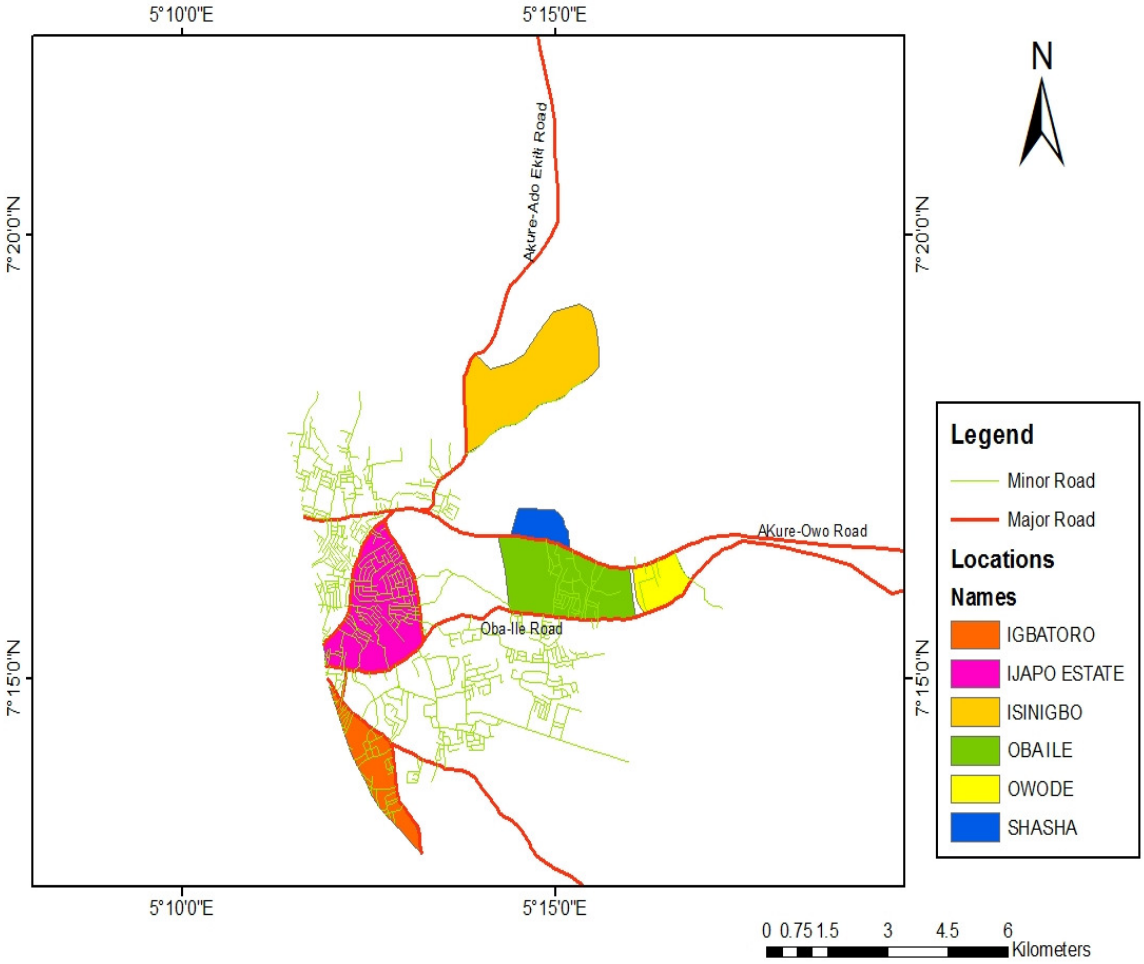

Fig. 1. Map of Akure North local government area showing the sampling sites

2.4 Statistical Analysis

Data obtained were analyzed using One-Way ANOVA and significant differences that exist among the means were separated using New Duncan Multiple Range Test at P<0.05. Percentage abundance for wet and dry season was calculated as the ratio of abundance in season to total abundance i.e

$$\text{Percentage abundance} = \frac{\text{Abundance in Season}}{\text{Total Abundance}} \text{ X } 100$$

3. RESULTS

3.1 Larva Habitats, Abundance of Mosquito Genera and Larvae Breeding Activities in Akure, North Local Government Area Ondo State, Nigeria

The habitats where breeding was observed in the study area include plastic containers, stagnant pools, abandoned tyres, drum and concrete gutters. It was noted in Fig. 2 that concrete gutters harbored the largest number of mosquito larvae (1702) while drum harbored the least number of mosquito larvae (127). Similarly, result presented in Fig. 3 showed that *Culex* genus has the highest percentage abundance (74.77%) in the study area, followed by Aedes (22.02%) while Anopheles and Toxorhynchites have the least percentage abundance of 1.75% and 1.45% respectively. An overview of Table 1 showed that there were much breeding activities in Igbatoro community than the other locations because all the habitats sampled were positive for mosquito breeding. It also showed that least breeding activities were observed in Ijapo and Oba-Ile Estates. In these two locations, breeding activity was only found in concrete gutters, stagnant pools and abandoned tyres and completely absent in plastic containers and drums. Breeding in drum was only positive in Igbatoro community (Table 1). Further result presented in Fig. 3 shows that 4 mosquito genera were encountered during the study. Of all these genera, *Culex* had the highest abundance (74.77%) while *Toxorhynchites*; a predacious genus had the lowest abundance (1.45%) in Akure North Local Government Area.

3.2 Relative Abundance as Related to Physico-chemical Parameters and Seasonal Variation of Mosquito Species in Akure, North Local Government Area, Ondo State, Nigeria

Table 2 shows the relative abundance of mosquito larvae as related to their physico-chemical parameters in Akure North Local Government Area of Ondo State. The result shows that the highest relative abundance of mosquito larvae (98.44) was found in Shasha Market where 16 (80%) of the 20 sites sampled were positive for mosquito breeding. The highest abundance recorded in Shasha Market also strongly correlated with highest temperature (28°C), highest dissolved oxygen (7.69 mg/l), fairly high conductivity (85.25µs) and low alkaline (7.43). In contrary, lowest relative larval abundance (20) was recorded in Ijapo Estate; a predominant residential area. This lowest abundance correlated with lowest dissolved oxygen (6.55 mg/l) and relatively low temperature (27.48°C). The result in Table 3 shows that there is significant difference in the seasonal abundance of mosquitoes in Akure North Local Government Area of Ondo State. It was noted that the percentage abundance of mosquito during the rainy season (88.80) was significantly higher than that of the dry season (11.20). T-test showed that there was a significant difference (P=0.00, df= 20, P < 0.05) in the abundance of mosquito species during the rainy and dry season. It also showed a strong positive correlation (r=0.70) in species found in rainy season and dry season, that is there was an increase in the number of mosquito species found during the rainy season when compared to the dry season. It was further observed that *Ae. irritans*, *Ae. durbanensis*, *Ae. metallicus*, *Ae. amaltheus*, *Ae. vittastus*, *Cx. stratipes*, *Cx. nebulosus*, *Cx. horridus*, *Cx. philipi*, *Cx. stellatus*, *Cx. macfei, Cx. pruina* and *An. gambiae* were completely absent in the study during the dry season. It was also observed that even among the species that were present in both season with the exception of *Cx. arbeeni*, the percentage abundant was significantly higher in the rainy season than in the dry season (Table 3).

3.3 Composition and Distribution of Mosquito Species in Akure North Local Government Area, Ondo State, Nigeria

General overview of Table 4 revealed 6 species of *Aedes*, 13 species of *Culex*, 1 species of *Anopheles* and *Toxorhynchites*. Among the *Aedes* species; *Ae. aegypti* is the most distributed and the most abundant species in Akure North Local Government Area of Ondo State. This species was found in all the locations with significant population. In contrary, *Ae. amaltheus* was the least abundant. It was further observed from Table 4 that *Ae. vittatus* and *Ae. amaltheus* were only found in Igbatoro community and absent in other locations under study. Of the thirteen species of *Culex* observed in Akure North Local Government Area, *Culex andersoni* was the most abundant (790) both among the *Culex* species and the entire mosquito population sampled. The least

abundant of *Culex* spp in the study area was *Culex stratipes* (3.0) while the least distributed *Culex* species were *Cx. stratipes* which was only found in Ijapo Estate, *Cx. nebolusus* only found in Owode community and *Cx. philipi* only found in Igbatoro community. It was only one species of *Anopheles* (*An. gambiae*) that was encountered throughout the study. This species (*An. gambiae*) was found in Shasha Market (n=35), Owode community (n=12) and Isinigbo community (n=17). Meanwhile, it was noted that *An. gambiae* (malaria vector) was absent in Ijapo Estate, Oba-Ile Estate and Igbatoro community. *Toxorhynchite brevipalpis* which is a predatory mosquito at the larval stage was present in Shasha Market, Oba-Ile Estate and Igbatoro community. This predatory mosquito species was absent in Ijapo Estate, Owode community and Isinigbo community. In terms of species richness per location, Shasha Market was the richest location containing thirteen (13) of the twenty one (21) species of mosquitoes followed by Ijapo Estate, Owode and Igbatoro communities, containing nine (9) of the twenty one (21) species of mosquito each. Eight mosquito species were obtained in Oba-Ile while the least location in terms of species richness was Isinigbo community where seven (7) species of mosquitoes were observed (Table 4).

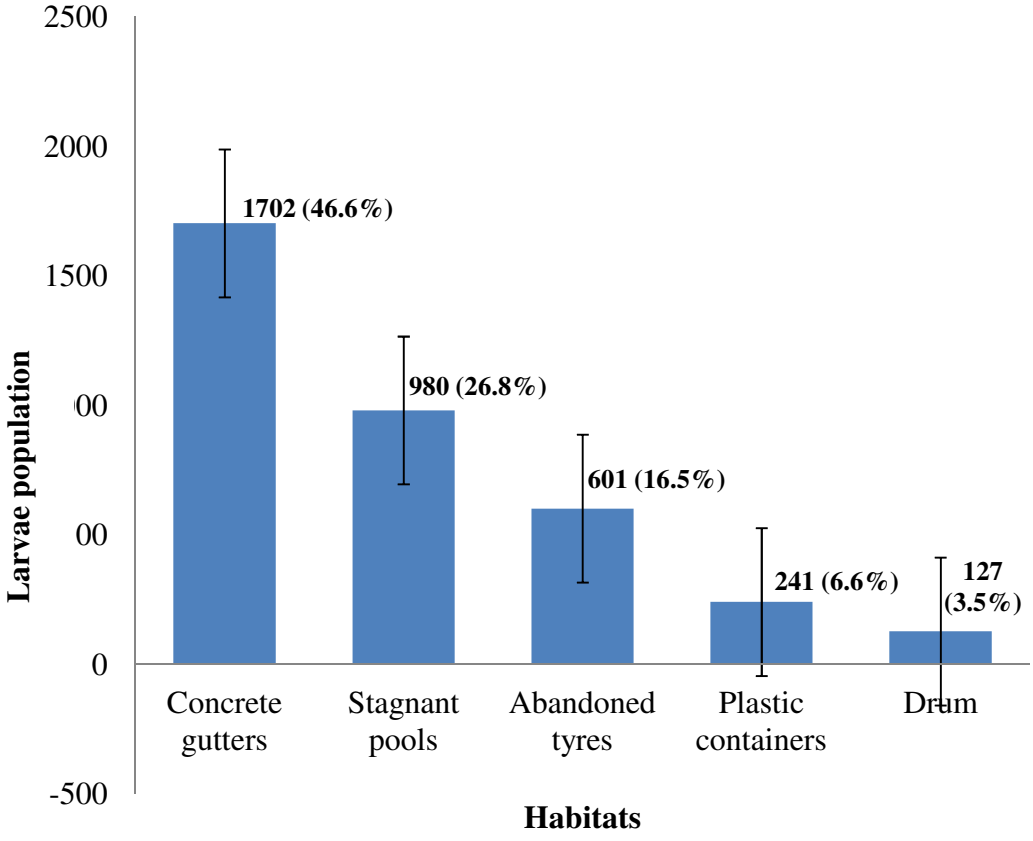

Fig. 2. Number and percentage of mosquito encountered in different habitats

Table 1. Habitats that support mosquito breeding in the Akure, North local government area

Location	Concrete gutters	Stagnant pools	Abandoned tyres	Plastic containers	Drum
Ijapo Estate	+	+	+	_	_
Shasha Market	+	+	+	+	_
Oba-Ile Estate	+	+	+	_	_
Owode Community	+	+	+	+	_
Isinigbo Community	+	+	+	+	_
Igbatoro Community	+	+	+	+	+

The sign minus (-) indicates the absence of mosquito in the breeding habitats while the sign plus (+) indicates the presence of mosquito in the breeding habitats

Table 2. Relative abundance of larval mosquitoes as related to physico-chemical parameters in Akure North local government area of Ondo State

Location	Physiochemical parameters				Number of pool		Number of larvae collected (%)	Relative abundance	Larval no per pool
	Temp(°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µs)	Examined	Positive (%)			
Ijapo Estate	27.48	7.45	6.55	84.73	20	11(55)	220(6.03)	20.00	11.00
Shasha Market	28.00	7.43	7.69	85.25	20	16(80)	1575(43.14)	98.44	78.75
Oba-Ile Estate	27.48	7.50	5.53	73.63	20	8(40)	329(9.01)	41.13	16.45
Owode Community	27.00	7.40	5.54	80.08	20	12(60)	565(15.48)	47.08	28.25
Isinigbo Community	27.50	7.50	7.20	79.52	20	12(60)	445(12.19)	37.08	22.25
Igbatoro Community	27.30	7.60	7.48	87.10	20	13(65)	517(14.16)	39.77	25.85
Total	**164.76**	**44.88**	**39.99**	**490.32**	**120**	**72(60)**	**3651(100)**	**283.54**	**30.43**
Average	**27.46**	**7.48**	**6.67**	**81.72**	**20**	**12**	**608.5**	**47.26**	**5.07**

Table 3. Seasonal variation of mosquito species in Akure North local government area

Species	Abundance in rainy season	Abundance in dry season	Total	% Abundance in rainy season	% Abundance in dry season	Total
Aedes irritans	92	0	92	100.00	0.00	100
Aedes aegypti	398	102	500	79.60	20.40	100
Aedes durbanensis	62	0	62	100.00	0.00	100
Aedes metallicus	45	0	45	100.00	0.00	100
Aedes vittatus	74	0	74	100.00	0.00	100
Aedes amaltheus	31	0	31	100.00	0.00	100
Culex tigripes	524	45	569	92.09	7.91	100
Culex horridus	198	0	198	100.00	0.00	100
Culex decens	62	41	103	60.19	39.81	100
Culex andersoni	675	121	796	84.80	15.20	100
Culex quinquefasciatus	543	47	590	92.03	7.97	100
Culex stellatus	17	0	17	100.00	0.00	100
Culex macfei	114	0	114	100.00	0.00	100
Culex stratipes	3	0	3	100.00	0.00	100
Culex nebulosus	60	0	60	100.00	0.00	100
Culex philipi	47	0	47	100.00	0.00	100
Culex univittatus	80	17	97	82.47	17.53	100
Culex arbeeni	8	26	34	23.53	74.47	100
Culex pruina	102	0	102	100.00	0.00	100

Species	Abundance in rainy season	Abundance in dry season	Total	% Abundance in rainy season	% Abundance in dry season	Total
Anopheles gambiae	64	0	64	100.00	0.00	100
Toxorhynchites brevipalpis	43	10	53	81.13	18.87	100
Total	**3242**	**409**	**3651**	**1895.84**	**202.16**	**2100**
% Abundance	-	-	-	**88.80**	**11.20**	-

Table 4. Composition and distribution of mosquito species in Akure North local government area

Species	Ijapo Estate	Shasha Market	Oba-Ile Estate	Owode Community	Isinigbo Community	Igbatoro Community	Total	Mean and standard error	Percentage (%)
Aedes irritans	12	75	5	0	0	0	92	15.33 ±12.08[a]	2.52
Aedes aegypti	11	105	104	45	188	47	500	83.33±25.74[bc]	13.69
Aedes durbanensis	0	45	5	12	0	0	62	10.33±7.20[a]	1.70
Aedes metallicus	0	0	0	0	45	0	45	7.50±7.50[a]	1.23
Aedes vittatus	0	0	0	0	0	74	74	12.33±12.33[a]	2.03
Aedes amaltheus	0	0	0	0	0	31	31	5.17±5.17[a]	0.85
Culex tigripes	66	216	45	242	0	0	569	94.83±43.83[bc]	15.58
Culex horridus	0	147	0	0	0	51	198	33.00±24.27[ab]	5.42
Culex decens	0	51	0	41	11	0	103	17.17±9.37[a]	2.82
Culex andersoni	94	378	41	35	135	113	796	132.67±51.65[c]	21.80
Culex quinquefasciatus	20	305	115	103	47	0	590	99.17±45.28[c]	16.16
Culex stellatus	4	11	0	0	2	0	17	2.83±1.76[a]	0.47
Culex macfei	0	89	0	0	0	25	114	19.00±14.58[a]	3.12
Culex stratipes	3	0	0	0	0	0	3	0.50±0.500[a]	0.08
Culex nebolusus	0	0	0	60	0	0	60	10.00±10.00[a]	1.64
Culex philipi	0	0	0	0	0	47	47	7.83±7.83[a]	1.29
Culex univittatus	2	78	0	0	0	17	97	16.17±12.67[a]	2.67
Culex arbeeni	8	0	11	15	0	0	34	5.67±2.69[a]	0.93
Culex pruina	0	0	0	0	0	102	102	17.00±17.00[a]	2.78
Anopheles gambiae	0	35	0	12	17	0	64	10.67±5.70[a]	1.75
Toxorhynchites brevipalpis	0	40	3	0	0	10	53	8.83±6.43[a]	1.45
Total	**220**	**1575**	**329**	**565**	**445**	**517**	**3651**	**28.976±5.360**	**100%**
No of species per location	**9**	**13**	**8**	**9**	**7**	**9**	**21**		

Means followed by the same superscript letters are not significantly different from each other ($P > 0.05$); $P= 0.06$; $df= 20$; $P < 0.05$

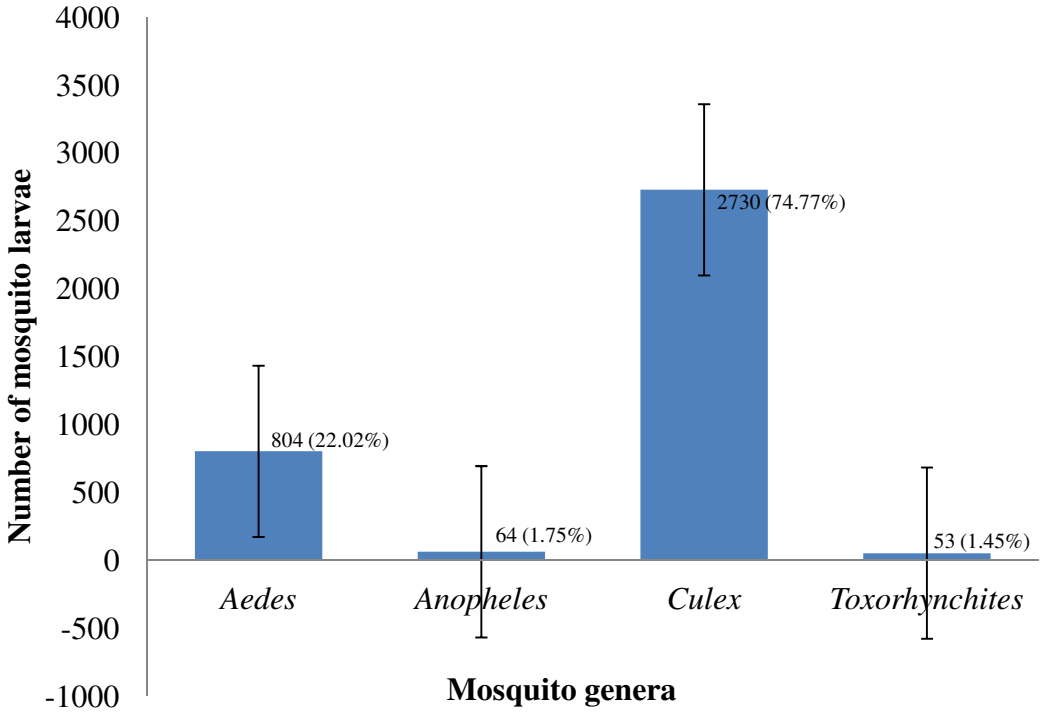

Fig. 3. Abundance and percentage of mosquito genera in the study area

4. DISCUSSION

Mosquito breeding was observed across all the locations sampled in the study area. The major habitats positive for mosquito species breeding are; concrete gutters, plastic containers, stagnant pools, drum and abandoned tyres. Meanwhile, concrete gutters, stagnant pools and abandoned tyres provided the highest number of breeding sites in Akure North Local Government Area. This report agrees with the report of Mafiana [9] in Abeokuta. The authors reported that tyres and domestic containers provide the highest number of breeding sites in both wet and dry seasons. The intense breeding of mosquitoes was also observed in tyres and domestic containers, during the rainy seasons, while concrete gutters were observed to provide the highest number of breeding sites in the dry season. The poor sanitation of Akure North Local Government Area appears to be responsible for this. Most of the gutters have been blocked with refuse and sewage, therefore rendering the water stagnant and providing breeding sites for mosquitoes.

The study also revealed mosquitoes species belonging to four genera; *Anopheles*, *Culex*, *Aedes* and *Toxorhynchites*. Among these genera, *Culex* is the most dominant genera observed in this study. Dominance of Culex mosquitoes had been reported in Nigeria by several researchers [3,17,18].

The distribution and abundance of mosquito species was significantly different across the locations with *Aedes aegypti* and *Culex andersoni* evenly distributed in all the locations while other species were sparsely distributed. *Culex andersoni* has the highest abundance in the study area. This finding agrees with the report of Afolabi et al. [3] that the predominance of *Cx. andersoni* in the study area suggests that the species is an indiscriminate breeder as the species was found in all the habitats sampled. *Cx. quinquefasciatus was* the second most abundant species encountered in Akure North Local Government Area. According to the report of Odo et al. [19], the species is known to be the most widely distributed mosquito in the world and it is found on every continent except in Antarctica. *Cx. quinquefasciatus* is known to breed in concrete gutters that are usually polluted [18]. This attribute has been reported by many researchers that the association of *Cx .quinquefasciatus* with pollution dates back to the 1950s when organochlorine insecticides were used as vector control in the tropics. *Cx. quinquefasciatus* showed tolerance to these insecticides and this led to its rapid establishment and spread to polluted breeding places in urban cities [1,13]. *Aedes aegypti* was the most abundant species in the genus *Aedes* and also the only species that is evenly distributed in all the locations, this species is the only one in its genus that exists during the dry season and raining season. According to Russell et al. [20] eggs of *Ae. aegypti*

when embryonated, can survive up to one year until they are flooded and hatched. Also, it is well known that *Aedes* eggs are capable of withstanding desiccation. This can be attributed to the fact that *Aedes* eggs have the ability to withstand desiccation and are thus found in the dry season. Abundance of *Ae aegypti* reported in this study concurs with the report of Soniran et al. [21] who reported that *Ae. aegypti* is an indiscriminate breeder. Also, Adebote et al. [2] in their survey in Zaria stated that *Aedes aegypti* is the most versatile species in its choice of breeding. This is likely to be the reason why the species was the most abundant species in its genus and also the only species in its genus found in all the locations. It is also important to note that *Ae. aegypti* is a confirmed vector of yellow fever [22] and its presence is therefore of socio-medical importance. Apart from its yellow fever transmission potential, Anyanwu et al. [23] had incriminated *Ae. aegypti* as a potential vector of the zoonotic dog filaria, *Dirofilaria repens*.

Anopheles larvae have a low abundance [64 (1.75%)] in Akure North Local Government Area of Ondo State, and it is only present during rainy season. The scarcity of *Anopheles* can be attributed to lack of appropriate breeding grounds since *Anopheles species* are known to breed mostly in clean waters devoid of pollutants [24]; the breeding grounds observed during this investigation were mostly foul, stagnant, dirty bodies of water presumably unsuitable for supporting larvae of the species. Hence, low abundance of *Anopheles* reported in this study may be as a result of polluted environment that does not support its breeding, *Anopheles* mosquitoes breed in transient habitats such as shallow sun lit fresh water pools or human made habitats, hoof prints and tyre tracks [15]. *An. gambiae* was the only anopheline mosquito found during the study and observed in low abundance in Shasha Market. Shasha Market is notable commercial area with high anthropological activities which resulted in litters of packaging materials such as cans and plastics where this species was found breeding. The least encountered genus in this study was *Toxoryhnchites.* This genus had a low abundance in all the locations and this might be due to its prolonged life cycle. *Toxoryhnchites* spend longer time in developing from egg to adult than the other mosquito species. This finding agrees with the reports of Hammon [25] and Anosike et al. [26]. According to Hammon [25], the larvae of *Toxorhynchites* are predaceous to all instars of mosquito larvae. Among the mosquitoes species found only *Toxorhynchites* spp has not been incriminated to transmit disease since the adults do not feed on blood.

In the study, it was observed that Shasha has the highest relative larval abundance (98.48) compare to others, and this location is known for heavy social and anthropological activities such as markets and also known for its high polluted environment while Ijapo which is an estate with high discipline and strict laws, also known for its environmental cleanliness was observed to have the lowest relative abundance (20.00). This finding was in accordance with the work of Simon-Oke et al. [27] which observed that mosquito distribution and abundance are related to population, land use and human activities.

The breeding temperature observed during the study suggested that mosquitoes breed at water temperature of 27.0 to 28.0°C. This finding was supported by Afolabi et al. [28] who reported that female mosquitoes preferred water temperature range of 24.7 to 28.3°C. The pH range of 7.4 to 7.6 supported breeding in all the habitats sampled. This result concurred with the findings of Odo et al. [19]. Okogun et al. [18] in their findings showed that water near pH 6.8 to 7.2 is suitable for the weakening of the egg shells for the first instar larva to emerge. The amount of dissolved oxygen (DO_2) present in water range from 5.53 mg/l to 7.69 mg/l. The highest abundance of mosquitoes species observed in Shasha Market might be as a result of high dissolved oxygen present in the water samples. Robyn et al. [29] had earlier reported that oxygen gas present in water is vital to the existence of most aquatic organisms; the diversity and abundance of organisms are greatest at higher DO_2 concentrations as observed in Shasha Market. The species abundance of mosquito was noticed to increase during the rainy season. More mosquito species were encountered during the rainy season than the dry season. The seasonal variation in abundance of mosquito species concurs with the finding of Afolabi and Simon-Oke [30], who reported that temperature and relative humidity are factors that determine the preference of many mosquito species, and that low relative humidity is known to cause death of mosquitoes through desiccation. Also during the dry season, mosquito development is deemed to be slower, while during the rainy season mosquito development is rapid with the stagnant water site serving as a main breeding site for the mosquito species. Adebote et al. [31] also stressed on aquatic microhabitat drying out due to cessation of rainfall.

5. CONCLUSION

This study has documented 21 mosquito species encountered January, 2016- December, 2017 within 6 settlements in Akure North Local Government Area of Ondo State, Nigeria. Some of these mosquitoes encountered such as *Cx. andersoni*, *Cx. quinquefasciatus, Ae. aegypti* and *An. gambiae* are of medical importance as they are known vectors of

filariasis, dengue fever malaria, yellow fever, malaria etc. Human activities, favorable physico-chemical parameters and increasing environmental pollution were identified as factors that encouraged mosquito breeding in the area. Therefore, the state, local government and individuals should embrace proper environmental sanitation in order to reduce the mosquito breeding sites and the morbidity and mortality associated with mosquito –borne diseases in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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