

Habitat Characteristics, Mosquito Breeding Status and Colour Preferences for Oviposition in Artificial Containers: Evidence from Orodo Mbaitolu Imo State, Nigeria

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Abstract

Introduction:

Mosquitoes are associated with different breeding sites which are either natural or man-made (artificial). This study investigated habitat characteristics, mosquito breeding status, and colour preferences for oviposition in artificial containers in Orodo, Mbaitolu, Imo State, Nigeria.

Methods

Mosquito larvae were collected using the standardized dipping technique. A total of 280 artificial containers representing seven different colours were filled with 600mL of water and monitored weekly for two months. All mosquito specimens were identified morphologically.

Results

A total of 7,386 mosquito larvae were collected. Of the 280 containers, 164 contained only water, while 116 contained both water and mosquito larvae. Oboroche recorded the highest larval density (22.7%); however, the distribution of mosquito-positive containers among the five villages did not differ significantly ($\chi^2 = 4.916, p = 0.296$). White containers (19.2%) attracted the highest number of mosquito larvae ($\chi^2 = 12.334, p = 0.055$). Plastic containers accounted for 58.2% of all positive breeding sites and showed a significant association between mosquito species and sampling locations ($\chi^2 = 116.257, p < 0.001$). Although species composition varied among villages, the differences were not statistically significant ($\chi^2 = 19.49, p = 0.077$).

Discussion

The findings demonstrate that human activities and artificial containers provide favourable breeding habitats for mosquitoes and that container colour influences oviposition preference. Incorporating less attractive colours into the design and painting of household water-holding containers and surrounding structures may help reduce mosquito breeding. These findings provide useful information for developing integrated mosquito control strategies and supporting public health efforts to reduce mosquito-borne diseases.

Introduction

Mosquitoes (Diptera: Culicidae) are among the most medically important insect vectors, with their larval and pupal stages developing in a wide range of freshwater habitats (1). Beyond the nuisance caused by their bites and buzzing, which often disrupt sleep and reduce human comfort, mosquitoes are responsible for the transmission of numerous pathogens of significant public health concern (2). Different mosquito species serve as vectors of several human diseases, including malaria, dengue fever, yellow fever, Japanese encephalitis, lymphatic filariasis, West Nile fever, and Zika virus disease. They also transmit pathogens that affect animals, causing diseases such as canine heartworm, fowl pox, Rift Valley fever in sheep, and myxomatosis in rabbits (3, 4). There are approximately 3500 species of mosquitoes in 40 genera (5). Except Antarctica, Iceland, Faroe Islands, New Caledonia, Central Pacific islands, Seychelles mosquitoes have been recorded in all parts of the world (6, 7). Mosquitoes are biting pests, but they do not bite people (8). They spread many diseases, which are even worse than wild fires! These diseases result in the death of 1 billion people annually and are a matter of public health concern (9). Therefore, it is no wonder that mosquitoes have been described as the most dangerous animal on the planet (10). Mosquitoes usually reproduce in various types of water bodies such as ponds, swamps, marshes, puddles, and many other forms of wetland. While adult females may live up to a month in laboratory conditions, they can only survive for two

weeks in natural environments. The survival and development of these mosquitoes depend on several environmental factors such as temperature, precipitation, and humidity (1). Of all these factors, temperature is the most important since it affects development and metamorphosis. Higher temperatures generally accelerate larval growth, resulting in shorter developmental periods and increased population abundance, provided other environmental conditions remain favourable (11).

Rainfall increases breeding grounds and influences relative humidity. The biting intensity of mosquito decreases in connection with reduction in rainfall and could be halted by low temperatures. Vegetation affects resting sites and mosquito population could be associated with vegetation coverage (12). In addition to environmental factors, behavioural characteristics such as oviposition site selection are important determinants of mosquito population dynamics. Female mosquitoes rely on visual and environmental cues when selecting breeding sites, and colour has been identified as one of the factors influencing oviposition behaviour, although responses vary among mosquito species (8). Previous studies have investigated mosquito breeding preferences and oviposition behaviour (8, 13–17). Unfortunately, despite all the measures taken to control mosquitoes, they do not seem to be endangered or close to extinction (18). However, information on the influence of container colour on mosquito oviposition, particularly in artificial water-holding containers commonly found in residential environments, remains limited. This study therefore aims to investigate the effect of colour on the oviposition preference of mosquitoes in natural and artificial water-retaining habitats Orodo, Mbaitolu, Imo State, Nigeria. The findings will contribute to a better understanding of mosquito ecology, habitat characteristics, breeding site selection, and species abundance. Furthermore, the study is expected to provide valuable epidemiological information that can support the development of more effective mosquito surveillance and control strategies for sustainable habitat management in Orodo, Imo State, and Nigeria as a whole.

Materials and Methods

Study area

This research work was carried out in Orodo (Figure 1) located in Mbaitoli Local Government Area, Imo State, Nigeria from May to October 2022. The area is located in the Western part of Imo State at latitude 5°35'16"N and longitude 7°3'0"E. The habitation site is situated within the Sudan savannah area characterized by wet and dry seasons. The vegetation comprises of short grass and medium bushes. The population mostly comprises civil servants, students, teachers, petty traders, businessmen, artisans, travelers, farmers, transporters, etc. Most of the people are largely Igbo and Christians. The community has basic amenities like healthcare centers, markets, pipe borne water, electricity, etc. Individuals live and move within the community, dumping waste wherever they go. The community uses drainages and pit toilets as their main waste disposal facility. Supply of water to the community is through both boreholes and pipe borne water supply.

Selection of Study Community and Sampling Sites

Study community and Sampling sites were purposely selected to cover rural setting. The sampling sites were areas of high human activities, these include places where people store water for use in all sorts of containers around their home.

Study Design

The study was conducted using two mosquito breeding site categories: natural breeding sites and artificial breeding sites. The natural breeding sites were located in areas characterized by intense human activities, including indiscriminate disposal of used tyres and refuse, vulcanizer workshops, farming activities, cassava and maize processing, and the storage of water in uncovered containers. These locations also included residential areas, schools, offices, and markets, all of which provide suitable conditions for mosquito breeding. The artificial breeding sites consisted of coloured plastic containers strategically placed in five selected villages within the study area: Oboroche, Umuduru, Amorji, Obinokwu, and Okparaduru, which were coded as A, B, C, D, and E, respectively. A total of 280 containers representing seven colours (Ash, Black, Blue, Green, Red, Tan, and White) were used, with 40 containers allocated to each colour. In each village, four containers of each colour were

placed at locations with high levels of human activity, namely churches, motor parks, schools, and markets, to assess mosquito oviposition colour preference. Overall, 56 coloured containers (eight containers per colour) were deployed at each of these four location types across the study area. Each container was filled with 600 mL of clean water and suspended approximately 1 m above ground level under full shade at intervals of 5m. The containers were arranged alphabetically according to colour (Ash, Black, Blue, Green, Red, Tan, and White) and inspected weekly for a period of two months. Following each weekly inspection, the water in every container was discarded and replaced with fresh water using the same standardized procedure across all study sites and exposed in the field for a further 7-day period before the subsequent observation.

Mosquito sampling, observation and counting

Mosquitoes were collected through the standard dipping method (20). Containers were observed once a week for mosquito larvae for 2 months at about 7.00am to 10.00am and from 4.00pm to 6.00pm from the containers. Weekly oviposition and larva in each container were counted and recorded. From the collection sites, only the containers positive for mosquito larvae were taken while others that did not have the mosquitoes were excluded. Mosquito larvae collected from the containers were sieved into another container (plastic bowl) to separate them from any debris, transferred to sample bottles containing 10% formalin for preservation, and transported to the Entomology Laboratory, Imo State University, Owerri, Nigeria, where they were identified and enumerated.

Identification of Mosquitoes Larvae

Mosquito larvae were classified in the laboratory through the use of the Olympus dissecting microscope that uses an objective lens with magnification 10x and 20x based on pictorial keys and morphological characteristics described by Becker et al. (1), Nwoke and Amaechi, (21), Oyerinde (22). This was done through the classification of characters like tiffs, gills, meta-pleural spines, and tergal appendages.

Data Analysis

The data collected were analyzed using descriptive and inferential statistical methods. Descriptive statistics, expressed as simple percentages, were used to summarize the data. The Pearson Chi-square (χ^2) test was applied to determine whether there were significant differences in the distribution of mosquito-positive containers among the five study villages, to assess whether mosquito larvae were equally distributed across different container colours, to examine the association between mosquito species and human activities, and to evaluate whether the distribution of mosquito species differed significantly among the five study villages. Statistical significance was determined at a 5% significance level ($p < 0.05$), while p-values greater than 0.05 ($p > 0.05$) were considered not statistically significant.

Results

Table 1 show that seven major human activities promoted mosquito breeding in the study area. These included indiscriminate disposal of used tyres and vulcanizer activities, farming activities, cassava and maize processing, refuse dumps, residential areas, schools/offices, marketplaces, and the exposure of water-holding containers. Abandoned tires, plastic containers, broken pots, and metallic items played crucial roles as larval habitats for mosquitoes. Table 2 highlights the habitat characteristics of mosquito larvae in the study area. The majority of mosquito larvae were collected in temporary, still water bodies, and none of the larvae was detected in permanent or running water. The larvae were found under the water surface in both vegetative and non-vegetative habitats. All mosquito species were breeding in clean water and artificial breeding habitats having sandy bottom substrate. According to Table 3, all mosquito taxa consisting of three genera and four species were found in all study sites within the study villages. It is shown in Table 4 that a total of 280 (3.8%) containers were sampled out of which 164 (2.2%) had water and 116 (1.6%) contained both water and mosquito larvae. In all, 7,386 mosquito larvae were collected from larva positive containers. Highest mosquito density was reported in Village A (Oboroche), with 1,679 larvae (22.7%), followed by Village B (Umuduru) with 1,500 (20.3%), Village C (Amorji) with 1,494

(20.2%), Village D (Obinokwu) with 1,366 (18.5%), and Village E (Okparoma) with 1,347 (18.2%). These findings are also illustrated in Figure 2. Statistical analysis showed no significant difference in the distribution of containers containing only water and those positive for mosquito larvae among the study villages. Although Villages A and C recorded relatively higher proportions of larva-positive containers (24.1% and 23.3%, respectively), whereas Villages B and E had lower proportions (17.2% and 16.4%, respectively), these differences were not statistically significant ($\chi^2 = 4.916$, $df = 4$, $p = 0.296$). This suggests that larva-positive containers were similarly distributed across the study area. Table 5 illustrates the distribution of mosquito larvae according to container colour. Overall, 280 (3.8%) coloured containers were examined, of which 116 (1.6%) contained mosquito larvae. White containers harboured the highest proportion of larvae (19.2%), followed by black (17.7%) and green (16.3%) containers, whereas ash-coloured containers recorded the lowest proportion (5.7%). Statistical analysis showed **no statistically significant association** between container colour and mosquito breeding status ($\chi^2 = 12.334$, $df = 6$, $p = 0.055$). Table 6 presents the distribution of mosquito species according to specific habitat types associated with human activities. Of the 3,086 larvae collected, marketplaces accounted for the highest proportion (39.5%), indicating that they provided the most favourable breeding conditions. Plastic containers harboured higher populations of *Aedes spp.* and *Culex quinquefasciatus* than *Anopheles spp.* In contrast, mosquito populations recovered from tyres and metal containers did not differ significantly among the four mosquito species. These results are also presented in Figure 3. The distribution of mosquito species across human activity locations differed significantly within all habitat types. Plastic containers showed a significant association between mosquito species and sampling locations ($\chi^2 = 116.257$, $df = 9$, $p < 0.001$). Similarly, tyres exhibited a significant relationship ($\chi^2 = 81.967$, $df = 6$, $p < 0.001$), although the school location was excluded from the analysis because no mosquito larvae were recorded there. Metal containers also demonstrated a significant association between mosquito species and sampling locations ($\chi^2 = 34.218$, $df = 9$, $p < 0.001$). These findings indicate that human activities significantly influenced the distribution of mosquito species within different artificial breeding habitats. Table 7 presents the distribution of mosquito species recovered from water-holding containers across the study villages. Overall, Village A (Oboroche) recorded the highest abundance (22.7%), followed by Village B (Umuduru) (20.3%), Village C (Amorji) (20.2%), Village D (Obinokwu) (18.5%), while Village E (Okparoma) recorded the lowest abundance (18.3%). Among ash-coloured containers, Villages A (Oboroche) and E (Okparoma) recorded the highest larval abundance, accounting for 24.5% and 24.0%, respectively. In black containers, Village A (26.8%) and Village B (21.5%) had the highest mosquito abundance. For blue containers, Village A (20.7%) and Village D (18.2%) recorded the highest values. Within this container category, *Aedes aegypti* had the highest proportion (7.2%), whereas *Culex quinquefasciatus* recorded the lowest (1.1%). For green containers, Villages A (20.9%) and D (18.7%) had the highest larval abundance. *Aedes aegypti* accounted for the highest proportion (7.4%), while *Culex quinquefasciatus* had the lowest (0.9%). In red containers, Villages A (22.7%), B (22.2%), and C (20.4%) recorded higher mosquito abundance than Villages D (17.9%) and E (16.9%). For tan-coloured containers, Villages A (23.2%), D (23.2%), and C (20.9%) had the highest larval abundance, whereas *Culex quinquefasciatus* accounted for the lowest proportion (0.8%). In white containers, Villages C (20.7%), B (20.5%), and E (20.2%) recorded relatively higher mosquito abundance than the other villages, although their abundances did not differ appreciably from one another. These findings are also illustrated in Figure 4. Statistical analysis showed that variation in mosquito species composition among the villages was not statistically significant ($\chi^2 = 19.49$, $df = 12$, $p = 0.077$). This indicates that mosquito species were relatively uniformly distributed across the study villages.

Table 1: Human Activities, Identified breeding sites and characteristics of Mosquitoes in the Study Area.

Human Activities	Habitat	Breeding sites	Characteristics
Indiscriminate Dumping, Vulcanizer shop, Farming	Abandoned tyres	Abandoned tyres	Black colour, dump, Indiscriminately some had alga growth
Processing of Cassava/Maize as food	Pots, Stagnant water	Fermenting cassava/maize	Appear in different sizes shapes and colour. Found to be littered Indiscriminately.
Indiscriminate dumping of Refuse	Plastic /Broken pots, metals	Refuse dump containers etc	Appear in various shapes and sizes. With algae growth. Found to be littered indiscriminately.
Exposure of Stored water in containers	Pots of all sizes	Water containers of all sorts.	Appear in different Sizes, shapes and colours. Found to be littered indiscriminately
Residents	Plastic/Broken Pots etc	Plastic containers	Apear in various shapes and sizes. With algea growth.
Schools/ Offices/Markets	Plastic/Broken pots, metals	Plastic container drums etc	Appear in various shapes and sizes. With algae growth. Found to be littered indiscriminately.

Table 2: Habitat Characteristics and Occurrence of Mosquito larvae

Breeding Sites Characteristics	Mosquito Species and Villages				
Habitat Situation	A	B	C	D	E
Permanent	-	-	-	-	-
Transient	+	-	+	-	+
Standing water	+	+	+	+	+
Slow moving water	-	-	-	-	-
Vegetation Situation					
Without Vegetation	-	-	+	+	+
With Vegetation					
Water Surface	-	-	-	-	-
Out of Water	+	-	-		-
Beneath water surface	+	+	+	+	+
Bottom types					
Mud	+	-	-	-	+
Sand	-	+	+	+	-
Gravel	-	-	-	-	-
Water Situation					
Turbid	-	-	-	-	-
Clear	+	+	+	+	+
Habitat Kind					
Natural	-	-	-	-	-
Artificial (Man made)	+	+	+	+	+

Key: + = Presence of mosquito larvae, - = Absence of mosquito larvae,

Key: A=Oboroche, B=Umuduru, C=Amorji, D= Obinokwu, E=Okparaduru

Table 3: Occurrence of Mosquitoes in the Study Area

Species	Villages				
	Oboroche	Umuduru	Amorji	Obinokwu	Okparaoma
<i>Aedes aegypti</i>	+	+	+	+	+
<i>Aedes albopictus</i>	+	+	+	+	+
<i>Culex quinquefasciatus</i>	+	+	+	+	+
<i>Anopheles species</i>	+	+	+	+	+

Keys + Present - Absent

Table 4: Number of Mosquito larva found in the Study Area

Village/Area	No(%) Container Sampled	No(%) Container with only water	No container (%) +ve for water and mosquito larvae	No(%) Total of larva
A	56(20.0)	28(17.1)	28(24.1)	1679(22.7)
B	56(20.0)	36(22.0)	20(17.2)	1500(20.3)
C	56(20.0)	29(17.7)	27(23.3)	1494(20.2)
D	56(20.0)	34(20.7)	22(18.9)	1366(18.5)
E	56(20.0)	37(22.6)	19(16.4)	1347(18.2)
Total	280(3.8)	164(2.2)	116(1.6)	7,386(100)

Table 5: Number of Mosquitoes found in different coloured Artificial containers

Colour of Container	No(%) Container	No(%) Container With water	No (%) +ve for water and Mosquito	No (%) of Larvae found
Ash	40(14.3)	21(12.8)	19(16.4)	420(5.7)
Black	40(14.3)	29(17.7)	11(9.5)	1305(17.7)
Blue	40(14.3)	19(11.6)	21(18.1)	1164(15.8)
Green	40(14.3)	26(15.9)	14(12.1)	1206(16.3)
Red	40(14.3)	27(16.5)	13(11.2)	1098(14.9)
Tan	40(14.3)	25(15.2)	15(12.9)	775(10.5)
White	40(14.3)	17(10.4)	23(19.9)	1418(19.2)
Total	280(3.8)	164(2.2)	116(1.6)	7,386(100.0)

Table 6: Specific Habitat Population And Mosquito densities

Human Activities					
Habitat/Species	Church No(%)	Motor Park(%)	School (%)	Market No(%)	Total No (%)
Plastic					
<i>Aedes aegypti</i>	171(35.3)	32(6.6)	86(17.7)	196(40.4)	485(15.7)
<i>Aedes albopictus</i>	165(34.8)	44(9.3)	73(15.4)	192(40.5)	474(15.4)
<i>Culex quiquifasciatus</i>	162(33.1)	76(15.5)	67(13.7)	185(37.8)	490(15.9)
<i>Anopheles Sp</i>	150(43.2)	88(69.2)	54(15.6)	55(15.9)	347(11.2)
Total	648(36.1)	240(13.4)	280(15.6)	628(34.9)	1796(58.2)
Tyre					
<i>Aedes aegypti</i>	35(17.7)	25(12.6)	0(0)	138(69.7)	198(6.4)
<i>Aedes albopictus</i>	42(23.9)	27(15.3)	0(0)	107(60.8)	176(5.7)
<i>Culex quinquifasciatus</i>	22(14.7)	35(23.3)	0(0)	93(62.0)	150(4.9)
<i>Anopheles Sp</i>	74(35.6)	72(34.6)	0(0)	62(29.8)	208(6.7)
Total	173(23.6)	159(21.7)	0(0)	400(54.6)	732(23.7)
Metal					
<i>Aedes aegypti</i>	22(13.5)	17(10.4)	63(38.7)	61(37.4)	163(5.3)
<i>Aedes albopictus</i>	28(20.0)	11(7.9)	49(35.0)	52(37.1)	140(4.5)
<i>Culex quinquifasciatus</i>	27(18.2)	38(25.7)	41(27.7)	42(28.4)	148(4.8)
<i>Anopheles Sp</i>	30(28.0)	13(12.1)	27(25.2)	37(34.6)	107(3.5)
Total	107(19.2)	79(14.2)	180(32.3)	192(34.6)	558(18.1)
Grand Total	928(30.1)	478(15.5)	460(14.9)	1220(39.5)	3,086(100)

Table 7: Distribution of water holding containers according to Species/ category

Colour of Container	Species	Total No (%)					
		A	B	C	D	E	Total
ASH	<i>Aedes aegypti</i>	37(27.6)	14(10.4)	29(21.6)	22(16.4)	32(23.9)	134(1.8)
	<i>Aedes albopictus</i>	23(22.8)	17(16.8)	22(21.8)	16(15.8)	23(22.8)	101(1.4)
	<i>Culex quinquefasciatus</i>	6(13.0)	10(21.7)	9(19.6)	7(15.2)	14(3.0)	46(0.6)
	<i>Anopheles Sp</i>	37(26.6)	27(19.4)	30(21.5)	13(9.4)	32(23.0)	139(1.9)
	Sub Total	103(24.5)	68(16.2)	90(21.4)	58(13.8)	101(24.0)	420(5.7)
BLACK	<i>Aedes aegypti</i>	138(24.5)	125(22.2)	118(20.9)	94(16.7)	90(16.0)	562(7.6)
	<i>Aedes albopictus</i>	60(30.5)	49(24.9)	31(15.7)	26(13.2)	31(15.7)	197(2.7)
	<i>Culex quinquefasciatus</i>	16(18.6)	13(15.1)	20(23.3)	19(22.1)	18(20.9)	86(1.2)
	<i>Anopheles Sp</i>	135(29.5)	93(20.4)	95(20.8)	75(16.4)	59(12.9)	457(6.2)
	Sub Total	349(26.8)	280(21.5)	264(20.3)	214(16.4)	59(12.9)	457(6.2)
BLUE	<i>Aedes aegypti</i>	110(20.7)	104(19.6)	109(20.5)	100(18.8)	108(20.3)	531(7.2)
	<i>Aedes albopictus</i>	79(22.3)	83(23.4)	62(17.5)	63(17.8)	67(18.9)	354(4.8)
	<i>Culex quinquefasciatus</i>	13(15.8)	17(20.7)	21(25.6)	19(23.2)	12(14.6)	82(1.1)
	<i>Anopheles Sp</i>	57(28.9)	40(20.3)	34(17.2)	30(15.2)	36(18.3)	197(2.7)
	Sub Total	259(22.3)	244(20.9)	226(19.4)	212(18.2)	223(19.2)	1164(15.8)
GREEN	<i>Aedes aegypti</i>	114(20.9)	103(1.9)	118(21.7)	102(18.7)	108(19.8)	545(7.4)
	<i>Aedes albopictus</i>	88(19.9)	98(22.1)	73(16.5)	92(20.8)	92(20.8)	443(5.9)
	<i>Culex quinquefasciatus</i>	19(29.7)	14(21.9)	11(17.2)	12(18.8)	8(12.5)	64(0.9)
	<i>Anopheles Sp</i>	38(25.3)	18(12.0)	32(21.3)	28(18.7)	34(22.7)	150(2.0)
	Sub Total	259(21.5)	233(19.4)	234(19.5)	234(19.5)	242(20.1)	1202(16.3)
RED	<i>Aedes aegypti</i>	93(23.8)	86(21.9)	79(20.2)	71(18.2)	62(15.9)	391(5.3)
	<i>Aedes albopictus</i>	73(26.4)	69(25.0)	52(18.8)	47(17.0)	35(12.7)	276(3.7)
	<i>Culex quinquefasciatus</i>	12(21.8)	15(27.3)	10(18.2)	7(12.7)	11(20.0)	55(0.7)
	<i>Anopheles Sp</i>	71(18.9)	74(19.7)	83(22.1)	72(19.1)	76(20.2)	376(5.1)
	Sub Total	249(22.7)	244(22.2)	224(20.4)	197(17.1)	186(16.9)	1098(14.9)
TAN	<i>Aedes aegypti</i>	52(26.4)	34(17.3)	44(22.3)	38(19.3)	29(14.7)	197(2.7)
	<i>Aedes albopictus</i>	48(20.9)	54(23.6)	37(16.2)	58(25.3)	32(13.9)	229(3.1)
	<i>Culex quinquefasciatus</i>	6(26.7)	12(20.0)	8(13.3)	11(18.3)	13(21.7)	60(0.8)
	<i>Anopheles Sp</i>	64(22.1)	41(14.2)	73(25.3)	73(25.3)	38(13.1)	289(3.9)
	Sub Total	180(23.2)	141(18.2)	162(20.9)	180(23.2)	112(14.5)	775(10.4)

WHITE	<i>Aedes aegypti</i>	130(21.9)	115(19.4)	128(21.6)	112(18.9)	108(18.2)	595(8.0)
	<i>Aedes albopictus</i>	105(18.2)	112(19.4)	118(20.5)	120(20.8)	122(21.1)	577(7.8)
	<i>Culex quiquinfasciatus</i>	14(21.5)	11(16.9)	18(27.7)	9(13.8)	13(20.0)	65(0.9)
	<i>Anopheles Sp</i>	31(16.9)	52(28.4)	30(16.4)	26(14.2)	44(24.0)	183(2.5)
Sub Total		280(19.7)	290(20.5)	294(20.7)	267(18.8)	287(20.2)	1418(19.2)
Grand Total		1,679(22.7)	1500(20.3)	1,494(20.2)	1,366(18.5)	1,347(18.3)	7,386(100)

Key: A= Oboroche, B=Umuduru, C=Amorji, D= Obinokwu, E= Okparaduru

Discussion

This study provides important information on the habitat preferences, breeding sites, and colour preferences of mosquito species within the study communities. Several mosquito species of public health importance were identified, including malaria vectors (*Anopheles* spp.), dengue vectors (*Aedes aegypti* and *Aedes albopictus*), and filariasis vectors (*Culex* spp.). Although entomological surveillance data were limited, information obtained from key informant interviews suggested that these mosquito species have become well established within the study area. The findings therefore indicate that malaria and other mosquito-borne diseases have become endemic in the study communities, posing a significant public health risk to the residents. The results further revealed that these mosquito species utilize a wide range of artificial or human-made containers as breeding sites. Similarly, Mgbemena et al. (23) reported the presence of eight mosquito species in Owerri and Orlu, and seven species in Okigwe. The differences observed between the present study and previous reports may be attributed to variations in sampling season, ecological conditions, and mosquito collection methods. In both studies, common breeding habitats included plastic containers, metallic objects, and vegetated environments. Earlier studies by Nwoke et al. (24) also demonstrated that such habitats provide suitable conditions for mosquito breeding.

Four mosquito species identified in this study exhibited indiscriminate breeding behaviour across multiple habitat types, confirming previous observations by Mafiana et al. (25). Plastic containers constituted the most preferred breeding habitat, followed by discarded tyres and metallic containers commonly found in areas of intense human activity such as markets, schools, churches, and motor parks. Household water-storage containers and other discarded domestic items also served as secondary breeding sites. The abundance of these artificial breeding habitats reflects inadequate waste management, poor sanitation practices, and socioeconomic challenges within the study communities. Human activities have consequently created numerous water-holding containers that support the accumulation of stagnant water and the growth of microorganisms, thereby providing ideal conditions for mosquito oviposition and larval development. Similar observations have been reported by Ayanda (26) and Ye et al. (27).

A high proportion of water-filled containers contained mosquito larvae, highlighting the strong association between artificial water-holding containers and mosquito breeding. The study communities shared comparable ecological characteristics, agricultural practices, and breeding habitats, which may explain the similarity in mosquito species composition across the different sampling locations.

Mosquito oviposition is influenced by numerous abiotic and biotic factors. Abiotic factors include light intensity, container size and colour, water depth, turbidity, temperature, pH, and dissolved oxygen concentration, whereas biotic factors include predation and interspecific competition (8). The presence of certain mosquito species within breeding habitats may attract gravid females of the same species while discouraging females of competing species, thereby reducing interspecific competition and indicating habitat suitability (28).

The color hatred and preference of mosquitoes has been documented. According to Collins and Blackwell (8), mosquitoes hate yellow lights in front of houses and like ultra-violet lights and blue lights. It has been shown that they prefer dark color

of clothes worn by humans. Backel (17) had noted that the color served as the oviposition attraction and stimulation as the *Aedes aegypti* mosquitoes respond to the green color in his study. In another study conducted by Collins and Blackwell (8), color preference of black and red containers has been significantly preferred for oviposition by Toxorhynchites species, the larviparous mosquitoes. In their study, green color has not been found to be a significant color cue for oviposition of *Anopheles* and *Culex*. There is a relation between the environment and mosquito abundance (6). Mosquitoes can adapt themselves to environmental changes and water pollution (Awolola et al 2007).

Container colour was found to significantly influence mosquito oviposition in the present study. *Anopheles* species showed a marked preference for black-coloured containers, whereas *Aedes* species were more frequently associated with white containers. Nevertheless, several mosquito species were capable of utilizing more than one container colour for oviposition. Overall, coloured containers supported higher larval densities than non-coloured containers. The attraction of *Aedes aegypti* and *Aedes albopictus* to coloured containers agrees with the findings of Collins and Blackwell (8). Similarly, previous studies have demonstrated that *Anopheles* mosquitoes are strongly attracted to dark backgrounds, particularly black and red surfaces, because these colours absorb more light across much of the visible spectrum and may provide visual cues that favour oviposition. Among the mosquito species identified, *Aedes* spp. were the most abundant and widely distributed. Their predominance is of considerable public health concern because they serve as vectors of several viral diseases, including dengue fever and yellow fever, as well as other arboviral infections. Their abundance may be attributed to their ability to exploit a wide variety of domestic containers and discarded household materials as breeding habitats, consistent with the observations of Bing et al. (29). In addition, *Aedes* mosquitoes readily breed in used tyres, including imported second-hand tyres, which are well recognized as efficient breeding sites. The presence of polluted drains, abandoned tyres, stagnant pools, plastic containers, and metallic receptacles throughout the study communities provided favourable breeding conditions for both *Aedes* and other mosquito species, consistent with the findings of Luza et al. (30).

Conclusion and Recommendation

Based on the findings of the current study, it can be observed that the breeding sites have a major influence on the prevalence and species of mosquitoes in the study location. The mosquitoes had different breeding preferences, and white plastic containers emerged as the most preferable breeding site. *Aedes* spp were the most common mosquito species in the study location, and this is an indication of their adaptation to artificial container breeding sites. Plastic containers being productive as mosquito breeding sites present a great public health challenge as it will contribute to the spread of mosquito-borne diseases. Poor drainage systems and inadequate sewage disposal were also associated with the abundance and prevalence of mosquitoes in the study locations.

Declarations

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Author Contribution

IJI and PAO conceptualized the study. IJI, PAO, and CCA designed the study. UBVC, NNN, JCO, OPU, JL, JCO and OCN participated in fieldwork and data collection. DMS and OKK performed the data analysis; SMD, KKO and WN interpreted the data. IJI prepared the first draft of the manuscript, reviewed by all the authors. All authors contributed to the development of the final manuscript and approved its submission.

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Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation

Ethical Approval

This study was reviewed and approved by the Research Ethics Committee of the Department of Animal and Environmental Biology, Imo State University Owerri Nigeria, under approval number **IMSU/AEB/ETHICS/052-061**. Prior to the commencement of the study, informed consent was obtained from the village heads of the participating communities.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

References

1. Becker N, Petric D, Zgomba M, Boase C, Madon MB, Dahl C et al. Mosquitoes: identification, ecology and control. Springer Cham Switzerland 3rd edition. 2020;571 pp. <https://doi.org/10.1007/978-3-030-11623-1>
2. Li Z, Wang J, Cheng X, Hu H, Guo C, Huang J, et al. The Worldwide Sero prevalence of DENV, CHIKV and ZIKV Infection: A Systematic Review and Meta-Analysis. PLoS Negl Trop Dis. 2021;15:e0009337.
3. Adnan RA, Ramli MF, Othman HF, Asha ZH, Ismail SNS, Samsudin S. The Impact of Sociological and Environmental Factors for Dengue Infection in Kuala Lumpur, Malaysia. Acta Trop. 2021;216:105834.
4. WHO. Global programme to eliminate Lymphatic filariasis. <http://www.who.int/lymphaticfilariasis/elimination-programme>. 2018;Accessed 14 Oct 2018. World Health Organization, Geneva, USA.
5. Awolola TS, Oduola AO, Obansa JB, Chukwura NJ, Unyimordu JP, et al. *Anopheles gambiae* breeding in polluted water in urban Lagos, South western Nigeria. J Vector Borne Dis. 2007;44(4):181–888.
6. Chapman HC. Biological control of mosquitoes. Trop Med Int Health. 2000;10:888–93.
7. Gillet JD. Common Africa mosquitoes and their medical importance: William Heinmann Medical book. Limited London. 1972;p. 106.
8. Collins LE, Blackwell A. Colour cues for oviposition behavior in *Toxorhynchites moctezuma* and *T. amboinensis* mosquitoes. J Vector Ecol. 2000;25(2):127–35.
9. WHO. World malaria Report. World Health Organization, Geneva, USA. 2014;p. 242.
10. WHO. Global strategy for Dengue prevention and control. Geneva, USA: World Health Organization; 2015. p. 43.
11. Kelly-Hope, Hemingway LAJ, Mackenzie FE. Environmental factors associated with malaria vectors *Anopheles gambiae* and *Anopheles funestus* in Kenya. Malar J. 2009;8:268.
12. Okogun GRA, Nwoke BEB, Okere AN, Anosike JC, Esekhegbe AC, et al. Epidemiological implications of preferences of breeding sites of mosquito species in Mid- western Nigeria. Annual Agricultural Environ Med. 2013;10(2):217–22.
13. Martínez-Barciela Y, Polina A, Garrido J. Habitat characterization and breeding preferences of mosquito larvae in northwestern Spain: abundance, diversity, and species composition. Parasites Vectors. 2025;18:165.
14. Njila HL, Sani HS, Ombugadu A. Tanko. Evaluation of Coloured Containers as Attractants to Gravid Mosquitoes for Oviposition. Trends Tech Sci Res. 2023;6(1):555679.

15. Oguche OD, Auta IK, Ibrahim B, Yayock HC, Johnson O. Breeding sites Characteristics and Mosquito Abundance in some selected locations within Kaduna Metropolis. FUDMA J Sci. 2022;6(6):70–5.
16. Okwa OO, Savage AA. Oviposition and Breeding Water Sites Preferences of Mosquitoes within Ojo area, Lagos State, Nigeria. Biomed J Sci&Tech Res. 2018;7(5):6139–45.
17. Beckel WE. Oviposition site preference of *Aedes* mosquito (Culicidae) in the laboratory. Mosq News. 1995;15:224–8.
18. Awolola TS. (2017) Malaria, Mosquitoes and Man: The battle continues! Nigeria institute of Medical Research (NIMR). Distinguished lecture series (7th Edn.) p. 73.
19. ISMLS. Imo State Ministry of Lands and Survey: Imo State Ministry of Lands and Survey Publication. 2009.
20. Service MW. The Ecology of mosquitoes of Northern Guinea Savannah of Nigeria. Bull Entomol Res. 1993;54:601–32.
21. Nwoke BEB, Amaechi AA. Introduction to Entomology (2023): Mega soft publishers Owerri. 2023;P. 16–18.
22. Oyerinde JPO. Essentials of Tropical Medical Parasitology. Akoka: University of Lagos; 1999. p. 435.
23. Mgbemena IC, Adjero IA, Opara FN, Ezeagwuna D, Ebe T. Seasonal Variation and relative abundance of drainage breeding Mosquito Species in Imo State Nigeria. Int J Biosci. 2012;2(8):23–35.
24. Nwoke BEB, Nduka FO, Okereke OM, Ehighibe OC. Sustainable urban development and human health septic tanks as major breeding habitat of mosquito vectors of Human disease in South Eastern. Nigeria J Parasitol. 1993;34:1–10.
25. Mafiana CF, Anaeme L, Olatunde OC. Breeding site of Larval mosquitoes in Abeokuta, Nigeria. Nigeria J Entomol. 1998;15:136–43.
26. Ayanda OI. Relative abundance of adult female *Anopheline* Mosquito in Ugali Nasarawa State. Nigeria Journal Parasitol Vector Biology. 2009;1(1):3–8.
27. Ye Y, Patton E, Kilian A, Dovey S, Eckert E. Universal insecticide treated net campaigns achieve equity in coverage and use. The case of northern Nigeria. Malar J. 2012;28(7):29–32.
28. ICPE. 2009. African Insect Science for food and Health. Discovering the Mosquito's fatal attraction. Available from
29. Bing CK, Chum LE, Hsiang KC. Differential preferences of Oviposition. By *Aedes* mosquitoes in man-made Containers under field conditions. Southeast Asian J Trop Med Public Health. 2004;35(3):599–606.
30. Luza AL, Gualdi CB, Diefenbach LML, De AG, Schüler-Faccini L, Ferraz G. Dynamic Mapping of the Probability of Infestation by Urban Arbovirus Vectors in the Municipalities of Rio Grande do Sul State, Brazil 2016–2017. Epidemiol Serv Saúde. 2021;30:e2020154.

Figures

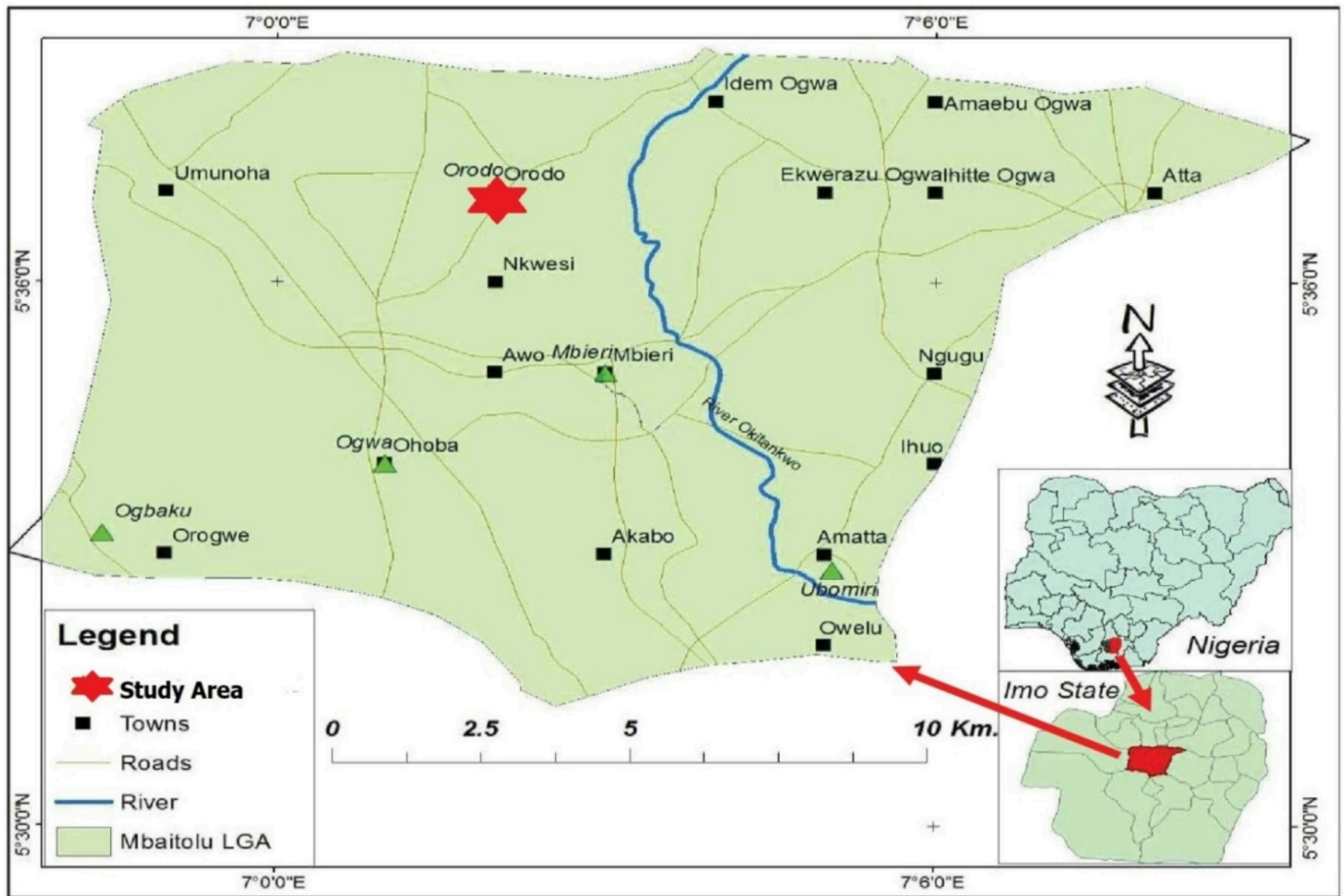


Figure 1

Map of Imo State Showing the Study Area

Source: ISMLS (19)

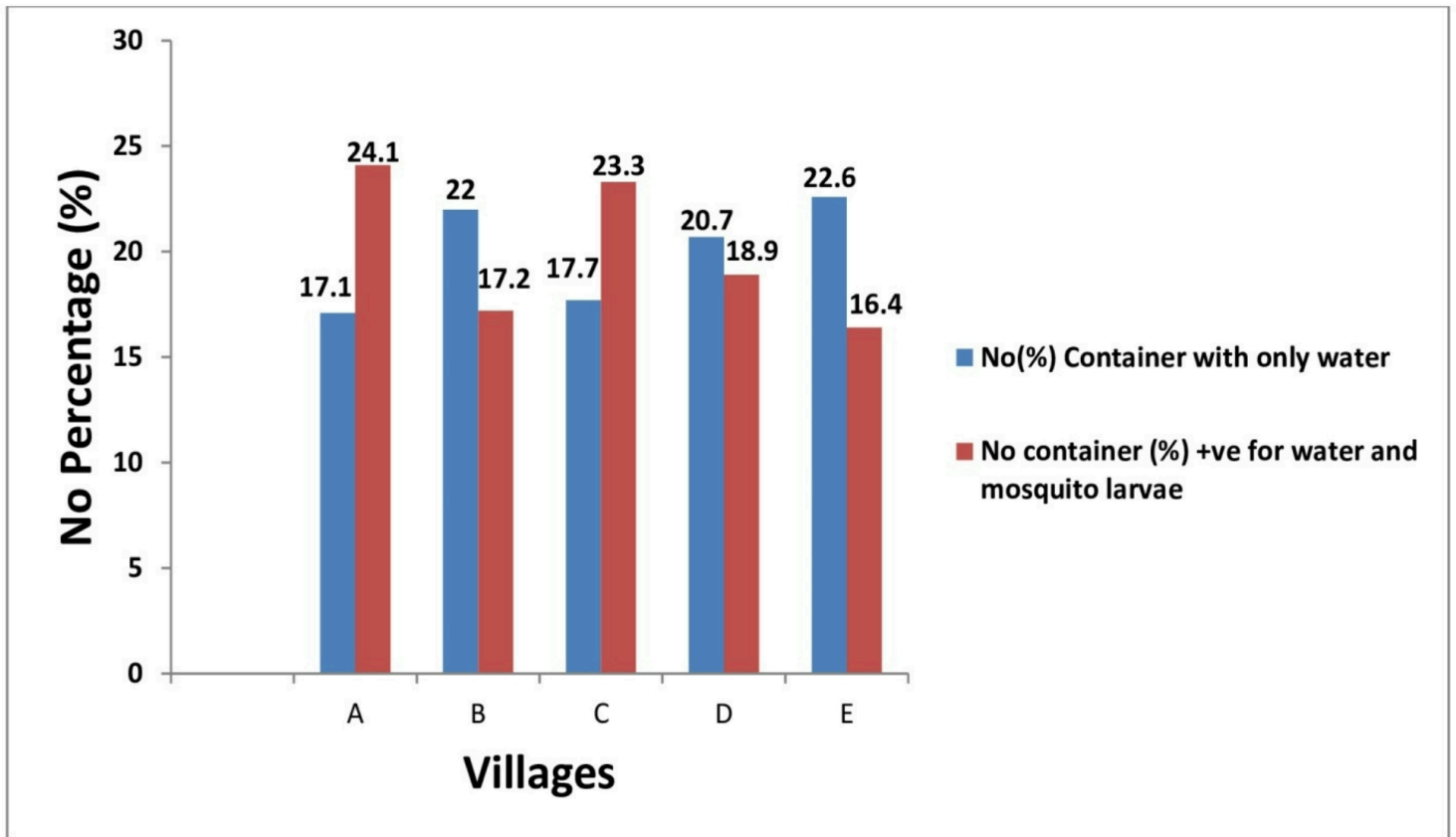


Figure 2

Percentage of containers positive for water and mosquito larvae

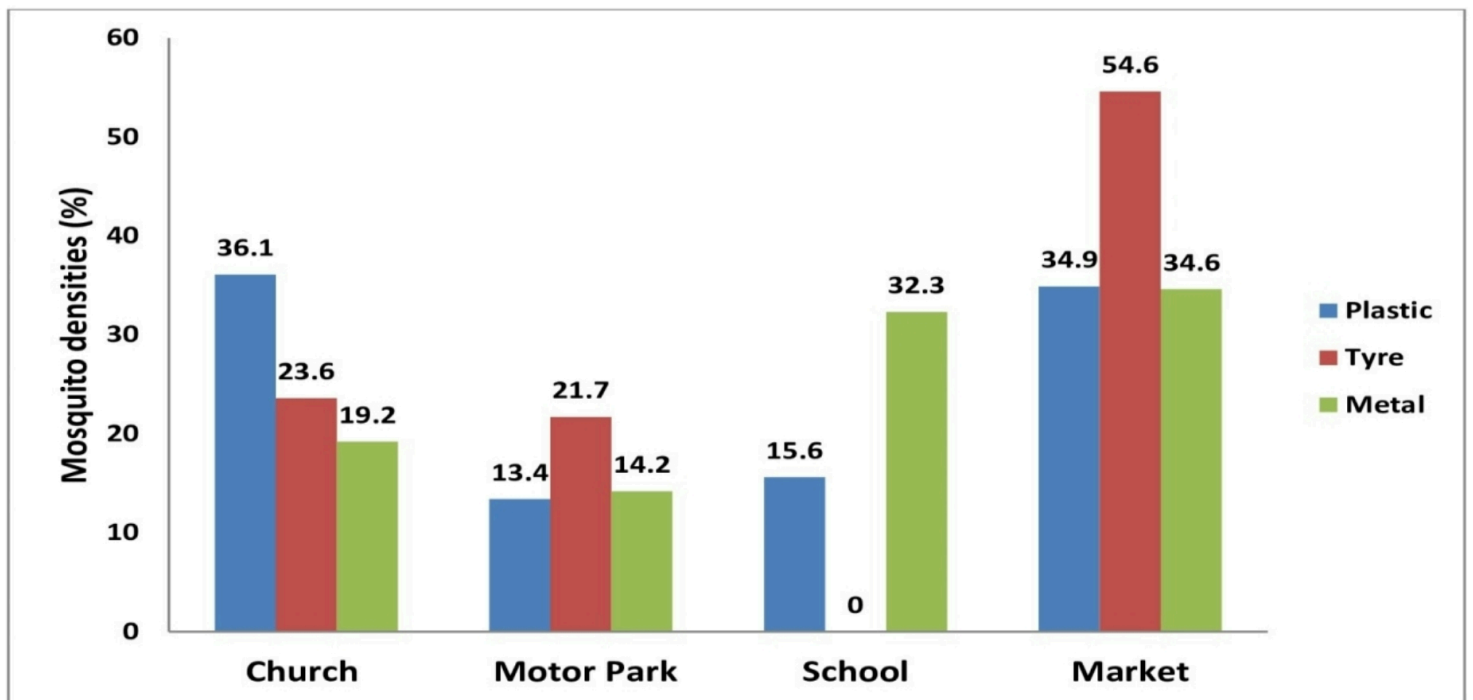


Figure 3

Habitat and Human activities

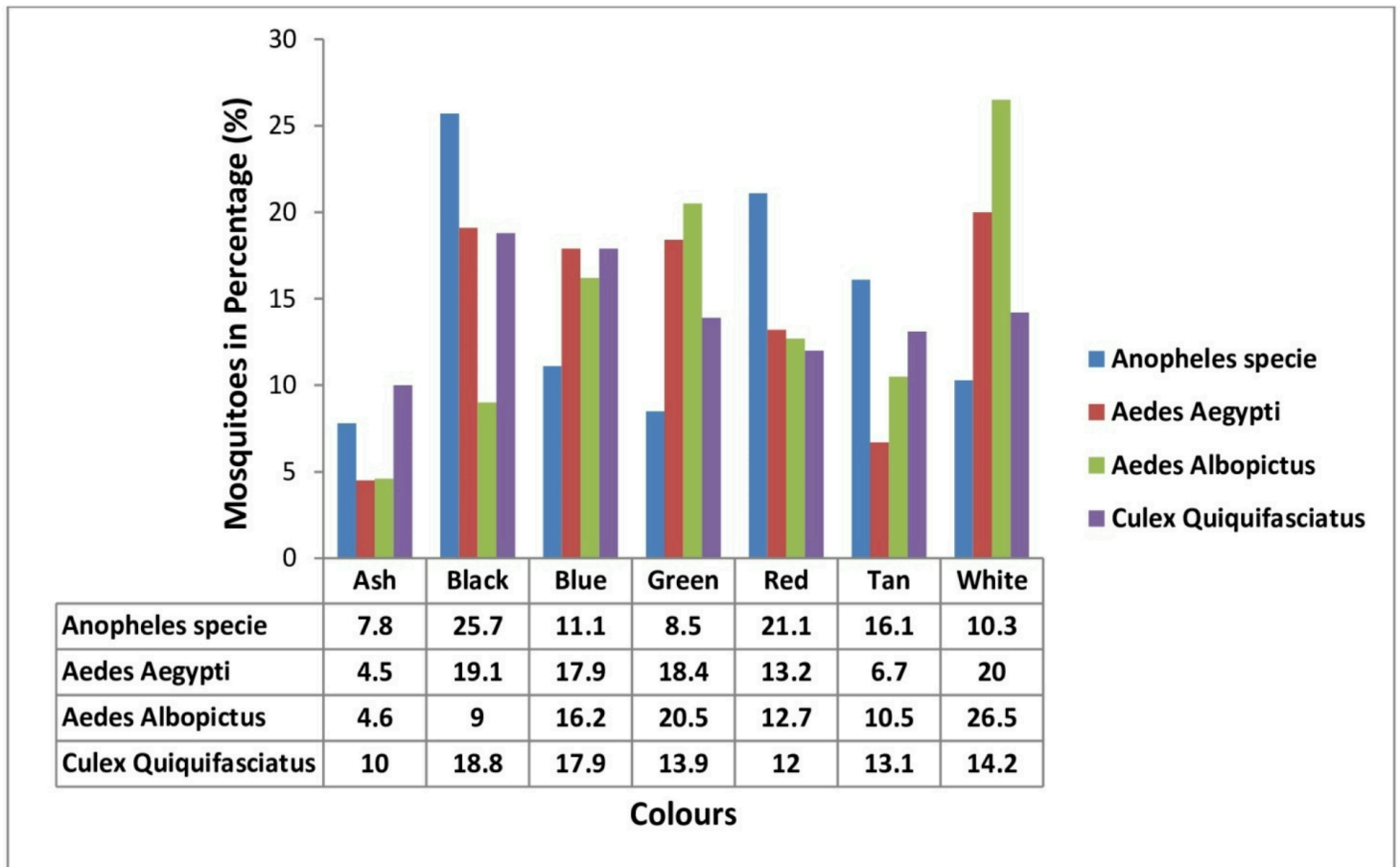


Figure 4

Proportions of mosquitoes on different colours of container