



Seasonal variation and relative abundance of drainage breeding mosquito species in Imo State, Nigeria

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Abstract

An ecological study of drainage - breeding mosquito vectors was conducted in the three urban centers (Owerri, Orlu and Okigwe) of Imo State, Nigeria. Twelve drainage sites located around markets, residence, streams and hotels were selected in each urban centre. Dipping method of sampling was employed and a total of 8,820 mosquitoes comprising eight species namely; *Aedes aegypti*, *Aedes vittatus*, *Culex quinquefasciatus*, *Culex tigripes*, *Culex horridus*, *Culex cinereus*, *Culex annuliorus* and *Anopheles gambiae* were encountered; in Owerri and Orlu with *Cx. cinereus* being completely absent in Okigwe. *Cx. quinquefasciatus* was predominantly present in all drainage sites with the highest occurrence of (372.83) followed by *Aedes aegypti* (151.17), *An .gambiae* (78.75), *Cx. tigripes* (40.25) *Ae. vittatus* (35.00), *Cx. horridus*(22.00), *Cx.cinereus*(21.75), *Cx. annuliorus* (13.25). Of all sites sampled, market drainages had the highest abundance of mosquitoes which was significantly higher than (ANOVA, $P \leq 0.05$) the residential, stream and hotel drainages. Residential drainages recorded second highest density followed by stream and hotel drainages had the least. The abundance of mosquitoes in Owerri (130.06) the State Capital was significantly higher (ANOVA, $P \leq 0.05$) than in Orlu (93.44) and Okigwe (52.13). Result of the Pearson correlation (2 - tailed) analysis showed significant correlation between mosquito abundance and rainfall in the three urban centers of Imo State with highest abundance in June. This work has actually provided information on 8 species associated with drains in the State together with the seasonality of these arsenals. During dry months, *Culex* species were found to be dominant while in rains *Aedes* and *Anopheles*. Possibly, effective larviciding against these various species could be targeted in these months.

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Introduction

Vector – borne diseases particularly mosquito – borne diseases have been the most important worldwide health problems for many years and still represent a constant and serious risk to a large part of the world's population. Most of the challenges posed by mosquito - borne diseases consist not only in their cosmopolitan nature and ability to survive in air, aquatic and terrestrial habitats, their ability to breed in any collection of standing water such as wheelbarrows, cesspits, flower vases and drainage systems make such a prolific source of mosquito production. Though these breeding sites of vectors are naturally available in most places, human activities and behaviors and the resultant changing environment have continued to create more and renewed disease transmission and prevalence. Zarechnaia and Severin (1989) have noted that man during his industrial, agricultural and economic activities produced considerable effect on the *Anopheles* urban population by changing the characters of the breeding sites as well as urban conglomerate microclimate. WHO/TDR (1992) reported that the unplanned and haphazard growth of urban settlements; stagnant water in ditches and drains, cesspits, septic tanks, water tanks, barrels and all sorts of containers all of which have increased the *Culex* breeding surface areas. On the other hand, Nwoke (2004) stated that the ever rising human population and the remarkable and rapid urban growth have resulted in serious overcrowding especially in the urban squatter settlements. This situation has been accompanied by deterioration of the urban environment, poverty and the emergence and re-emergence of parasites and infectious diseases. The awful state of this deteriorating environment is reflected in the poor housing conditions and in the volume of effluent and solid wastes, the collection and disposal of which have become an intractable problem in most places in Nigeria. The urban centers are highly populated having the necessary infrastructures characteristic of urban areas like piped - borne water, electricity, good roads, industries, educational and

health institutions. Also prominent in these urban centers are the drainage systems that run all through the nooks and cranny of the areas, interspersing major streets and roads, which facilitate waste disposal from industries, hospitals and residential sources. Consequently, this gives rise to the public health implications of the drainage systems which stem from all these junks (wastes) dumped into them, making it impossible for free flow of wastewater thereby creating enabling environment for mosquitoes to harbor and breed.

Ecological documentation of mosquito species in most states of Nigeria is available such as Bang *et al* (1980); Mbanugo and Okpalaononuju (2003); Okorie (1978) and Igbiosa (1989) for studies done in Enugu, Awka, Ibadan and Ekpoma respectively. There is no such ecological record of mosquito species for Imo state although there is evidence of mosquito borne diseases afflicting the inhabitants on regular basis. Sturt, (1984) pointed out that the incidence of malaria, filariasis and yellow fever were associated with the presence of their Dipteran vectors while Habluelezel and Esposite (1989) opined that the correct identification of these local vectors was necessary so that effective control measures could be employed.

Therefore, the present research aims at investigating whether or not these drainages actually constitute prolific sources of mosquitoes in these urban areas, and based on these provide necessary baseline data on the ecology of the mosquitoes available.

Materials and methods

Study area

The study was carried out in Imo State, Nigeria. Imo State is situated in the central part of the southeaster n region of Nigeria. The State is located in the tropical rain forest zone of West Africa with climatic conditions favouring the proliferation of arthropods including mosquitoes. Imo State occupies a landmass of 5,100sq kilometers with a population of 2.4million persons and

an annual growth of 2.8%, distributed in the 27 Local Government Areas (LGA) situated in the 3 geopolitical zones (MIC, 2000). The three geopolitical zones comprise of Owerri zone, Orlu zone and Okigwe zone with Owerri (where the state capital is situated), Orlu and Okigwe constituting the major urban centers in the State

Preliminary assessment to identify and map out the sampling sites in these areas was made. Visits were also made to obtain useful information from relevant bodies like the Ministry of Health, National Population Commission and Meteorological Unit of the Ministry of Aviation.

Selection of sampling sites

Selection and categorization of sampling sites were based on human activities involved:

- Markets – Intense human activities
- Residential - moderately high human activities
- Vegetation/stream – moderately low human activities
- Hotels/ Hospitals – low human activities

Locations considered

Markets

- Owerri (main market) – Douglas Road
- Orlu (main market - Market Road
- Okigwe (main market) – Market Road

Residential Houses –

- Njeribeako Street
- Bob Ihedioha Street
- Okpara Road

Vegetation/ Stream -

- Amakohia - Egbeda – Nwaorie
- Nwanzaza Road
- Ubaha Road – Iyichu

Hotels/Hospitals -

- Modotel –Bank Avenue
- Orlu Hotel – Umuna Road
- Cho Genesis – Okigwe Owerri Road

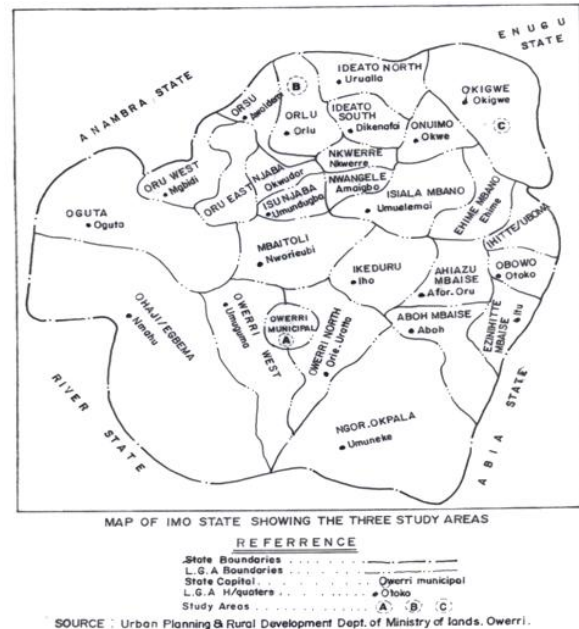


Fig. 1 Map of Imo State showing the 27 Local Government Areas and three study areas.

Sampling collection

During sampling, a fabricated dipper 20cm wide and 10cm deep holding 1.5 liters of water was dipped ten times at a sampling point of each of the selected systems/sites for collection of larvae and pupae. Every electric pole constituted a sampling point in these systems.

The contents were passed through a strainer of 20 meshes / cm mosquito nylon netting to retain larvae and debris. The larvae were then transferred to specimen bottles (which were half - filled with breeding site water) using pipette and subsequently taken to the laboratory for rearing and identification.

Larvae scooped from the different points of a system were pooled together and carefully labeled in a plastic container indicating the particular system, date and time of collection. Sampling was done fortnightly from February 2007 to January 2008 between the hours of 6.00a.m – 9.00a.m. Larvae were collected by the standard dipping procedure as described by O'Malley (1995).

Table 1. Monthly relative abundance of mosquito species sampled from drainage systems in Owerri from February 2007 to January 2008.

Species	Feb.'07	March	April	May	June	July	Aug	Sept	Oct	Nov.	Dec.	Jan.'08	Total
<i>Ae. Aegypti</i>	24	41	82	125	183	157	117	56	30	26	15	8	864
<i>Ae. Vittatus</i>	4	12	17	32	23	28	12	8	18	6	0	0	160
Subtotal	28	53	99	157	206	185	129	64	48	32	15	8	1024
<i>Cx. quinquefasciatus</i>	254	266	286	261	220	159	115	79	118	158	175	216	2307
<i>Cx. tigripes</i>	27	59	42	23	28	40	5	0	0	4	9	10	247
<i>Cx. horridus</i>	21	37	15	8	7	2	0	0	3	11	17	47	168
<i>Cx. cinereus</i>	19	31	17	9	4	0	0	0	0	0	2	5	87
<i>Cx. annuliorus</i>	8	16	7	1	0	0	0	0	0	2	6	2	42
Subtotal	329	409	367	302	259	201	120	79	121	175	209	280	2851
<i>An. gambiae</i>	0	0	22	33	86	71	38	19	12	6	0	0	287
Total	357	462	488	492	551	457	287	162	181	213	224	288	4162

Rearing

On arrival in the laboratory, the larval collections contained in the container were transferred into rearing buckets (5 liters size) whose open sides were covered with mosquito net. An opening was made from the side through which a netting sleeve was fixed to enable things to be taken in and out.

The larvae were reared to the fourth instars until they pupated with each bucket containing a single collection from a particular system. Quaker oats was used as larva's feed. Rearing was done according to the method described by Pecor and Gaffigan (1997) and Gerberg (1970).

The purpose of rearing the larvae to adult stage was to confirm identification into *Anopheles*, *Culex* and *Aedes* species. At the end of each day emerged adults were counted and recorded. The adults were killed by spraying with insecticide (Raid) for identification.

Identification

The adult mosquitoes were carefully removed from the rearing buckets with a pair of forceps and identified under the microscope using standard morphological and taxonomic keys. Distinguishing characters as reported by Gordon and Lavoipierre (1978) and Service (1980) were used for the identification. In addition the specimens were matched with previously confirmed specimens and microscopic slides maintained by the WHO/Arbovirus Vector Research Center in Enugu. The following records were taken:

1. The different species of mosquitoes encountered
2. Seasonal occurrence and abundance of the different species.

Statistical analysis

The data were analyzed with ANOVA and Correlation using SPSS package.

Results

Two categories of drainage systems were observed in the three urban centers – the closed and open systems,

with the closed ones being those covered with concrete slabs.

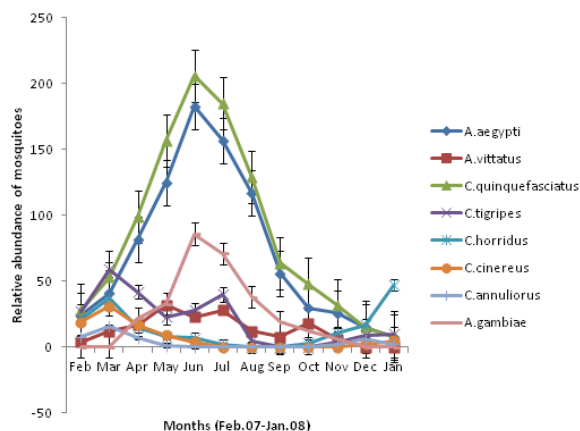


Fig 2. Relative abundance of mosquito species in Owerri from February 2007 to January 2008.

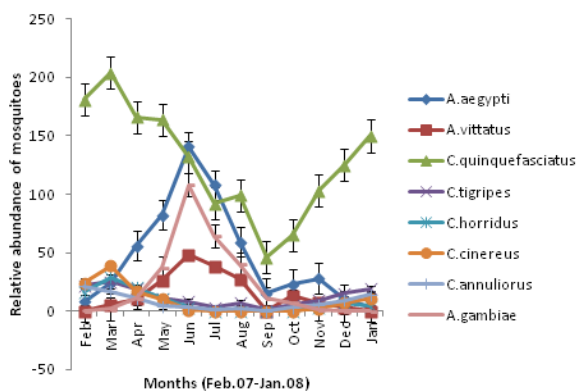


Fig. 3. Monthly Relative Abundance of Mosquito Species sampled from Drainage systems in Orlu.

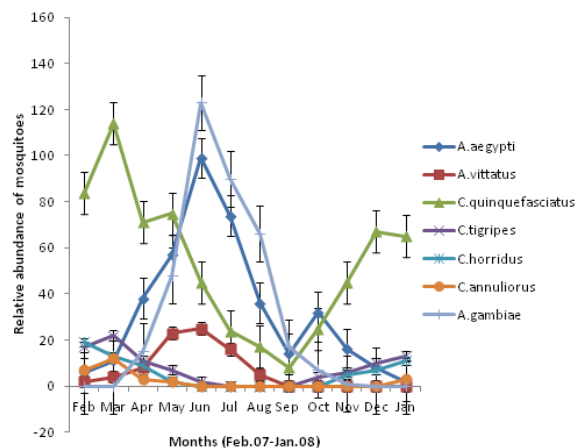


Fig 4. Monthly Relative Aabundance of mosquito species sampled from Drainage Systems in Okigwe.

Table 1 displays the result of monthly relative abundance of species sampled in Owerri from February 2007 to January 2008. A total of 8 mosquito species were encountered. *Cx. quinquefasciatus* was the major species with a total number of 2307(55.43%). *Ae. aegypti* 864(20.76%) and *An. gambiae* 287(6.90%) were the next highest in abundance. *Cx annuliorus* was the least encountered species 42(1.01%).

Highest number of species occurred in June 551(13.24%) and least in September 162(3.89%). *Cx. quinquefasciatus* and *Ae aegypti* were the only 2 species found to be present in the drainages all through the months of study. *Ae aegypti* recorded highest occurrence in June 183 (21.18%) and least in September 56 (6.48%) *Ae. vittatus* occurred highest in May 32(20.00%), absent in the months of December 2007 and January 2008. *Cx. tigripes* had a peak in March 59(23.89%) but absent in Sept. and Oct.

Cx. horridus increased from 21(12.84) in Feb to 37(22.02) in March with a peak in Jan. 2008 47(27.98). It was completely absent in August and Sept. *Cx cinereus* had a peak in March but completely absent from July to November. *Cx annuliorus* had a peak in March 16(38.10) while absent from July to Oct. *An. gambiae* were present in the months of April through November with a peak in June 86(29.97).

A total of 2990 species were observed in Orlu(Table 2). *Ae. aegypti* recorded highest in abundance in June 141(25.31%) and least in Jan.2008 3(0.54%). *Ae vittatus* had a peak in June 48(27.12%), absent in Feb, Sept 2007 and Jan.2008. *Cx. quinquefasciatus* recorded significantly high numbers in dry periods of the year Feb, April, Nov, Dec 2007 and Jan. 2008 with a peak in March 204(13.36%). *Cx, tigripes* had a peak in March 25(17.36%) and decreased so much during the rains May to Sept 11(7.64%) – 1(0.69%). *Cx. horridus* had highest occurrence in March 29(31.18%) but absent from July to Oct. *Cx cinereus* was highest

in March 39(35.14%), only 1(0.90%) and absent in June to Oct. *Cx. annuliorus* recorded a peak in Feb 21(23.33%) and nil in Sept. *An. gambiae* occurred from March to Nov with a peak in June 108(37.11%) and was absent in Feb, Dec 2007 and Jan 2008 (Fig 6B). Significant difference was found to exist in the monthly abundance of mosquitoes (ANOVA, $P \leq 0.05$) for Owerri and Orlu. Result of multiple range test confirmed that the highest number of mosquitoes occurred between May and July. The peak of mosquito abundance was June.

Table 3 depicts the results of the monthly relative abundance of mosquito species sampled in Okigwe from Feb.2007 to Jan 2008. 1668 species of

mosquitoes comprising of 7 species were encountered. The most abundance species were *Cx. quinquefasciatus* 640(38.37%), *Ae. aegypti* 393(23.56%), *An.gambiae* 367(22.00%) and *Cx. tigripes* 92(5.52%). *Ae vittatus* 83(4.98%), *Cx. horridus* 66(3.96%) and *Cx annuliorus* 27(1.62%) were the least in occurrence. *Ae . aegypti* increased from Feb 6(1.53%) with a peak in June 99(25.19%). *Ae. vittatus* occurred from Feb to August with a peak in June, absent in the months of Sept. 2007 to Jan. 2008.

Table 2. Monthly relative abundance of mosquito species sampled from drainage systems in Orlu from February 2007 to January 2008.

Species	Feb.'07	March	April	May	June	July	Aug	Sept	Oct	Nov.	Dec.	Jan.'08	Total
<i>Ae. aegypti</i>	8	24	56	82	141	108	59	15	23	28	10	3	557
<i>Ae. vittatus</i>	0	5	10	26	48	38	27	0	13	7	3	0	177
Subtotal	8	29	66	108	189	146	86	15	36	35	13	3	734
<i>Cx,</i> <i>quinquefasciatus</i>	181	204	166	164	132	92	99	46	65	103	125	150	1527
<i>Cx. tigripes</i>	22	25	19	11	8	3	7	1	5	9	15	19	144
<i>Cx.horridus</i>	16	29	20	11	3	0	0	0	0	3	7	4	93
<i>Cx.cinereus</i>	24	39	17	10	1	0	0	0	0	2	7	11	111
<i>Cx. annuliorus</i>	21	17	11	4	3	1	2	0	3	5	9	14	90
Subtotal	264	314	233	200	147	96	108	47	73	122	163	198	965
<i>An. gambiae</i>	0	2	11	37	108	74	40	11	7	1	0	0	291
Total	272	345	310	345	444	316	234	73	116	158	176	201	2990

Cx. quinquefasciatus was recorded throughout the whole period of the study with highest occurrence in March 114(17.81%). The population of *Cx. quinquefasciatus* was drastically down from June to Sept with records of 45, 24, 17and 8. *Cx. horridus* was most abundant in Feb.19(28.79%), had upward trend

in the months of June to Oct. 2007.*Cx annuliorus* was observed just in few months within the study period, that is Feb to May 2007 and Jan 2008 with highest occurrence in March 12(44.44%). *An gambiae* occurred highest in June with records of 123(35.51%) but was absent in Feb, March and Dec 2007 and Jan

2008. However, there was no significant difference ($P \geq 0.05$) in the monthly mosquito abundance. Generally, the result of the Pearson correlation (two tailed) showed significant correlation between vector

abundance and rainfall ($P \leq 0.05$) in the three urban centers of Imo State. Highest abundance of mosquitoes occurred in June.

Table 3. Monthly relative abundance of mosquito species sampled from drainage systems in Okigwe from February 2007 to January 2008.

Species	Feb.' 07	March	April	May	June	July	Aug	Sept	Oct	Nov.	Dec.	Jan.'08	Total
<i>Ae. aegypti</i>	6	11	38	57	99	74	36	14	32	16	8	2	393
<i>Ae. vittatus</i>	2	4	8	23	25	16	5	0	0	0	0	0	83
Subtotal	8	15	46	80	124	90	41	14	32	16	8	2	476
<i>Cx. quinquefasciatus</i>	84	114	71	75	45	24	17	8	25	45	67	65	640
<i>Cx. tigripes</i>	17	22	11	7	2	0	0	0	4	6	10	13	92
<i>Cx. horridus</i>	19	13	9	2	0	0	0	0	0	5	7	11	66
<i>Cx. annuliorus</i>	7	12	3	2	0	0	0	0	0	0	0	3	27
Subtotal	127	161	94	86	47	24	17	8	29	56	84	92	825
<i>An. gambiae</i>	0	0	15	48	123	90	66	17	7	1	0	0	367
<i>Total</i>	135	176	155	214	294	204	124	39	68	73	92	94	1668

Table 4 showed that *Ae. aegypti* was more abundant in Owerri, followed by Orlu while Okigwe had the least of observed *Ae. aegypti*. Orlu, on the other hand, had the highest abundance of *Ae. vittatus* while Okigwe had the least. *Culex quinquefasciatus* was more abundant in Owerri (576.75) followed by Orlu (381.75), while Okigwe recorded the least (160.00). Of the mosquito species encountered *Cx. quinquefasciatus* was the most abundant in the three locations. In all the observed mosquito species, Okigwe recorded the least, except for *Anopheles gambiae* where Okigwe had an average of 91.75 while Owerri and Orlu recorded 71.75 and 72.75 respectively. Owerri, on the contrary recorded the highest abundance of in *Culex tigripes* (61.75) as against 36.00 in Orlu and 25.00 in Okigwe as well as *Culex cinereus* 42.00 as against 23.25 in Orlu and 0.00 in Okigwe.

There is a significant difference in the abundance of mosquito species in Imo State ($P \geq 0.05$), *Culex*

quinquefasciatus(372.83) was predominant species following by *Ae. Aegypti*(151.17), *An. gambiae*(78.75) and *Cx annuliorus* was least(Table 5)

Discussion

Abundance of mosquito species in diverse habitats has been studied by different researchers (Ayanda, 2009; Lamidi, 2009 & Yee *et al* 2010). Drainage systems being a characteristic feature of urban centers tend to be an issue of public health concern. It has also been established that the underground portions of the drainage systems with stable microclimatic conditions offer ideal habitats for breeding of immatures and resting of adults of domestic and peri - domestic mosquitoes (Giorgio *et al*, 1994, Su *et al*, 2003). The preference for drainages, as breeding sites by different species of mosquitoes and to inhabit such polluted water cannot be unconnected with the fact that these drains contain water all year round. These have been associated with the common habit of indiscriminate

discharge of wastes into the open drains which often pollutes them to a very high level and further prevents the normal flow of water, thus providing excellent condition for larval development of these mosquitoes (Subra, 1981).

Table 4. Relative abundance of mosquito species in drainage systems in Imo State.

Mosquito species	Mean relative abundance
<i>Aedes aegypti</i>	151.17 ^b
<i>Aedes vittatus</i>	35.00 ^{cd}
<i>Culex quinquefasciatus</i>	372.83 ^a
<i>Culex tigripes</i>	40.25 ^{cd}
<i>Culex horridus</i>	22.00 ^d
<i>Culex cinereus</i>	21.75 ^d
<i>Culex annuliorus</i>	13.25 ^d
<i>Anopheles gambiae</i>	78.75 ^c

Table 5. Mean distribution of mosquitoes in the different sites among the three urban locations of Imo State.

Different drainage sites of Urban areas	Mean mosquito distribution
Markets	143.04 ^a
Residential	98.71 ^b
Stream/ Vegetation	68.17 ^{bc}
Hotels	57.58 ^c
Urban locations of Imo State	
Owerri	130.06 ^a
Orlu	93.44 ^b
Okigwe	52.13 ^c

Means with the same letter are not significantly different at $P \leq 0.05$.

In the present study, a total of eight species consisting of *Aedes aegypti*, *Ae. vittatus*, *Culex quinquefasciatus*, *Cx. tigripes*, *Cx. horridus*, *Cx. cinereus*, *Cx. annuliorus* and *Anopheles gambiae* were encountered in Owerri and Orlu respectively, while seven species were found in Okigwe where *Cx. cinereus* was completely absent in all the sampled sites. Of all the species, *Cx. quinquefasciatus* constitutes the most abundant in the 3 locations of the state. Calson and Knight (1987) recorded extremely high *Cx. quinquefasciatus* population in wastewater treatment ponds in Florida. Similarly, Calson *et al* (1986) reported very high *Cx. quinquefasciatus* population in untreated wastewater and at a later stage of wastewater treatment, *Anopheles gambiae* species became dominant. *Cx. quinquefasciatus* as well as *Ae. aegypti* have been reported to breed naturally in open drains, open cracked cesspits, pit latrines, water storage containers especially when these breeding sites are polluted with organic matter (Nwoke and Ebo 1988). *Ae aegypti* was next in abundant. The indiscriminate preference of all microhabitats by this species supports the findings of Okorie (1978), on which *Ae. aegypti* was found in all the microhabitat. However, the ubiquity of *Ae. aegypti* could be explained by considering the structure of the egg. The eggs of *Ae. aegypti* possess hardened endochorion which enables the eggs to resist desiccation. Hence the environmental conditions of microhabitat do not have adverse effect on these species as they would do to other mosquito species with no resistant endochorion (Clements, 2000). The ubiquity of *Ae aegypti* is important regarding man mosquito contact which increases the chances of disease transmission. *An. gambiae* which is unlikely to be found in polluted environments was surprisingly encountered in these study sites. This supports the result of Gimming *et al* (2001) who found increasing number of *An. gambiae* s.i larval densities with increasing turbidity.

Table 6. Environmental data (weather) representing rainfall, relative humidity and minimum and maximum temperatures.

Months/2007	Rainfall (mm)	Relative Humidity (%)	Maximum Temperature(°C)	Minimum Temperature(°C)
January	0.0	40	35.9	22.8
February	46.8	7	35.9	25.5
March	78.0	74	35.9	**
April	135.2	79	33.3	24.7
May	393.3	79	33.1	24.3
June	407.6	82	31.6	23.9
July	311.2	93	30.8	23.9
August	246.3		30.7	23.4
September	472.7	85	30.8	23.3
October	165.5	80	31.5	23.4
November	85.8	80	32.4	24.0
December	19.7	73	34.0	23.8
<i>January 2008</i>	13.6	52	33.5	22.7

Source: Ministry of Aviation, Nigerian Meteorological Agency Report

The presence of other mosquito species which are not commonly associated with drainage systems was equally surprising. *Cx. horridus*, *Cx. tigripes*, *Cx. cinereus* and *Cx. annuliorus* have not been previously reported as breeding in ammonia rich waters in Southeastern Nigeria and many other countries except the work of Irving – Bell *et al* (1987) that reported the presence of these species in such habitat in Jos North of Nigera.

Owerri recorded highest mean abundance (130.06) of mosquitoes which varied significantly (ANOVA, $P \leq 0.05$) with the two other areas, that is Orlu (93.44) and Okigwe (52.13). Owerri being a capital city of Imo State has the highest human population density with its attendant activities. The presence of industries and infrastructural facilities (such as piped - borne water and electricity) could account for this. However, the occurrence of mosquitoes has been associated with the presence and activities of humans which was highest in Owerri. O'Meara *et al*, (1997) reported that human activities are responsible for the establishment of vast

majority of aquatic habitats used by *Cx quinquefasciatus*. On the other hand, Orlu and Okigwe are rather semi – urban centers, and also possess undulating terrains and topography, have shallow drains which were relatively of smaller sizes. These together with low population size along with irregular supply of water may have direct bearing to the low density of mosquitoes recorded in these areas. *Cx cinereus* was completely absent in Okigwe in all sites of study. It is possible that this species was unable to establish or breed in Okigwe on account of the topographic features. Report has shown that topography of an area is an important factor in determining the breeding sites and the type of mosquito that will occur (Ukoli, 1990)

Monthly occurrence of mosquitoes showed significant difference (ANOVA, $P \leq 0.05$) in Owerri and Orlu. Highest occurrence of mosquitoes occurred in June while low abundance was observed between October and January (dry season) although there was a tremendous population decline in September. The

visible variations in the populations of mosquitoes between June and September, the rainy months could be attributed to intense rainfall in June and September (Table 6). The amount of rainfall is a principal factor that promotes breeding especially by providing the high humidity which prolongs the longevity of the adult mosquitoes. In this study, rainfall was shown to be positively correlated with mosquito density ($P \leq 0.05$). As a result the population peaks occurred during rainy months, April to August which could have extended to September but as a result of unusually high rainfall in September, most developing larvae were flushed out by excessive flooding resulting to drastic reduction in mosquito population encountered within this month.

Aedes aegypti and *Aedes vittatus* had their peaks during the rains, particularly between May and June. *Anopheles* recorded a peak in June in the 3 areas of study. With the peak of the rains, the water in the drains adequately got diluted to a level enabling the development of these species in various sites. It has been established that onset of rainfall supports additional mosquito breeding sites, hatching of eggs following oviposition (Igbiosa, 1989). *Culex quinquefasciatus* and *Aedes aegypti* were the only species that were prevalent in all the months of the study in the drainages. This corroborates the results of Gillet and Smith (1972) and Okorie (1978), in which *Culex* and *Aedes* predominate all year round differing from *Anopheles* which reach peak in abundance in wet months.

Culex quinquefasciatus, the most abundant throughout the study period had increased number from January – April with a peak in April for Owerri (286), Orlu (204) while Okigwe recorded their peaks in March (114) (Fig 2, 3& 4). This agrees with the observation of Service (1993) that the peak biting period of *Cx quinquefasciatus* was March to April dry season to early wet season. On the other hand, researchers in Australia have found that subterranean

habitats account for as much as 78% of the mosquito vectors during the dry season when surface water is scarce (Kay *et al*, 2000a). The low number of mosquitoes in the drier months October – January was probably due to no rainfall and high temperature. High temperature has been reported as being responsible for desiccation of mosquito eggs, incomplete digestion of blood meal, production of sterile adults while low temperatures do not enhance hatchability of the eggs and shortens the longevity of mosquitoes (Bruce – chwatt, 1985). Effective mosquito control interventions require knowledge of the timing of mosquito breeding activities and breeding site preferences. Therefore, these results obtained in this study could be very important for sustainable surveillance in mosquito control, as the peaks of various species of mosquitoes encountered in this study have been identified for the 3 areas of study; effective vector control could be targeted in these months.

The presence and occurrence of established vectors such as *Ae.aegypti*, *Cx. quinquefasciatus* and *An. gambiae* in these drainage systems is an indication that such habitats could contribute to vector disease risks in these urban areas. These mosquitoes have been incriminated in the transmission of important human diseases such as yellow fever, dengue, lymphatic filariasis and malaria. *Aedes aegypti* is known vector of yellow fever while *Cx. quinquefasciatus* is known to transmit filariasis. In East Africa, however it is a major vector of urban Bancroftian filariasis (White, 1971). Ogunba (1979) incriminated *Culex pipiens fatigans*, *Cx. nebulensis*, *Cx. decens*, *Cx tigripes* and *Cx. cinereus* as principal vectors of filariasis due to *Wuchereria bancrofti*. In addition, *Cx. quinquefasciatus* is a worldwide vector of various arbovirus such as Chikungunya virus in Tanzania (White, 1971), Rift valley fever in Egypt (WHO, 1975) and Sindbis in Africa and Hepatitis B in West Africa (Willis *et al*, 1976). Mosquitoes of the genus *Anopheles* are primary malaria vector worldwide. In Nigeria, the most common are *Anopheles gambiae* complex. This

species carry the parasite *Plasmodium falciparum* which causes malaria and has also been associated with the transmission of filariasis (Verma, 1989). The other species encountered in this study that included *Ae. vittatus*, *Cx. horridus*, *Cx. annuliorus* are potential vectors of arbovirus pathogens.

The changes in the physico – chemical and biotic characteristic of habitats may have created the conditions favorable for the breeding successes of mosquitoes. Breeding water quality has been reported to be an important determinant of whether female mosquitoes will lay their eggs and whether the resulting immature stages will successively complete their development to the adult stage (Piyaratne *et al*, 2005). In their previous studies, Mgbemena *et al* (2009) reported sulphate to correlate significantly with the abundance of mosquito species in their studied areas.

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