International Scholars Journals

African Journal of Insects ISSN 3257-7856 Vol. 4 (5), pp. 138-146, May, 2017. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Abundance and distribution of mosquito larval fauna (Diptera: Culicidae) in relation to physico-chemical indices along River Benue at Makurdi, North Central Nigeria

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Accepted 12 July, 2016

Studies on mosquito fauna in relation to physico-chemical parameters along river Benue at Makurdi, were done from August to December, 2015. Mosquito larvae and water samples were collected using standard techniques at five sampling stations. *Culex quinquefasciatus* 93(59.23%) > *Anopheles gambiae* s.l. 50(31.85%) > *Mansonia africanus* 10(6.37%) > *Aedes aegypti* 4(2.55%) were identified using standard keys. *Anopheles gambiae/Culex quinquefasciatus*, *Mansonia africanus* and *Aedes aegypti* larvae were collected from all, four and three of the stations respectively. Larval distribution varied significantly ($P < 0.05$) across two stations but not across the other stations ($P > 0.05$). Results of the physico-chemical indices showed that temperature, dissolved oxygen, transparency and conductivity varied significantly ($P < 0.05$), unlike dissolved solids and phosphate ions. Only P^H had significant effect ($P < 0.05$) on the mosquito larval abundance and distribution. The occurrence of *Anopheles* and *Culex* species across the stations implies endemicity of malaria and filariasis in Makurdi, while the presence of *Aedes* species reflects potential risk of arbo-viral infections in the area. This study provides information on mosquito ecology in relation to physico-chemical characteristics of breeding habitats along river Benue. The need for concerted efforts towards mosquito vector control in this area has been stressed.

Key words: Mosquitoes, physico-chemical factors, River Benue, Makurdi, Nigeria.

INTRODUCTION

Mosquitoes have been reported to be of public health importance as they constitute serious biting nuisance and transmit most deadly and life-threatening diseases such as malaria, dengue fever, yellow fever and filariasis (Adeleke *et al.,* 2008). The brunt of these diseases is mostly felt in Africa due to the poor socio-economic conditions and large expanse of the aquatic habitats which provide suitable breeding sites for mosquitoes (Idowu *et al.,* 2014). Another factor that is probably promoting the persistent transmission of these diseases in the African region as reported by Tiimub *et al*. (2012) and Idowu *et al.* (2014) is premised on the vast larval habitats available for mosquito vectors which ensure prolific and continuous breeding of these vectors.
Mosquitoes have been known to be widely distributed

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throughout the world and that they utilize different water bodies for their breeding (Adeleke *et al.,* 2008, Moussa *et al*., 2013). Many mosquito species breed in both natural and man-made containers such as ground pools, gutters, coconut shells, tree holes, bamboo stumps, leaf axils, septic tanks etc (Oyewole *et al.,* 2009, Tiimub *et al*., 2012). The distribution of mosquitoes is influenced both directly and indirectly by climatic and environmental factors (Githeko *et al.,* 2000). Mosquitoes prefer an environment with certain resources (food, shelter, breeding sites, favorable temperature and suitable humidity) in sufficient amount and at appropriate time for survival and development (Githeko *et al.,* 2000, Kudom *et al.,* 2011).

Recent increase in ecological and environmental changes due to agricultural activities and urbanization has been observed to contribute to the breeding of various mosquito species (Kudom *et al.,* 2011). Unplanned urban growth, inadequate waste disposal, irrigation and poor drainage, usually alter the ecosystem and thus promote prolific breeding of mosquitoes (Mgbemena *et al*., 2012). Part of the challenges militating against effective and sustained control of mosquitoes is their ability to breed in diverse aquatic habitats that are naturally occurring and the creation of breeding sites by human activities (Philbert and Ijumba, 2013, Aribodor *et al.,* 2013).

In light of the emerging threats posed by mosquito-borne diseases, there is ever growing need for vector control through mosquito surveillance, vector ecological research, and environmental check for effective control of mosquito vectors. These tools are considered significant in reducing human mortality and morbidity (Idowu *et al.,* 2014, Garba and Olayemi, 2015), especially in the case of dengue where prevention is entirely dependent on vector control due to the current lack of specific treatment and unavailability of vaccines (Almarinez and Claveria, 2014).

It has been reported that water is an important component of ecosystem and its quality in the breeding site is an important determinant of whether or not the female mosquitoes will lay their eggs and the resulting immature stages will successfully complete their development to the adult stage (Piyaratne *et al*., 2005; Oyewole *et al*., 2009). It is also known that streams and Rivers are usually fast flowing water bodies that are not good for mosquito larval breeding (Mulambalah *et al*., 2011). However, with these streams and rivers, there are often associated fringe areas where the water only moves very slowly or is stagnant in areas where water pools along the river and stream edges (Okogun *et al.,* 2005). These fringe areas can provide good breeding habitats for mosquitoes. It has also been reported that rivers and streams that are drying up leave stagnant, pooling water behind, which can serve as larval habitats for mosquitoes (Okogun *et al.,* 2005).

Investigations from Makurdi, a town in the North central area of Nigeria, reveals that the area is endemic for malaria (Sanganuwan and Adelaiye, 2007; Houmsou *et al*., 2010, Jombo *et al.,* 2010[a & b]; Amuta *et al.,* 2014), and filariasis (Manyi *et al.,* 2014). However, there is paucity of information on the role of river Benue which intercepts the town, in the breeding of mosquito vectors in the metropolis. It is against this background that the present study was carried out to provide information on mosquito breeding ecology in relation to prevailing physico-chemical indices of possible breeding sites along River Benue at Makurdi, which may have bearing on mosquito species diversity, distribution and disease transmission in the area and beyond.

MATERIALS AND METHODS

Study Area

River Benue arises from the Adamawa Plateau in the Western Cameroon and flows west across Central Nigeria and joins River Niger 483 km from the Coast. Its width varies from about 488 to 979 m and its navigable length is more than 965 km during the wet season and it is about 1,370 km long. The River Benue enters Makurdi metropolitan area (latitude 7^0 44′ and longitude 8^0 31′ E) at its tributary with a minor river Mu, and flows on by dividing the Makurdi metropolitan area into two -North bank and South bank respectively (Ishaq *et al.,* 2012).

The River Benue is characterized by sluggish flow except during the rainy season, when heavy rainfall causes a manifold increase in the runoff. At Makurdi metropolitan area, the approximate size of the river within its 30 km stretch is 671m (Udo, 1981). The rainy season in this area is from April to October, with rainfall that produces a river regime of peak flows from August to October, and the total annual rainfall in Makurdi ranges from 1200-2000 mm.

Makurdi is the capital city of Benue State, Nigeria, and according to the federal republic of Nigeria official gazette of 2006 population census, published in 2010, the town had the population of 297,398 people (comprising 157, 295 males and 140,103 females).There is a constant high temperature throughout the year, averaging 28-33^{0}C between March and April.

Both point sources and non- point sources discharge numerous effluents into River Benue. The river, within Makurdi metropolitan area, receives effluents majorly from the Wurukum Abattoir, Wadata Market and industries of Coca-Cola Plc and Brewery Plc. The river collects large amounts of human and industrial wastes through small open drainages as it flows through the highly populous localities of Makurdi. These features of the river and its tributaries provide potential breeding sites for mosquitoes and may have an impact on transmission of vector diseases in the study area throughout the year (Solomon *et al.,* 2009). Detailed account of

the geographical and regional indices of the study area has been provided by Udo (1981) and Nyagba (1995), while the map of the study area is depicted in Figure 1.

Mosquito Larval Collection

Accessible breeding sites for mosquito larvae were sampled at five (5) stations on the bank along river Benue during part of the wet season (August-October, 2015) and early dry season (late October-December, 2015) on a daily basis between 7:00 am to 11:00 am for five consecutive months (August to December, 2015). The stations included: Coca-cola, Benue Brewery, Benue State University, Wurukum and Wadata respectively. The mosquito larvae were collected with the use of plastic dippers and sieves of 0.55 mm mesh–size into labeled sample bottles. The larvae were collected by skimming plastic scoopers and sieves through the water or lowering the dipper slowly into the water at an angle of 45^{o} just below the water surface so that water flowed in together with any larvae that were present as described by Adeleke *et al*. (2008). In occasions that the larvae could not be identified immediately, they were preserved using 4% formaldehyde solution (Olayemi *et al*., 2010).

Identification of Mosquito larval specimens

The specimens were identified as far as possible using keys provided by Hopkins (1952) and Gillies and Coetzee (1987). The larvae were viewed and identified using taxonomic features as; absence or presence of siphon, pectin comb, sub-ventral tuffs, gills, meta-pleural spines and tergal plates as described by Service (2012).

Collection of water samples for physico-chemical analyses

All physico-chemical parameters for this study were determined based on the methods of Ishaq *et al*. (2012). At each sampling station, water samples were collected alongside the mosquito larvae. The samples were taken 30cm below the water surface five (5) times with 500 ml white glass bottle that had been rinsed with acetone and heated at 105^{o}C for an hour before use and transferred into 2.5 liter brown borosilicate glass bottle. After collection of the water sample from each station, they were stored in improved ice box (A 50 – liter plastic bucket with cover packed with ice box). The samples were transported to the laboratory, kept in the freezer and analyzed within three (3) days. An average of three hours was used for sampling and transportation to the laboratory.

Analytical procedure

Readings for temperature ($T^{o}C$) electrical conductivity (EC), transparency and total dissolved solids (TDS) were taken on the field. In the laboratory, water samples were analyzed for P^{H}, dissolved oxygen (DO) and phosphate ions as described by Ishaq *et al*. (2012).

Dissolved Oxygen (DO)

About 100 mL of 50% sodium sulphite solution was stirred constantly with electric stirrer for about five (5) minutes and the DO probe was dipped in it and the meter was finally set to zero mark. After the setting, the probe was now dipped in 100 mL water sample which was constantly stirred, and the DO was recorded in mg/L from the dial.

Phosphates (P)

25mL of water sample was taken in a flask and 1mL of ammonium molybdate solution and 3 drops of stannous chloride solution were added. A blue colour appeared. After 10minutes, the sample was run on a spectrophotometer at 690 nm and the concentration obtained in mg/L.

P^{H}

A JENWAY digital portable model P^{H} meter 3505 with glass electrode was used to determine the P^{H} of the water samples in the laboratory. The P^{H} meter was initially calibrated with standard buffer solutions at P^{H} 4.0, 7.0 and 10.0 before use. About 40 m/L of water sample was collected into 50 m/L beaker from the sampling bottles from each sampling station and the P^{H} was determined at ambient temperature.

Temperature ($T^{o}C$)

A general purpose JENWAY digital portable model conductivity meter/TDS 470 was used to determine the water surface temperature on the field. The custom liquid crystal display simultaneously showed temperature compensated conductivity or TDS and temperature. Water surface temperature was determined by lowering the probe to about 1cm below the surface for about 5 minutes until it stabilized and temperature was recorded immediately. The value was expressed in degree Celsius (^{o} C) with an accuracy of ±0.5%

Transparency of water (TW)

A Hydrological Investigation Data Sheet was used to determine the transparency of water samples on the field. The transparency tube was shaded; water sample was slowly poured into the tube using the cup. The tube was rotated slowly to make sure whether any of the patterns at the bottom of the tube was seen. The depth of water in the tube on the Hydrological Investigation Data Sheet was recorded to the nearest cm (>120 cm). The measurement was repeated twice with different observers

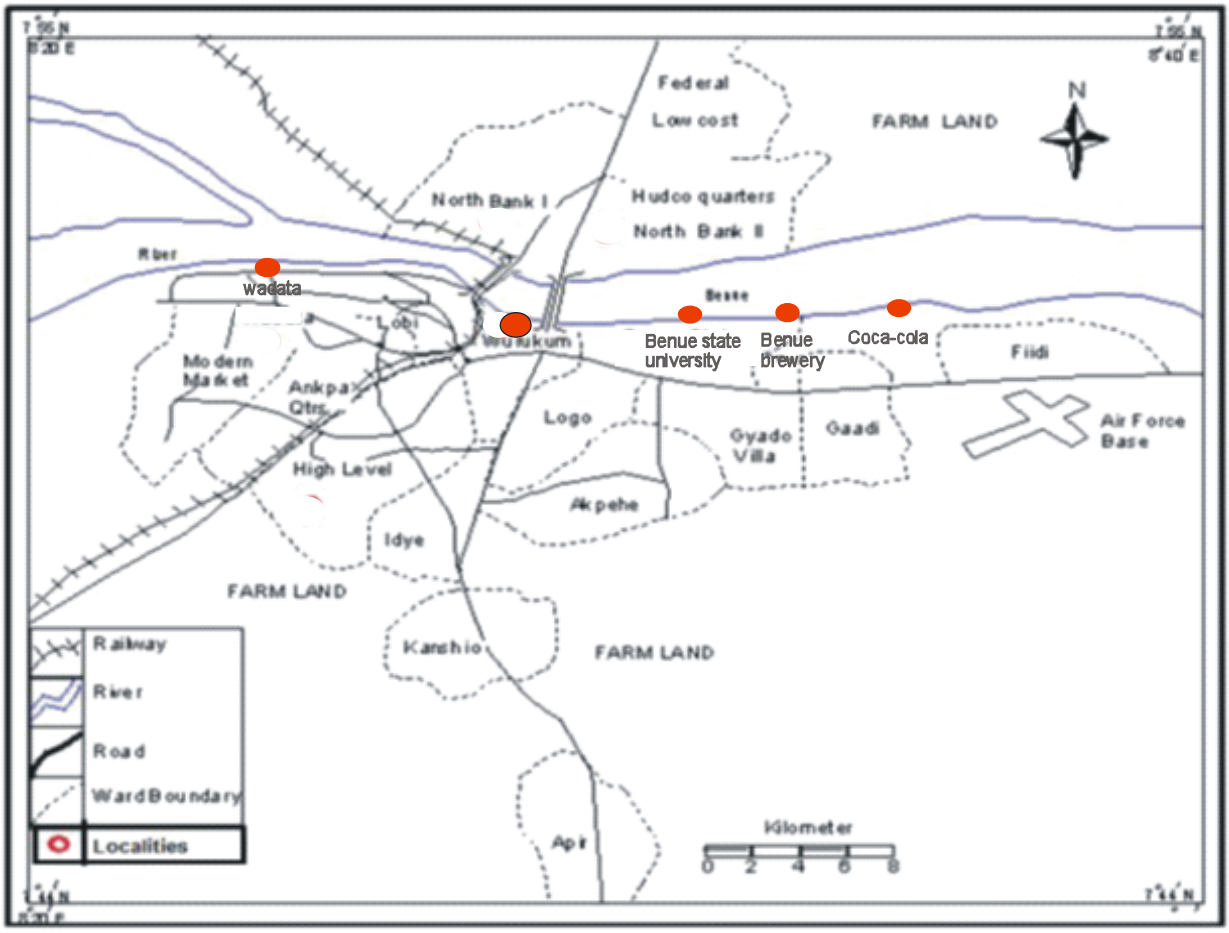

Figure 1. Map of Makurdi showing the sampling points along river Benue (Ministry of Lands and Survey, 2014).

using the same water sample.

Total dissolved solids (TDS)

A general purpose JENWAY digital portable model conductivity meter/TDS 470 was used to determine the TDS of the water samples on the field. The custom liquid crystal display simultaneously showed temperature compensated conductivity or TDS and temperature. About 300 mL water samples were taken using 500 mL white glass bottle and the TDS was recorded immediately by dipping the probe for about 1 minute. The value was expressed in milligram per liter (mg/L) with an accuracy of ±0.5%.

Conductivity (C)

A general purpose JENWAY digital portable model conductivity meter/TDS 470 was used to determine the conductivity of the water samples on the field. The custom liquid crystal display simultaneously showed temperature compensated conductivity. About 300 mL water samples were taken using 500mL white glass bottle and electrical conductivity was recorded immediately by dipping the probe for about 1 minute. The value obtained was expressed in micro-Siemens per centimeters (µS/cm); the accuracy was ±0.5%.

Statistical Analysis of data

Statistical correlation analysis and ANOVA test were used to analyse the association between physico-chemical parameters and larval mosquito abundance, using SPSS version 17.0. Significant levels were measured at 95% confidence level with significant differences considered at $P < 0.05$.

RESULTS

A total of 157 mosquito larvae were collected from five locations on the bank, along river Benue at Makurdi from August to December, 2015. Mosquito larvae identified from the collections in order of abundance were: *Culex quinquefasciatus* 93(59.23%) > *Anopheles gambiae* s.l. 50(31.85%) > *Mansonia africanus* 10(6.37%) > *Aedes aegypti* 4(2.55%) respectively. The results revealed significant variations ($P < 0.05$) in the mosquito species' abun-

Table 1. Mosquito larval abundance and distribution at five stations along River Benue at Makurdi, during the early dry season of 2015.

Species /Location	N	Coca-cola	Brewery	BSU	Wurukum	Wadata	F	P-Value
Aedes aegypti	3	1 ± 0.33^{b}	1 ± 0.33^{b}	0 ± 0.33^{a}	0 ± 0.33^{a}	3 ± 0.33^{c}	22.60	0.001
An. gambiae s.l.	3	5 ± 0.39^{a}	7 ± 0.39^{b}	11 ± 0.39^{c}	15 ± 0.39^{e}	12 ± 0.39^{d}	735.57	0.001
Cx. quinquefas.	3	13 ± 0.49^{a}	14 ± 0.49^{a}	23 ± 0.49^{c}	28 ± 0.49^{d}	16 ± 0.49^{b}	1602.00	0.001
M. africanus	3	6 ± 0.45^{d}	1 ± 0.45^{ab}	0 ± 0.45^{a}	2 ± 0.45^{bc}	3 ± 0.45^{c}	45.67	0.001

NB. Values followed by same superscript alphabets in a row are not significantly different at P = 0.05 level of significance.

Table 2. Physico-chemical properties of mosquito larval breeding habitats along River Benue at Makurdi during the early dry season of 2015

Parameters	Cocacola	Brewery	BSU	Wurukum	Wadata	Means $\pm$ SD
T (°C)	28.51 ± 0.01^{b}	28.91 ± 0.01^{e}	28.32 ± 0.02^{a}	28.62 ± 6.02^{c}	28.65 ± 0.01^{d}	28.59 ± 0.22^{c}
DS(mg/l)	45.81 ± 0.02^{b}	45.31 ± 0.01^{a}	44.18 ± 0.59^{a}	45.63 ± 0.01^{ab}	46.62 ± 0.02^{c}	45.56 ± 0.76^{a}
TP (m)	0.14 ± 0.01^{d}	0.06 ± 0.01^{b}	0.09 ± 0.01^{c}	0.13 ± 0.01^{d}	0.02 ± 0.01^{a}	0.09 ± 0.05^{d}
DO(mg/l)	2.53 ± 0.01^{b}	3.20 ± 0.01^{c}	3.41 ± 0.01^{d}	2.31 ± 0.01^{a}	3.61 ± 0.01^{c}	3.01 ± 0.56^{c}
PI(mg/ l)	1.90 ± 0.01^{c}	2.13 ± 0.01^{e}	2.01 ± 0.01^{d}	1.89 ± 0.01^{b}	1.74 ± 0.01^{a}	1.93 ± 0.15^{c}
C (μ s/cm)	128.60 ± 0.01^{b}	145.90 ± 0.01^{e}	123.30 ± 0.01^{a}	133.20 ± 0.01^{d}	129.70 ± 0.01^{c}	132.14 ± 8.47^{d}
P^{H}	7.26 ± 0.01^{c}	7.44 ± 0.01^{d}	7.21 ± 0.01^{b}	6.92 ± 0.01^{a}	7.22 ± 0.01^{b}	7.21 ± 0.19^{b}

Values followed by same superscript alphabets in a row are not significantly different at P = 0.05 level of significance. (T °C= Temperature, DS= Dissolved Solids, TP= Transparency, DO= Dissolved Oxygen, PI= Phosphate Ions, C= Conductivity, P^{H}= Hydrogen ion Concentration.

dance along the river.

In terms of locations where larval collections were made, Wurukum location had the highest number of larval mosquitoes, 43(27.4%) followed by Benue State University location, 34(21.7%), Wadata location recorded 32(20.4%) larvae while 25(15.9%) larvae were collected from Coca-cola location and the least in terms of larval abundance was Benue Brewery which recorded 23(14.7%) larvae respectively (Table 1).

Results also showed that larvae of *Culex quinquefasciatus* and *Anopheles gambiae* s.l. were collected from all the sampled locations, larvae of *Mansonia africanus* were collected from four locations while *Aedes aegypti* were collected from only three of the locations. The results showed that the distribution of mosquito larvae varied significantly ($P < 0.05$) between Coco-cola and Wurukum locations but did not vary significantly ($P > 0.05$) across the other locations. There was also a significant difference ($P < 0.05$) in distribution between the four mosquito species collected from the study area.

Physico-chemical properties of mosquito breeding habitats along river Benue and correlations between mosquito larval abundance and physico-chemical properties of breeding habitats along River Benue are presented in Tables 2 and 3 respectively. The results showed that temperature, dissolved oxygen, transparency and conductivity varied significantly ($P < 0.05$) among the five larval sampling points along River Benue.

However, dissolved solids and phosphate ions did not differ significantly ($P > 0.05$) across the sampling points.

Table 3. Correlation between physico-chemical parameters and Mosquito Larval Population and Distribution along River Benue at Makurdi.

Correlations									
Parameters	**T^0C**	**DS**	**TRAN**	**DO**	**PHOS**	**COND**	**P^H**	**MLP**	**N(Months)**
T^0C	1	0.366	-0.414	0.047	0.217	0.938*	0.393	-0.375	5
DS	0.366	1	-0.514	0.174	-0.799	0.043	-0.272	0.267	5
TRAN	-0.414	-0.514	1	-0.892*	0.142	-0.220	-0.461	0.236	5
DO	0.047	0.174	-0.892*	1	0.000	-0.069	0.550	0.301	5
PHOS	0.217	-0.799	0.142	0.000	1	0.521	0.498	-0.401	5
COND	0.938*	0.043	-0.220	-0.069	0.521	1	0.420	-0.390	5
P^H	0.393	-0272	-0.461	0.550	0.498	0.420	1	-0.944*	5
MLP	-0.375	0.267	0.236	-0.301	-0.401	-0.390	-0.944*	1	5

*Correlation is significant at the 0.05 level (2-tailed)
Key: T^0C = temperature, DS = Dissolved solids, TRANS = Transparency, DO = Dissolved oxygen, PHOS = Phosphates, COND = conductivity, P^H = Potency of Hydrogen, MLP = Mosquito Larval population.

Meanwhile, of all the physico-chemical indices measured, only p^H had a significant effect ($P < 0.05$) on the population of mosquito larvae across the five sampling points (Fig. 2).

DISCUSSION

Previous studies have shown that characteristics of aquatic habitats determine whether mosquitoes will oviposit, hatch, develop, pupate and successfully emerge into adults or not, thus influencing which mosquito species will occupy a habitat (Piyaratne *et al*., 2005; Oyewole *et al*., 2009; Ndenga *et al.* 2012).The present study determined whether physiochemical characteristics differ along river Benue at Makurdi with presence of mosquito larvae.

It is perceived that the passage of river Benue at Makurdi would support the breeding of different mosquito vector species that may be responsible for the transmission of vector borne diseases in the study area. Moreover, it has been reported that proper assessment of mosquito breeding sites is necessary in the recent event of the persistent transmission of mosquito-borne diseases in different parts of the world (Idowu *et al.,* 2014). Some of the major determinants of the mosquito larval distribution have been reported to include the size and nature of the breeding sites, physico-chemical parameters of the sites, raining pattern and the presence/absence of the predators (Garba and Olayemi, 2015). In the present study, three of the four species of mosquitoes that were identified from the larval collections are known to be efficient vectors of some parasitic diseases; *Aedes aegypti* is an important vector of yellow fever virus, *Anopheles gambiae* transmits *Plasmodium* species, *Culex quinquefasciatus* transmits filarial parasites that cause loiasis and elephantiasis, while *Mansonia africanus* is an important vector in the transmission of *Wuchereria bancrofti (*Idowu *et al.,* 2014).

Of all the mosquito species collected and identified in this study, *Culex quinquefasciatus* had the highest abundance followed by *Anopheles gambiae* s.l. The large occurrence of *Cx. quinquefasciatus* compared to the other species is not surprising because of its preference for polluted water while *An. gambiae* s.l. has been reported to utilize other habitats apart from ground pool in which it has been known for (Adeleke *et al*., 2010). The low occurrence of *Aedes aegypti* along the river is in agreement with the report of Philbert and Ijumba (2013), that the species prefers to breed in peri-domestic and domestic polluted waters. The fact that a few *Aedes aegypti* have been collected from the study area is of apparent health danger, being a principal vector of viral infections such as yellow fever, dengue fever virus, encephalitis virus, haemorrhagic fever virus, Chikungunya, and Rift Valley viruses (Gillet, 1972, Service, 2012, Philbert and Ijumba, 2013). Meanwhile, *Cx*. *quinquefasciatus* has been reported to be an efficient transmitter of bancroftian filariasis in Africa (Adeleke *et al*., 2010).

The occurrence of mosquito larvae at all the sampled locations along the river in the present study is worrisome, indicating that the river supports the breeding of different species of mosquito vectors, posing a serious danger in terms of vector disease transmission. Wurukum, BSU and Wadata locations had higher numbers of mosquito larvae than Brewery and Coca-cola locations. This may be as a result of differences in the microhabitats and physico-chemical conditions of these sampling points as separately reported by Okonkwo *et al*. (2014) and Itina *et al*. (2014).

In the present study, different species of mosquitoes appear to prefer one habitat to the other and it was found that temperature, dissolved oxygen transparency and conductivity varied significantly among the five sampling points along River Benue. It is therefore, suspected that the variations in the physico-chemical parameters may have been responsible for the habitat preferences shown

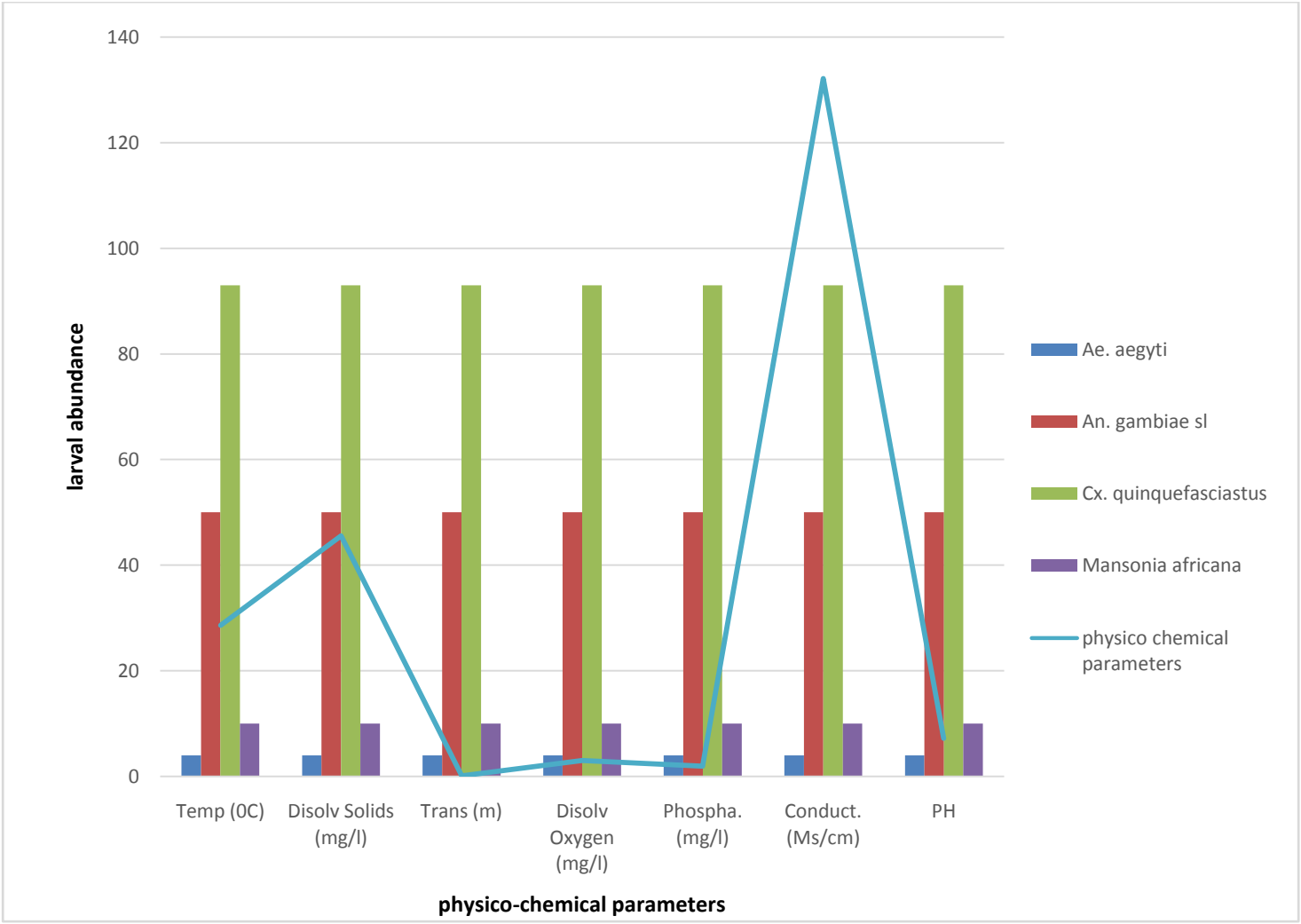

Figure 2. Relationship between Mosquito Larval Abundance and Physico-chemical Properties of Breeding Habitats along River Benue at Makurdi, Nigeria.

by these species in the study area. However, dissolved solids and phosphate ions did not differ significantly across the sampling points along the River. This is comparable to the reports of Garba and Olayemi (2015) in Minna, North Central Nigeria, Tiimub *et al*. (2012) in Ghana, Moussa *et al.* (2013) in Iran and Philbert and Ijumba (2013) in Tanzania on habitat preferences by mosquito larvae in relation to the prevailing physico-chemical parameters of the various study localities.

Meanwhile, of all the physico-chemical parameters measured, only p^H had a significant effect on the population of mosquito larvae across the five sampling locations. *Culex* larvae formed the bulk of larval collections (59.23%) while *Aedes* had the least larval population (2.55%). This is in agreement with Sattler *et al*. (2005) who reported that a P^H value of less than 7.3 was associated with high culicine larval density. However, the findings of this study are in contrast to those of Kudom *et al.* (2011) who found high culicine larval densities in breeding sites with P^H values of 7.6 and above.

The fact that *Aedes aegypti* was found in the Benue river during this investigation justifies the reports by Idowu *et al. (*2014) and Adeleke *et al*. (2010) that the vector breeds indiscriminately while other species of *Aedes* have been reported to prefer man made or artificial breeding sites. *Aedes aegypti* were found more in Wadata location than Coca-cola and Brewery locations but were completely absent in Wurukum and BSU. This is probably due to the high algal growth that was observed in these locations, in consonance with the report of Okonkwo *et al*. (2014).

Meanwhile, *Culex quinquefasciatus* and *Anopheles gambiae* s.l. appeared to be less selective in their larval

habitats, *Mansonia africanus* was more predominant at Coca-cola location than the other locations, and completely absent at BSU location. The high occurrence of *Culex quinquefasciatus* in all the breeding sites shows that most of the breeding sites were polluted since the species has been reported to breed exclusively in polluted water (Idowu *et al.,* 2014).

Findings from this study have shown that the total mosquito larval population was small, compared to other studies on smaller and shallow bodies of water (Oyewole *et al*., 2009; Kudom *et al*., 2011; Tiimub *et al*., 2012; Moussa *et al.,* 2013; Philbert and Ijumba, 2013; Garba and Olayemi, 2015 respectively). This may be due to the fact that mosquitoes prefer shallow water bodies than deep ones like river Benue, and or it may be that their specific requirements for water quality, shade and vegetation also differ. Moreover, Oyewole *et al*. (2012), Ndenga *et al*. (2012) and Okonkwo *et al*. (2014) reported separately that *Culex quinquefasciatus* preferred water with high organic content and high algal growth, *Aedes* and *Anopheles* species preferred clear or turbid water with little or no algal growth while *Anopheles* species showed preference for sunlit water against semi shaded and shaded breeding habitats of *Culex* and *Aedes*. It is therefore, correct to state here that for a big water body like river Benue to harbor mosquito larvae up to the number reported in this investigation, it is perceived that other breeding sites in the study area would likely support more numbers of these vectors.

The present study therefore, reveals a high vector breeding potential and transmission threshold of malaria, filariasis and viral infections such as yellow fever, dengue fever, encephalitis virus, hemorrhagic fever etc. There is therefore, the need for routine surveillance to monitor outbreaks of mosquito-borne infections in the study area and beyond.

CONCLUSION

The mosquito species collected in this study are medically important as they have been incriminated as vectors of lymphatic filariasis, malaria, yellow fever and dengue fever among others. These mosquitoes also breed, although not in high abundance, in unusual habitats like river Benue, due to changes in environmental factors. The findings of this study also reveal that chemical and physical factors play significant roles in mosquito larval habitat preferences. The human inhabitants of the study area are therefore, at risk of being infected by malarial and filarial parasites as well as other arboviral infections which could be born at any time if not averted.

RECOMMENDATION

There is need for mass public health education for the improved environmental sanitation and larvicidal spraying to reduce the breeding sites of potential mosquito vectors along River Benue at Makurdi. Pollution indices of river Benue should be investigated and more research should be carried out to provide data on the entomological profile and dynamics of the malaria, filarial and other vectors in this area.

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