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Research Article

Studies on Malaria Vectors and Climatic Factors: The Cause of Malaria Transmission in Selected Communities of Benue State, North Central Nigeria

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ABSTRACT
Mosquitoes are nuisance pests and vectors of disease-causing pathogens. This study investigated the species distribution and abundance of *Anopheles* mosquitoes in relation to temperature and relative humidity in three LGAs of Benue State, Nigeria: Agatu, Makurdi, and Otukpo. Sampling was conducted using Pyrethroid Spray Catch (PSC) and CDC light traps, with morphological identification using standard keys. Six species were identified: *Anopheles gambiae s.l, An. funestus, An. nili, An. coustani, An. rufipes,* and *An. pharoensis. An. gambiae s.l* and *An. coustani* were most dominant. Overall abundance was higher in the rainy season (61.17%) than in the dry season (38.81%), attributed to increased breeding sites from rainfall. Agatu's swampy grassland supported the highest vector density compared to Makurdi and Otukpo. Monthly variation showed peaks in May (12.88%) and June (12.37%), with the lowest in February (5.40%). In Agatu, *An. gambiae s.l* accounted for 46.95% of collections, while *An. coustani* was least abundant (0.60%). In Makurdi, *An. gambiae s.l* was highest (65.76%) and *An. pharoensis* lowest (5.98%), with no *An. coustani* recorded. In Otukpo, *An. gambiae s.l* was also highest (75.76%) and *An. coustani* lowest (3.09%). The predominance of *An. gambiae s.l* reflects its adaptability to varying environments. Statistical analysis revealed significant differences ($p<0.05$) in species composition across the LGAs. These findings highlight seasonal and ecological influences on vector distribution, with implications for targeted mosquito control strategies in Benue State.
Keywords: *An. Coustani*; *An. Rufipes*; Makurdi; Mosquitoes; Otukpo; Pyrethroid

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INTRODUCTION

Mosquitoes are responsible for the spread and transmission of several harmful diseases such as malaria and lymphatic filariasis. It is known to infect over 700 million people causing 1 million deaths each year especially in developing regions of the world including sub-Saharan Africa (WHO, 2016). Despite years of control efforts, malaria continues to be a major threat to public health in parts of sub-Saharan Africa, Nigeria inclusive. About 97% of Nigeria's population is at risk of malaria where 60% of hospital outpatient visits and 30% of hospitalization among children under five years and pregnant women occur due to malaria (Minakawa *et al.,* 2012).

Mosquitoes, under favorable environmental conditions of the tropics, are successful and cause several diseases of medical and veterinary concerns such as malaria, lymphatic filariasis, dengue fever, amongst other infections (WHO, 2020). With the continued increase in climate change, case reports of these diseases have skyrocketed especially in Africa where insecticide resistance has become a major challenge to vector control (Muhammad *et al.,* 2021). The climate system of the Earth strongly affects human life and has a wide range of health impacts. It is well known that the warm and humid climate conditions in the tropics are suitable for diseases like malaria (Githeko *et al*., 2000). In Africa, temperatures are mostly suitable for malaria transmission and optimal breeding conditions for mosquitoes are provided by rainy seasons (Hay *et al.,* 2000). According to Aigbodion and Anyiwe (2005), a number of factors relating to environment and climate directly influence the abundance and distribution of mosquitoes.

However, among the sub-Saharan African countries, Nigeria has the highest share of the global burden of malaria disease (WHO, 2018}. More than 95% of the malaria cases in Nigeria are caused by *P. falciparum* (Okorie *et al*., 2013; Akpan *et al*., 2019; The Federal Republic of Nigeria, 2015), mostly occurring in children under the age of 5 years (WHO, 2018; Akpan *et al*., 2019; The Federal Republic of Nigeria, 2015). At present almost more than 70% of the Nigerian population live in endemic areas (Onyiri, 2015; Onwujekwe *et al*., 1998). An important partway to understanding malaria distribution patterns and planning effective intervention strategies is the identification of important influencing factors to malaria prevalence and transmission (Grillet, 2000; Adigun *et al*., 2015). A challenge in studying malaria risk in Nigeria is the heterogeneity of the prevalence, which is attributed to high variability in climate conditions as well as the landscape (Akinbobola and Bayo, 2013). Few published studies in Nigeria have linked malaria prevalence to several influencing factors, including climate and environmental conditions (Awolola *et al*., 2007; Ebenezer *et al*., 2014; Kalu *et al*., 2012; Efe and Ojoh, 2013), socioeconomic factors (Adebayo *et al*., 2016; Gayawan *et al*., 2014; Onwujekwe *et al*., 2013), geographical factors (Onwujekwe *et al*., 2010), and control strategies as well as prevalence of other febrile illnesses (Dike *et al*., 2006; Onwujekwe *et al*., 2000; Gunda *et al*., 2017). Additionally, several authors in other malaria endemic countries have investigated the correlation between malaria and important meteorological variables as observed in Venezuela (Laguna *et al*., 2017), in Zimbabwe (Gunda *et al*., 2017), in Zambia (Shimaponda-Mataa *et al*., 2017; Riedel *et al*., 2010), in Côte D'Ivoire (M'Bra *et al*., 2018), in Ghana (Awine *et al*., 2018), in Burundi (Nkurunziza *et al*., 2010), in Ethiopia (Ghebreyesus *et al*., 1999; Teklehaimanot *et al*., 2004) and many more. It was found that malaria infections are not uniformly distributed in space. According to the findings of Grillet *et al*. (2000), Laguna *et al*. (2017), Awolola *et al*. (2007), Nkurunziza *et al*. (2010), the epidemiological patterns of mosquito-borne pathogens could be extraordinarily heterogenous by cause of a complex interactions among parasites, vectors and host, which occurs at definite locations and time, inducing irregular patterns of epidemic spread (malaria), that may reflect spatial variation in the disease distribution.

It is evident that malaria disease is spatially correlated because children living in a given geographical location may exhibit similar behavior that influences the rate of infection. Public health policy makers may want to understand the geographical distribution of malaria across the states and regions rather than just the prevalence across states, and this might shade more light on the distributional patterns across space. This paper determines the abundance and distribution of malaria vectors and interactions in relation to malaria transmission in selected communities in Benue State North Central Nigeria. This study may provide information on the geographical patterns of under-5 malaria distribution which could inform public health policy makers and program managers on the priority areas that need enhanced malaria control and intervention across Nigeria.

MATERIALS AND METHODS

Study Area

This study was carried out in Benue state in three randomly selected communities. Benue state is located in the North central part of Nigeria within the guinea savannah vegetation zone of the country Nigeria. The state has a tropical climate condition with a mean annual temperature and relative humidity ranging from 27^0-33^0 and 65%- 80 (%) respectively.

Study design/Description of the study areas

Entomological surveillance was conducted across the three selected communities of Local Government Area of Otukpo. The communities are located in the

Guinea Savannah ecological zone; the landscape of the LGA is mostly forested savannah. The climate also presents two distinct seasons i.e the rainy season which usually commences from the month of May to October and the dry seasons commences from the month of November to April with annual rainfall varying from 1,200 mm -1,500 mm. The prime period for malaria transmission is six months from the month of May to October (Ayanlade *et al.,* 2010).

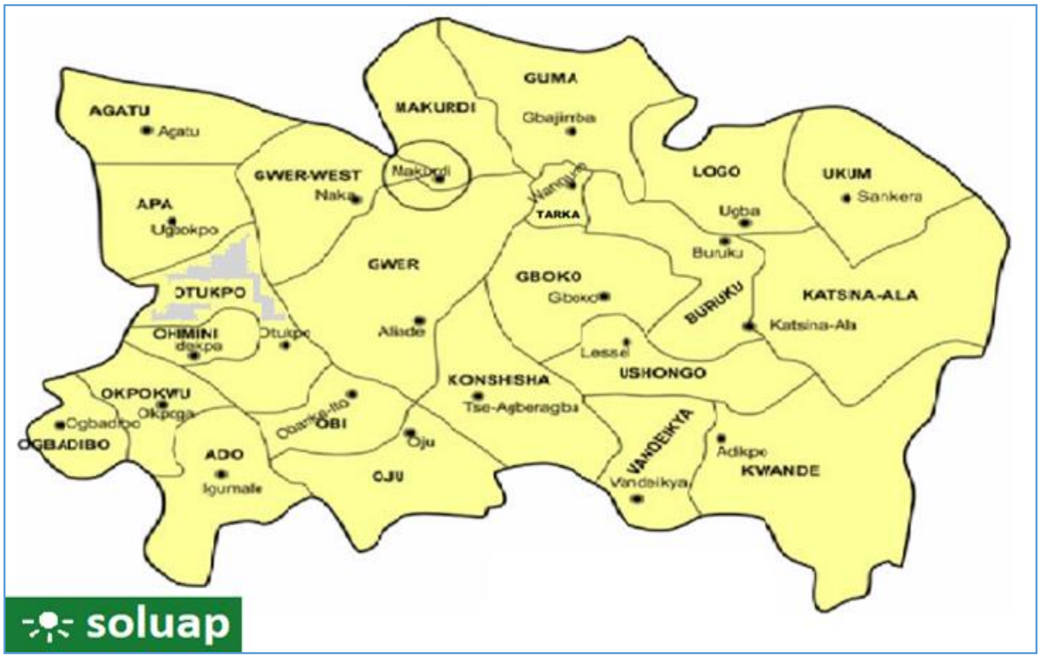

Figure 1: Map of Benue State showing the study sites and various Local Government for the sample collections across the state (Source: Solution Applications, 2022)

Sample Collection

CDC light trap collection

CDC light trap methods (baited traps, was placed indoors and outdoors) in two different houses monthly for 3 nights per site to measure mosquito biting time. The light trap bag was monitored hourly by two mosquito collectors from 18:00 to 06:00 per house per night in order to have proxy estimate on the peak biting time following the methods of Yohannes and Boelee (2012). The trap was placed close to the legs of a person sleeping under an untreated bed net as bait both indoors and outdoors with the cups changed hourly. The mosquitoes collected were kept in separate labeled paper cups for identification and further analysis.

Pyrethrum spray collection

A total of 9 houses per LGA per month were sampled using the Pyrethrum Spray Collection (PSC) method as described by the WHO (2005) to sample indoor-resting mosquitoes. The houses sampled by two people, one inside and the other one outside, using an aerosol insecticide (Baygon) containing the active ingredients of 0.05 percent Imiprothrin, 0.05 percent Prallethrin, and 0.015 percent Cyfluthrin. The two sprayers begin spraying at the same time as they move in opposite directions spraying inside the room as well as the eaves outside of the house, after which the door was closed for 15 minutes and then opened as the sprayers entered and collected the knocked down mosquitoes on the white cloth that was laid down prior to spraying from 5:30am to 8:30am. The mosquitoes were collected using feather weight forceps and then placed in petri dishes or paper cups containing damp filter paper. Anopheline mosquitoes were preserved on damp absorbent paper in a cool box and later identified to the species level by morphological criteria (Gillies and De Meillon 1968; Gillet 1972; Gillies and Coetzee 1987; Kent, 2006).

Morphological Identification of Mosquito Samples

All mosquitoes collected were identified and sorted out under a stereomicroscope (Leica model NSW series IMNS 210 EZ4). All mosquitoes identified as far as possible using morphological keys of Gillies and De Meillion (1968), Gillies and Coetzee (1987) whether they were anophelines or culicines. After identification, the mosquitoes were preserved in dry labeled Eppendorf tubes over dry silica gel and the *Anopheles* later used for PCR identification. The Mosquitoes identification was carried out at Abt Associates Entomological Laboratory and Insectary, Nasarawa State University, Keffi.

PCR Identification of Members of the *Anopheles gambiae* Complex

Anopheles mosquitoes collected from the surveillance sites from the three LGAs were analyzed for species identification using the Polymerase Chain Reaction (PCR). At the Nigerian Institute of Medical Research (NIMR). All Mosquitoes presumed to be members of the *Anopheles gambiae* complex were analyzed using a standard method. The DNA was Extracted and amplified using the *Anopheles gambiae* species-specific multiplex PCR (Scott *et al.,* 1993). PCR products were separated in Agarose gel, stained with ethidium bromide and visualized under UV trans illuminator. The PCR diagnosis bands for this assay include: a 464-base pair (bp) band for *Anopheles melas*, 390 bp for *An. gambiae* s.s. and 315bp for *An. arabiensis.* 367 for the M form of *An. gambiae* and 267 for the S form of the *Anopheles gambiae s.s*

The adult mosquito samples morphologically identified as *Anopheles gambiae* s.l. was further differentiated into species level and also to M and S forms using PCR as indicated above. Five sets of primers designed from the DNA sequences of the intergenic spacer (ITS) region of *An. gambiae* complex ribosomal DNA (rDNA) will be used in PCR for the member species (Gillies and Coetzee, 1987)

Blood Samples Assay

Blood samples were collected from the three health care facilities within the three LGAs for the examination of malaria parasites within the communities (Makurdi, Oturkpo and Agatu). Thick and thin blood films were prepared for the detection of the malaria parasite's as the blood samples will be collected in the EDTA containers to avoid blood clotting (Cheesbrough, 2010).

Sample collection and Processing

Blood samples were collected by venipuncture. 5mls of blood was collected from the patient using a well labeled Ethylene Diamine Tetra Acetic Acid (EDTA) vacutainer tube to avoid clotting (Cheesbrough, 2010).

Data Analysis

Data generated were analyzed using the SPSS software version 23.0 and Excel package. Chi – square (χ2) test was used to compare the mosquito's species at various collection sites, seasons, indicative of a statistically significant difference. The relationship between *Anopheles* species and months/season was carried using one way ANOVA analysis.

RESULTS AND DISCUSSION

Results

Composition of *Anopheles* mosquito species encountered across the encountered across the selected Study Locations

Table 1 showed the spatial composition of *Anopheles* species encountered across the three selected location. Four (4) species of *Anopheles* vectors were encountered in all the selected location during the period of study. The various species encountered are; *Anopheles gambiae s.l, An. funestus, An. coustani,* and *An. pharoensis. An. gambiae s.l* was the most dominant species (72.36%) encountered followed by *An. funestus* (21.02%) while *An. coustani,* had the least number of species (1.12%) across the study areas. There was a statistical difference ($p<0.05$) in the abundance of *Anopheles* species.

In respect to location, Agatu had the highest number of collected *Anopheles* species. Having *An. gambiae s.l* as the highest (46.95%) and *An. coustani* had the least (0.60%) number of *Anopheles* mosquito species in Agatu; in the same way, total number 184 (25.95) Anopheles species was collected in Markudi of *An. gambiae s.l* had highest (65.76%) and *An. pharoensis* had the least (5.98%) and no record for *An. coustani* in Markudi. while *An. gambiae s.l* was equally higher (75.76%) and *An. coustani* had the least (3.09%) number of *Anopheles* mosquito species encountered in Otukpo. Statistically, there is a significant difference ($p<0.05$) in the composition of *Anopheles* mosquito species encountered across the selected locations in Benue State.

The distribution of malaria vectors *Anopheles* mosquitoes in relation to climatic factors

The results in the Table 1b showed the composition of *Anopheles* species encountered across the three selected locations in relations to the climatic factors Agatu had the highest collection of mosquitoes with 331 (46.95%) which is higher than Otukpo and Makurdi respectively also the temperature ranges between 23-28 and the relative Humidity ranges between 80-95%.

Table 1a. Composition of *Anopheles* mosquito species encountered across the selected Study Locations

Location	Site of Collection	*An. gambiae* (%)	*An. Funestus* (%)	*An. Coustani* (%)	*An. Pharoensis* (%)	Total (%)
Makurdi	Wadata	121 (65.76)	52 (28.26)	-	11 (5.98)	184 (25.95)
Otukpo	Ugboju	147 (75.77)	24 (12.37)	6 (3.09)	17 (8.76)	194 (27.36)
Agatu	Okokolo	235 (71.00)	73 (22.05)	2 (0.60)	21 (6.34)	331 (46.95)
Total		513 (72.36)	149 (21.02)	8 (1.12)	39 (5.50)	709 (100)

Table 1b. The distribution of malaria vectors *Anopheles* mosquitoes in relation to climatic factors

Location	Site of collections	No. Mosquitoes Sampled %	Temperature Ranges (°C)	Relative Humidity (%)	Rainfall Ranges (mm)
Makurdi	Wadata	184 (25.95)	27 – 33	65-85%	1280 – 1666
Otukpo	Ugboju	194 (27.36)	25 – 29	60-80%	1164 – 1590
Agatu	Okokolo	331 (46.95)	23 – 38	80-95%	1492 - 2119

Monthly spatial composition of *Anopheles* species encountered in the study areas.

The monthly spatial composition of *Anopheles* species encountered in the study areas is presented in Table 2. Four (4) species of *Anopheles* mosquito were encountered during the study period. *Anopheles gambiae s.l* was the most dominant (102.58±13.59) species encountered throughout the months of the study period followed by *An. funestus,* (29.80±2.92) while *An.coustani* was the least encountered species (1.6±4.61). Interestingly, all the four (4) species of *Anopheles* mosquito encountered during the study period were peaked in the month of July.

Prevalence of Malaria Infection in the Study Area.

Prevalence of malaria infection in the study areas is presented in Table 3a. Two hundred and ninety-nine out of six hundred samples examined were positive. Higher prevalence was record among the sample in Agatu (74.5%) while Makurdi and Otukpo recorded the prevalence of 33.5% and 41.5% respectively. There was a statistical difference (p<0.05) in the malaria prevalence among the study locations.

Table 2. Monthly Mean composition of *Anopheles* species encountered in the study areas

Months/Species	*An. gambiae*	*An. funestus*	*An. coustani*	*An. pharoensis*
May	$77.00±11.00^a$	$18.50±1.10^a$	0.00±0.00	$5.0±1.00^a$
June	$119.50±12.50^b$	$42.00±1.00^c$	$2.00±0.00^{ab}$	$11.00±1.00^c$
July	$126.00±6.00^b$	$46.50±0.50^c$	$3.00±0.0^c$	$9.50±.50^b$
August	$119.00±6.00^b$	$20.50±0.50^b$	$1.00±0.00^a$	$8.50±1.50^b$
September	$72.00±7.00^a$	$23.00±1.00^{ab}$	$2.00±0.05^{ab}$	$5.00±1.00^a$
Mean Total	**102.50±13.59**	**29.80±2.92**	**1.6±4.61**	**7.8±1.61**

Values with the same superscript within a column are not significantly different at P>0.05

Table 3. Prevalence of Malaria Infection in the Study Area

Location	Site of collection	No. Sample Examined	No Positive (%)	No Negative (%)	Prevalence	χ^2	P-value
Markudi	Wadata	200	67 (33.5)	133 (66.5)	33.5		
Otukpo	Ugboju	200	83 (41.5)	117 (59.5)	41.5		
Agatu	Okokolo	200	149 (74.5)	51 (25.5)	74.5		
Total		600	299 (49.83)	301 (1.12)		18.768	<0.001

Monthly Climatic Conditions parameters across the collection sites

The results in the Table 4 showed the monthly variations of the climatic factors in relation to the malaria transmission encountered across the three selected locations the highest rainfall was witness in the month of September with 135.1mm while the least was in the month of May with 131.1mm respectively also the temperature ranges between 27-33 degrees Celsius and the relative Humidity ranges between 50-95% in the month of May it was 50% and 95% in the month of September as that was a measure factor that leads to the high number of mosquitoes the relative humidity and the temperature were optimum for the distribution and abundance of the mosquitoes in Agatu compare to the other sites of collections the high amount of rainfall within the ranges of 1492mm to 2119mm has also contributed more in the distribution of the mosquitoes because the rain has created a lot of breeding sites for the vectors within the location compare to other sites of collections.

Table 4. Monthly Climatic Conditions parameters across the collection sites

Months	Temperature (^oC)	Relative Humidity (%)	Rainfall (mm)
May	25-33	50-65	130.1
June	24-32	60-72	131.1
July	22-29	70-78	133.1
August	20-28	75-80	134.1
September	18-27	80-95	135.1

DISCUSSION

The results of the present study revealed that the populations of *Anopheles* mosquitoes were more abundance. This observation may be attributed to rainfall pattern and water storage habits of the inhabitants across the study areas. The topography of the areas is undulating with some valleys which allows water to be retained that created a lot of water pools that serve as a potential breeding sites for the vectors as ground pools have been known to form the prolific breeding sites of the *Anopheles* mosquitoes as compared with culicines according to the findings of Olayemi and Ande (2008a) and Adeleke *et al.* (2010).

In all the three eco – settings studied, it was observed that there was presence of numerous water bodies created by rain in addition to breeding in small water storage containers utilized by people for household chores. In all the sampled towns and villages, the supply system was erratic and this explains the use of numerous water storage facilities to provide water for domestic chores, irrigation, car wash and other construction purposes. All these turned out to be conducive breeding sites for mosquitoes within and near human habitation. It was also observed that water storage in cemented and plastic tanks was largely responsible for the abundance of *Anopheles* mosquitoes in all the zones, especially in the rainy season. This finding is also similar report of Sharma (2008) in semi-arid district of Rajasthan, India and Oyewole *et al*. (2010) in Badagry axis of Lagos Lagoon, Lagos, Nigeria. The result of the morphological examination of the mosquitoes revealed the predominance of *Anopheles* mosquitoes over *Culex* mosquitoes. This observation is very important because it pomp out that *Anopheles* species of mosquitoes are breeding in the study areas most of which are encouraged by human activities.

The swampy grassland eco-settings in Agatu LGA had more and abundance of the vectors compare to other selected eco-settings of Makurdi and Otukpo LGAs as this may be attributed and linked with the swampy areas that has created abundant and potential breeding sites than other eco-settings as this explain why the vectors were highly prolific in terms of their feeding and distributions across the eco-setting this finding is in conformity with the findings of Lamidi *et al.* (2017) in Taraba state North east Nigeria. The presence of large water bodies across the eco-settings was also responsible for the distribution and abundance of the mosquitoes which easily invaded the nearby houses to feed and transmit Malaria. Sinka *et al.* (2010) reported that 88% of the World malaria cases occurred among 9.4 million individuals who live in a nearby dams, and irrigation schemes in sub-Saharan Africa which was the case across the selected eco-settings. As many authors also reported that mosquitoes can travel up to 5 kilometers from the breeding from their breeding sites to invade human habitations according to Charlwood *et al*. (2000b). Extensive farming activities within the selected eco-settings have negative implications on the mosquito's distribution, abundance, and vectorial capacity within the selected eco-settings, more so lack of proper and adequate canals and channels of sewage disposal, constructions of road and other temporary/permanent breeding sites have attracted a lot of mosquitoes across the selected eco-settings all these human activities have contributed to the distribution and abundance of the mosquitoes due to the potential breeding sites created alongside Agricultural activities involved. In similar vein the intense Agricultural activities such as irrigation and enormous rice farms were also responsible for the high density and abundance of the Anopheline mosquitoes encountered this is in line with the findings of Scott *et al.* (1993) who stated that malaria transmission is 150 times higher in a Manmade breeding sites than the natural eco-settings and 90% of the malaria infections is caused by *An. gambiae. s.s* and *An funestus* which is in line with the findings in this study.

This study has also observed that fallow lands left after rice harvesting were highly responsible and suitable potential breeding sites for the vectors that causes a large number of mosquitoes to emerge from such sites and invade the human habitations around as *An. gambiae* and *An. funestus* were the dominant species encountered which are the principal vectors of malaria transmission within the selected eco-settings this findings agrees with the findings of Adeleke *et al.* (2010) who reported that farmlands constitute about 40% of the mosquitoes larval habitat.

In this study also in terms of the seasonal variations in the population density of Anopheline mosquitoes collected across the eco-settings *An. gambiae* were the predominant species they were significantly high due to the availability of the potential breeding sites created by rainfall that is being experienced within the selected eco-settings which is a natural phenomenon and occurrence within the guinea savannah region in addition to the heterogeneity in Anopheline mosquitoes species composition at the macro-geographic scale as Olayemi and Ande (2008a) also reported the differences in the relationship between mosquitoes population density and rainfall in different district of Kenya and narrow that to environmental heterogeneity which is in agreement with the findings in this study. More so the preponderances of *Anopheles* mosquitoes caught during the wet seasons compared to the dry seasons across the eco-settings were determined by the amount of annual and rainfall alongside temperatures, relative humidity and high vegetations which is inline with the In a similar report by Lamidi *et al*. (2017), they reported that *Anopheles* mosquitoes were most dominant in their study in three Riverine communities in Taraba state, North Eastern Nigeria. This finding is also in conformity or agreement with the work of and Oduola *et al*. (2016) in Kwara state respectively, who stated that *Anopheles* species were the most abundant mosquito species generally.

Although, the result of this study is not in conformity with the work of Afolabi *et al*. (2019) and in Akure, Ondo state and Nnamdi Azikiwe University, Awka respectively. In their separate studies, they all reported that *Culex* mosquito species were the most abundant the study area, which comprised of three eco – settings and has a guinea savanna type of vegetation with high temperature all year round and rainfall lasting in six (6) months therefore, might have occasioned the result obtained. The population of *Anopheles* mosquito is the highest in the adult mosquitoes collected from all the study sites because some *Anopheles* species do exhibit high sense of genetic heterogeneity that enables it to adapt to many ecological zones, as reported by Coluzzi *et al*. (2000). The adult stage can also withstand harsh environmental conditions when compared with other species.

On the basis of monthly variation of *Anopheles* mosquitoes collected in the study areas, the results revealed that the population density of the *Anopheles* species increased tremendously between the month of May and June and this corresponds to the onset of the rainy season. The monthly variation of *Anopheles* mosquitoes in the three eco – settings showed that *Anopheles* mosquitoes were most abundant in the month of May (12.88%) followed by June (12.37%) while the least was recorded in the month of February (5.40%). The variation in monthly abundance of *Anopheles* mosquitoes could be attributed to a number of factors, one of which is that the eco – settings are located around riverine areas and as such experienced seasonal flooding which usually provides favourable temporary and permanent breeding sites for *Anopheles* mosquitoes (Oyewole *et al.*, 2010). This finding is similar to a recent study conducted in three selected areas of Taraba by Lamidi *et al*. (2017). He reported that *Anopheles* mosquitoes were most abundant in the month of May and least in November. The result of this study is not in conformity with the work of Olayemi *et al*. (2011), who in his study reported that *Anopheles* mosquitoes were most dominant in the month of July.

In this study, the seasonal variation in the population of *Anopheles* mosquitoes across the selected three eco – settings of Benue State across the seasons were also studied. The result of this study showed high relative abundance of *Anopheles* mosquitoes in the rainy season (61.17%) compared to (38.81%) encountered in the dry season. The significantly higher *Anopheles* mosquitoes collected in the rainy was as a result of a lot of breeding sites created by the abundant rainfall experienced. The finding of this study is similar to that of Olayemi *et al*. (2011), and Ebenezer *et al* (2014), who reported a higher abundance of *Anopheles* mosquitoes in the rainy season and lower in the dry season in North Central Nigeria and Bayelsa State, respectively.

Similarly, the high preponderance of *Anopheles* mosquitoes in the wet (rainy) season was because the range and relative abundance of *Anopheles* mosquitoes are determined by the amount of annual rain, annual wet season temperatures coupled with high vegetation (Oyewole *et al.,* 2007).

The relatively higher number of *Anopheles* species in the area may be as a result of the favourable tropical weather and breeding conditions of the *Anopheles* species encountered in the study areas, *Anopheles gambiae s.l* and *An. coustani* were the most dominant species encountered. The high abundance of malaria vector (*Anopheles gambiae*) encountered in this study area means that there is a risk of malaria in the study areas and its environs. The unequal distribution of the *Anopheles* species within the area further suggests that the occurrence of the species truly varies according to the micro and macro environmental differences exhibited by different eco – settings as found in studies conducted by Oyewole *et al.* (2010).

The environmental conditions of the area were favourable to support the continual breeding and survival of the mosquito vectors. The predominance of *An*. *gambiae* could be attributed to the adaptability of these species making it possible for them to survive in an adverse environment as previously reported by Adebayo *et al*. (2016). The result of this study conforms to the work of Okwa *et al*. (2006), Oguoma and Ikpeze, (2008) who in Lagos and Kano respectively, reported that *An. gambiae* was the most predominant species. However, this result contrasts with the findings of Sinka (2010). The other species collected occurred in very low densities.

CONCLUSION

The findings from this research work show and revealed that more of the anopheline mosquitoes were encountered at Agatu LGA that could be as a result of the riverine habitats

and the nature of the swampy nature of the LGA follow by Otupko and Makurdi was the least in the abundance and the distribution of the vectors also due to the high amount of rainfall experience in the within Agatu and Otukpo LGA's that has created a lot of breeding sites for the vectors and that has correlated with the prevalence of the Malaria infection within the area due to the abundance and distribution of the vectors.

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