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Spatiotemporal Distribution and Composition of *Anopheles* Mosquito Species in Some Selected Eco-Settings of Nasarawa State North Central Nigeria

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Abstract

Mosquitoes are known to be notorious for their ability to constitute a nuisance as well as transmit disease-causing organisms (pathogens) to hosts. This study was aimed to determine the species distribution, abundance, and diversity of mosquitoes in three selected eco – settings of Nasarawa State, Nigeria. *Anopheles* mosquitoes were sampled using Pyrethroid Spray Catch (PSC) technique and were identified morphologically using keys. A total of Fifteen thousand, four hundred and seventeen (15,417) mosquitoes vector genera were encountered in the study areas between the period of January to December, 2017 and 2018. Of the 15417 (100%) mosquitoes encountered or sampled, 9881 (64.09%) were anopheline while 5536 (35.91%) were culicine. Statistical analysis showed that there is a highly significant difference ($p<0.05$) in the relative abundance of mosquito genera vector across the eco – settings studied. Out of the 9881 (64.09%) anopheline mosquitoes caught during the study period, the highest being 1273 (12.88%) were caught in the month of May followed by June 1222 (12.37%) while the least number of anopheline mosquitoes were recorded in the month of February 534 (5.40%). Six (6) species of *Anopheles* mosquito vectors were encountered in all the selected eco – settings of Nasarawa State. The various species encountered are as follows; *Anopheles gambiae s. l, An. funestus, An. nili, An. coustani, An. rufipes* and *An. pharoensis. An. gambiaes. l* were the most dominant species (41.89%) encountered across the eco – settings during the two seasons followed by *An. coustani* (19.49%) while *An. pharoensis* had the least number of species (5.83%) across the eco – settings. Statistically, there is a significant difference ($p<0.05$) in the spatial composition of *Anopheles* mosquito species encountered across the selected eco – settings of Nasarawa State. This study revealed that *Anopheles* species were higher in terms of abundancewhich is very important vectors of malaria in Nigeria. These results indicated that vectors of mosquito-bornediseases are breeding in the study area, most of which are encouraged by human activities.

Keywords

Mosquitoes, Abundance, *Anopheles*, Culicine, Nasarawa

1. Introduction

Mosquitoes of the family Culicidae are considered a nuisance and a major public health problem, because their females feeds on human blood and thus transmit extremely harmful diseases, such as malaria, yellow fever and filariasis. They are estimated to transmit diseases to more than 700 million people annually and responsible for the death of about 1 in 17 people [1]. Effective transmission of mosquito-borne disease requires successful contact between female mosquitoes and their hosts [2]. Among Anophelinae, the members of the genus Anopheles are best known for their role in transmitting malaria and filariasis worldwide [3, 4]. Of these diseases, malaria caused by Plasmodium parasite is one of the greatest killer diseases in the world [4]. WHO [4] reported an estimated 207 million cases of malaria in 2012 out of which 200 million cases (80.0%) were in Africa continent. The distribution pattern, transmission and intensity of the disease are dependent on the degree of urbanization and the distance from vector breeding sites [5]. The endemicity of malaria in any region is determined by indigenous *Anopheles* mosquitoes, abundance, feeding, resting behavior and their Plasmodium infectivity, among other factors [6, 7].

Federal Ministry of Health, Abuja reported that at least 50.0% of Nigerians suffered from one form of malaria or the other making it the most significant health problem in Nigeria [8]. The high transmission rate and prevalence of malaria is a result of the diverse mosquitoes breeding sites, which include practically receptacle that holds water, such as tins, cans, old tyres, tree holes, cisterns, open pools, drainage, stream and pond [9]. Part of the efforts being made is the official commemoration of April 25 every year, starting from 2008 as World Malaria Day [10] People living in poor rural areas are confronted with a multitude of barriers when assessing malaria prevention especially on the knowledge of the biology and ecology of the vectors, among others [9].

The mapping of malaria vectors is important in the control of malaria. This is because the species composition and distribution and other biological parameters of the mosquitoes are poorly known in different ecological zones of Nigeria and in most of the malaria endemic areas due to the difficulties in the morphological identification of certain complex species, the knowledge of which is required in the design of vector control programmes and in tackling the prevalence of the disease in endemic areas [11].

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 [12]. 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 [13]. Entomological studies focused on the diversity, density, behavioral patterns and temporal variations of *Anopheles* species have long been found to be beneficial in the identification and monitoring of malarial vectors [14]. A combination of factors that determine the capacity of a vector to transmit malaria include; abundance, anthropophily, zoophily, susceptibility to infection by the malaria parasite, infection rates and female longevity [15, 16].

Vector-borne diseases remain a major public health issue in the tropical and subtropical regions of the world [17]. Anopheline vector of malaria consists of various species with unique behaviour associated with their biting activities and transmission dynamics, Human malarial protozoa are transmitted by mosquitoes of the genus *Anopheles*. Mosquitoes of the family Culicidae are considered a nuisance and a major public health problem, because their females feeds on human blood and thus transmit extremely harmful diseases, such as malaria, yellow fever and filariasis [17]. Malaria leads to a lot of social and economic problems, such as school absenteeism, lower agricultural production among others; consequently, more control efforts are required in order to reduce the rates of disease incidences and mortality.

Globally, approximately 214 million cases of malaria occur annually and about 3.2 billion people are at risk of infection with larger proportion of the victims within the Sub – Saharan African continent of the World [18]. Approximately 438,000 deaths were attributed to malaria in 2015, particularly in sub-Saharan Africa, where an estimated 90% of all malaria deaths occur [18].

There are 465 formally recognized species and more than 50 unnamed members of species complexes. Approximately 70 of these species have the capacity to transmit human malaria parasites [19] and 41 species are considered to be dominant vector species complexes capable of transmitting malaria at a level of major concern to public health

The knowledge of major malaria vectors and their bionomics in Africa remains a problem. Hay *et al.* [20] as a focal disease, malaria will therefore differ in its characteristics from place to place, since all malaria vectors do not exhibit identical behavior and ability to transmit parasites. Globally medical reports have shown that mosquito-borne diseases-are responsible for significant effect on human morbidity and mortality throughout the world [4]. The global burden is 207 million malaria cases every year resulting into 627,000 deaths [4], sub-Saharan Africa being the most affected region. According to the latest WHO malaria report [17], there were in 2014 about 197 million malaria cases worldwide and an estimated 584 000 deaths, mostly among African children.

In Nigeria, malaria still remains a major health problem with about two-thirds of the population living in malarious areas [18]. Among the malaria vectors in Nigeria *Anopheles gambiae* complex, *An. funestus* and *An. arabiensis* seems to be the major vectors of malaria transmission in the country though there are other non and minor vectors who are now incriminated to be responsible for the malaria transmission [11].

2. Materials and Methods

1 Study Area

This study was carried out at Nasarawa state in three different LGA's Karu, Nasarawa Eggon and Doma. Nasarawa 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 conditions with a mean annual temperature and relative humidity ranging from 27^0-33^0 and 65%- 80 (%) respectively.

2 Description of the study areas

The study was conducted in Nasarawa State. It is bounded in the North by Kaduna and Plateau, in the South by Benue, and the West to the Federal Capital Territory (FCT) to the East by Kogi State. The locations were spreads across the three Local Government Areas namely Karu, Nasarawa Eggon and Doma LGA's. The mean annual rainfall of Nasarawa is 1335mm with August and September recording the highest monthly rainfall of about 300mm. the highest monthly temperature is recorded in March with an average daily temperature of 29°-30°C and the lowest in August at about 22°C. Nasarawa has a tropical wet and dry climate with a pronounced dry season. Six (06) different locations were randomly selected, two from each site of the local Government. The map of the study area is found in Figure 1. Also, the GPS coordinates of the study sites were also taken and recorded as seen in Table 1.

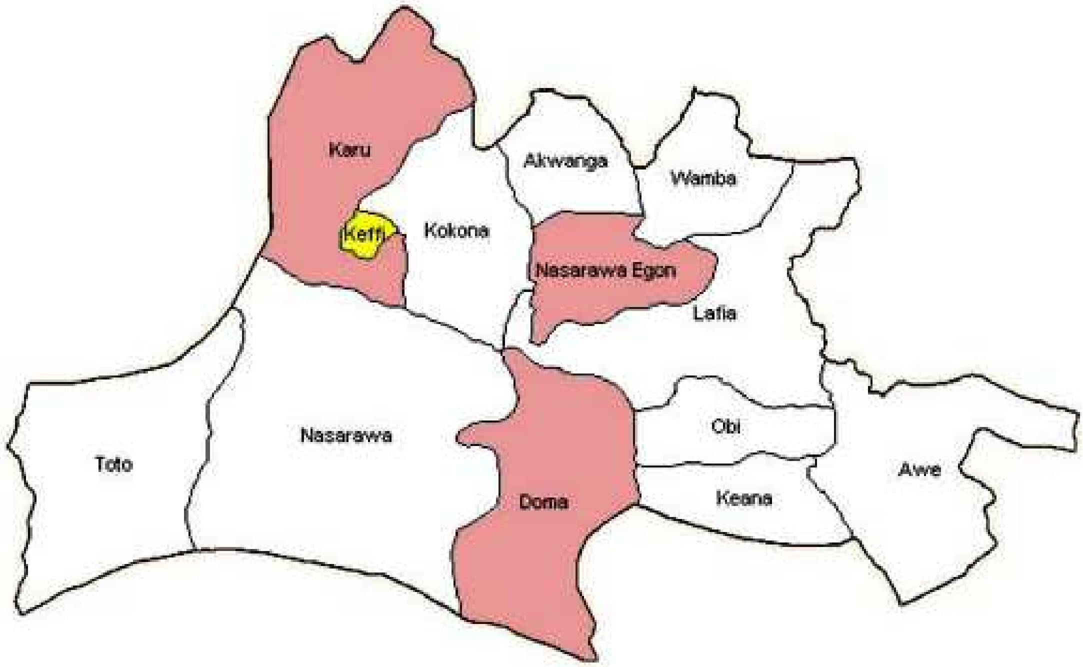

Figure 1. *Map of Nasarawa State Showing the study sites.*

Table 1. *GPS Coordinates of the Study Sites.*

S/No	Study Sites	Latitude	Longitude
1	Gitata	9°36'50"N	6°32'35"E
2	Panda	9°38'42"N	6°32'31"E
3	Alogani	9°36'52"N	6°32'50"E
4	Aripka	9°36'50"N	6°32'01"E
5	Doma Town	9°36'48"N	6°32'49"E
6	Alagye	9°38'24"N	6°32'29"E

2.1. Study design

Entomological surveillance was conducted in the Local Government Areas of Doma, Nasarawa Eggon and Karu Local Government Areas across the three senatorial zones of the state that represents the eco-settings within the state. The LGAs are located in the Guinea Savannah ecological zone; the landscape of the LGAs 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 [21].

Nasarawa 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 conditions with a mean annual temperature and relative humidity ranging from 27^0-33^0 and 65%- 80% respectively.

2.2. Sample Collection

2.2.1. CDC light trap collection

Centre for Disease Control light trap methods (baited traps, was placed indoors and outdoors) in two different houses monthly for three (3) nights per site to measure mosquito biting time. The light trap bag was replaced every hour 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. One collector worked from 18:00 to 24:00 and was replaced by a second collector both indoor and outdoor from 24:00 to 06:00 following the methods of [22]. 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 as the Indoor resting *Anopheles* were collected using Pyrethrum spray insecticide. Prior to spraying of the rooms, all materials were removed from the rooms to be sampled. All openings like windows, doors, eaves among others were closed. A white sheet was spread to completely cover the whole floor. The pyrethrum insecticide (Raid) was sprayed in a clockwise direction towards the ceiling until the whole room was filled with a fine mist of the insecticide. The door was closed and left for 15 minutes. Thereafter the door was opened and starting from the doorway, the sheets were folded and carried outside. All the mosquitoes on the sheet were transferred into petri dishes containing damp cotton wool and filter paper to maintain the physiological status of the mosquitoes.

2.2.2. Pyrethrum Spray Collection

A total of 8 houses per LGA per month were sampled using the Pyrethrum Spray Collection (PSC) method as described by the WHO **[23]** 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 began spraying at the same time as they moved 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 [24-27].

2.3. Morphological Identification of Mosquito Samples

All mosquitoes collected were identified and sorted out under a stereomicroscope (Leica model NSW series IMNS 210) and Olympus Tokyo VT-II 225329 Entomological microscope. All mosquitoes were identified as far as possible using morphological keys of **[24, 26]** whether they were Anophelines or Culicines. After identification, the mosquitoes were preserved in dry labeled Eppendorf tube 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).

2.4. Data Analysis

Data generated were analyzed using the SPSS software version 20.0 and Excel package. Chi – square (χ2) test was used to compare the mosquitoe species at various collection sites, seasons, indicative of a statistically significant difference. The relationship between *Anopheles* species and months/season was carried using ANOVA, Chi – square and correlation (r) analysis.

3. Results

3.1. Spatial Species Composition and Distribution Across the Different Eco – Settings of Nasarawa State

Spatial species composition and distribution of *Anopheles* mosquitoes across the different eco – settings of Nasarawa State is presented in Table 1. Six (6) different species of *Anopheles* mosquitoes were encountered in all the three eco – settings during the study period. There was no variation in the composition and distribution of *Anopheles* mosquito species encountered in the three eco – settings of Nasarawa State.

3.2. Relative Abundance of Mosquito Genera Across the eco –Settings of Nasarawa State

The relative abundance of mosquito vector genera across the eco – settings is presented in Table 2. A total of Fifteen thousand, four hundred and seventeen (15,417) mosquitoes vector genera were encountered in the study areas between the period of January to December, 2017 and 2018. Of the 15417 (100%) mosquitoes encountered or sampled, 9881 (64.09%) were anopheline while 5536 (35.91%) were culicine. The highest number of mosquitoes was caught in the Swampy grassland (Doma LGA) eco – setting 5644 (36.61%) while sparse woodland (Nasarawa Eggon LGA) had the least number of mosquitoes caught 4245 (27.53%). Out of the 9881 (64.09%) *Anopheles* mosquitoes caught, the highest being 3006 (50.39%) was recorded in Sparse woodland (Nasarawa Eggon LGA) eco – setting followed by wooded/grassland (Karu LGA) eco – setting 3463 (44.17%) while the least 3412 (42.64%) was recorded in the Swampy grassland (Doma LGA) eco – setting. Statistical analysis showed that there is a highly significant difference ($p<0.05$) in the relative abundance of mosquito genera vector across the eco – settings studied.

3.3. Monthly Variation of *Anopheles* Mosquito in the Selected Eco –Settings of Nasarawa State

The monthly variation of *Anopheles* mosquito vector in the selected eco – settings of Nasarawa State is presented in Table 3. Out of the 9881 (64.09%) anopheline mosquitoes caught during the study period, the highest being 1273 (12.88%) were caught in the month of May followed by June 1222 (12.37%) while the least number of anopheline mosquitoes were recorded in the month of February 534 (5.40%). In relation to the eco – settings, the highest number of anopheline mosquitoes were recorded in Swampy grassland (Doma LGA) eco – setting 3835 (38.81%) followed by wooded/grassland (Karu LGA) eco – setting 3175 (32.13%) while the least anopheline mosquitoes were recorded in Sparse woodland (Nasarawa Eggon LGA) eco – setting 2871 (29.06%). In sparse woodland eco – setting, anopheline mosquitoes were higher in the month of January and February (32.39% and 32.21%) respectively while the least was recorded in the month of May and June (27.42% and 27.33%) respectively. In the same vein, in wooded/grassland eco – setting, anopheline mosquitoes were peaked (34.27%) in the month of February and least (30.05%) in the month of July. There was a great variation in the numbers of anopheline mosquitoes encountered in swampy grassland eco – setting. Anopheline mosquitoes were higher in the months of April, June and May (41.56%, 41.52% and 41.33%) respectively while the least (33.52%) number of anopheline mosquitoes were recorded in the month of February. Chi – square analysis showed that there is a significant difference (p<0.05) in the monthly variation of anopheline mosquitoes in the selected eco – setting of Nasarawa State.

Table 2. *Spatial species composition and distribution across different eco – settings of Nasarawa State.*

Eco – settings	***An. gambiae***	***An. funestus***	***An. nili***	***An. coustani***	***An. rufipes***	***An. pharoensis***
Wooded/Grassland (Karu LGA)	√	√	√	√	√	√
Sparse woodland (Nas. Eggon LGA)	√	√	√	√	√	√
Swampy Grassland (Doma LGA)	√	√	√	√	√	√

Table 3. *Relative abundance of mosquito genera across the Eco – settings.*

LGAs	**Eco – settings**	**Anopheline (%)**	**Culicine (%)**	**Total (%)**
Nasarawa Eggon	Sparse woodland	3006 (50.39)	1239 (41.86)	4245 (27.36)
Karu	Wooded/Grassland	3463 (44.17)	2065 (47.17)	5528 (35.86)
Doma	Swampy Grassland	3412 (42.64)	2232 (48.63)	5644 (36.61)
	Total	9881 (64.09)	5536 (46.41)	15417 (100)

χ^2 Cal =426.78; χ^2 tab = 11.07; df = 5

Table 4. *Monthly variation of the mosquito genera in the selected eco-settings of Nasarawa state.*

Months	**Anopheline**			**Total (%)**
Months/Eco – settings	**Sparse Woodland (%)**	**Wooded/Grassland (%)**	**Swampy Grassland (%)**	
January	184 (32.39)	189 (33.27)	195 (34.33)	568 (5.75)
February	172 (32.21)	183 (34.27)	179 (33.52)	534 (5.40)
March	171 (29.69)	185 (32.12)	220 (38.19)	576 (5.83)
April	266 (28.15)	295 (31.22)	384 (40.63)	945 (9.56)
May	349 (27.42)	395 (31.03)	529 (41.56)	1273 (12.88)
June	334 (27.33)	383 (31.34)	505 (41.33)	1222 (12.37)
July	280 (28.43)	296 (30.05)	409 (41.52)	985 (9.97)
August	206 (29.43)	232 (33.14)	262 (37.43)	700 (7.08)
September	209 (29.56)	236 (33.38)	262 (37.06)	707 (7.16)
October	239 (28.52)	270 (32.22)	329 (39.26)	838 (8.48)
November	236 (30.10)	260 (33.16)	288 (36.73)	784 (7.93)
December	225 (30.04)	251 (33.51)	273 (36.45)	749 (7.78)
Total	2871 (29.06)	3175 (32.13)	3835 (38.81)	9881 (100)

3.4. Spatial Composition of *Anopheles* Mosquito Species Encountered Across the Selected eco – Settings.

Table 4 showed the spatial composition of *Anopheles* mosquito species encountered across the three selected eco – settings of Nasarawa State. Six (6) species of *Anopheles* mosquito vectors were encountered in all the selected eco – settings of Nasarawa State. The various species encountered are as follows; *Anopheles gambiae s. l, An. funestus, An. nili, An. coustani, An. rufipes* and *An. pharoensis. An. gambiae s. l* were the most dominant species (41.89%) encountered across the eco – settings during the two seasons followed by *An. coustani* (19.49%) while *An. pharoensis* had the least number of species (5.83%) across the eco – settings.

In respect to the eco – settings, *An. gambiae s. l* was higher (46.75%) and *An. rufipes* had the least (3.39%) number of *Anopheles* mosquito species in the woodland/grassland (Karu LGA) eco – setting; in the same way, *An. gambiae s. l* was higher (39.22%) and *An. rufipes* had the least (4.70%) number of *Anopheles* mosquito species in the sparse woodland (Nasarawa Eggon LGA) eco – setting while *An. gambiae s. l* was equally higher (39.37%) and *An. pharoensis* had the least (4.77%) number of *Anopheles* mosquito species encountered in the grassland (Doma LGA) eco – setting. Statistically, there is a significant difference (p<0.05) in the spatial composition of *Anopheles* mosquito species encountered across the selected eco – settings of Nasarawa

State.

Table 5. *Spatial composition of Anopheles mosquito species encountered across the selected eco-settings of Nasarawa State.*

Eco – settings	*An. gambiae*	*An. funestus*	*An. nili*	*An. coustani*	*An. rufipes*	*An. Pharoensis*
Wooded/Grassland (Karu LGA)	517.5±68.50^{a}	180.0±18.0^{b}	120±14.0^{a}	181.5±13.5^{b}	37.5±2.5^{b}	69.5±12.5^{a}
Sparse woodland (Nas. Eggon LGA)	363±15.0^{c}	210.5±13.5^{a}	98.0±5.0^{b}	148.5±13.5^{c}	43.5±2.5^{b}	62.0±10^{ab}
Swampy Grassland (Doma LGA)	458.50±11.5^{b}	91.0±9.0^{c}	69.50±5.5^{c}	293±28.5^{a}	124.5±9.5^{a}	55.5±35.67^{b}
Average	223.17±15.83	80.25±6.75	47.92±4.08	103.83±9.25	34.25±2.42	31.1±9.70

χ^2 Cal =1188.79; χ^2 tab = 37.65; df = 25

4. Discussion

Malaria is a common occurrence throughout the year and this has contributed to the all year round presence of the adult female anopheles mosquitoes in the three selected eco-settings of Nasarawa state. In this present study, six (6) different species of *Anopheles* mosquitoes were encountered in all the three selected eco-settings. 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 [28] in semi-arid district of Rajasthan, India and Oyewole *et al*. [29] in Badagry axis of Lagos Lagoon, Lagos, Nigeria.

Identification of mosquitoes using morphological characters was very effective up to species level, but did not allow for the identification of mosquitoes to sibling species. In this study, two species of adult mosquitoes were identified on the basis of their morphological characteristics as described by Gillet [25], Foss and Dearborn [30]; the species encountered were *Anopheles* and *Culex*.

According to WHO [12], in Nigeria as a whole, there are four major genera of mosquitoes namely; *Anopheles, Culex, Aedes and Mansonia*, with the most common species of the genus *Anopheles* in Nigeria being *Anopheles gambiae* and *Anopheles funestus*. The result of the morphological examination of the product mosquito 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. This finding is in conformity with work of Madera *et al*. **[31]**, in the University of Abuja main campus, Abuja FCT, Nigeria, who reported that *Anopheles* mosquitoes are the most abundant as compared to *Culex* and *Aedes* mosquitoes.

In a similar report by Lamidi *et al*. **[32]**, 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 Bunza *et al*. [33], in Katsina State and Oduola *et al*. [34] 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*. [35] and Akunne *et al*. [36] in Akure, Ondo state and Nnamdi Azikiwe University, Akwa 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 allyear 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*. [37]. 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 [38]. This finding is similar to a recent study conducted in three selected areas of Taraba by Lamidi *et al*. [32]. 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 Ebube *et al*. [39], 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 Nasarawa 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*. [40], and Ebenezer, *et al* [41], who reported a higher abundance of *Anopheles* mosquitoes in the rainy season and low in 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 couple with high vegetation [42].

Six (6) species of Anopheline mosquitoes were encountered throughout the study period and in all the eco – settings. Depinay *et al*. [43] put the usual number at less than five within a given area, and this has been confirmed in different localities in Africa [44-46]. The relative higher number of Anopheles species in the area may be as a result of the favourable tropical weather and breeding conditions of the six Anopheles species encountered in the study areas, *Anopheles gambiae s. l* and *An. coustani* were 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 Keateng *et al*. [47].

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 adverse environment as previously reported by Dondorp *et al*. [48]. The result of this finding is in conformity to the work of Okwa *et al*. [49], Oguoma and Ikpeze, [50] who in Lagos and Kano respectively, reported that *An. gambiae* was the most predominant species. However, this results contrasts with the findings of [51]. The other species collected occurred in very low densities.

Monthly spatial composition of *Anopheles* species encountered in the study areas was also noted. The highest *Anopheles* species population was recorded in the month of May (618±30.0) and least was recorded in the month of January (140±10.0). The composition and distribution of *Anopheles* species varies significantly ($p<0.05$). *Anopheles gambiae s. l* was the most dominant (111.58±13.59) species encountered throughout the months of the study. *An. gambiae s. l* abundance in this study is also in conformity with other studies in different geo – political zones within Nigeria [50, 52 -56].

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