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Relative abundance of *Anopheles* mosquitoes in selected eco – settings of Nasarawa state, North Central Nigeria

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ABSTRACT

The knowledge on human-vector contact is of great importance in order to tackle the point of transmission of mosquito-borne diseases through relevant control measures and interventions. This study was aimed to determine the relative abundance of mosquitoes in three selected eco – settings (Wooded Grassland, Sparse Woodland and Swampy Grassland) of Nasarawa State, Nigeria. *Anopheles* mosquitoes were sampled using Pyrethroid Spray Catch (PSC and Centre for Disease control light traps CDC) technique the mosquitoes were identified morphologically using taxonomic keys. Six (6) species of *Anopheles* mosquito vectors were encountered in all the selected eco – settings of Nasarawa State: *Anopheles gambiae* s.l, *An. funestus, An. nili, An. coustani, An. rufipes*and *An. pharoensis.* A total of Fifteen thousand, four hundred and seventeen (15,417) mosquitoes vector were encountered in the study areas between the months of January to December, 2017 and 2018. Most of the mosquitoes encountered were Anopheline (64.09%). Analysis revealed significant variations in the relative abundance of mosquito and distribution of the vector across the eco – settings studied.The highest number of mosquitoes was caught in the month of May 2017(1,273 mosquitoes; 12.88%). *Anopheles gambiae* s.l. was the most dominant species (41.89%) encountered across the eco – settings during the two seasons followed by *Anopheles coustani* (19.49%). Indoors *Anopheles gambiae* s.l. collection accounted for 68.21%. These results indicated that vectors of mosquito-borne diseases are breeding in the study area, most of which are encouraged by human activities.

Keywords: Diversity, Relative abundance, Eco – settings, Pyrethroid, *Anopheles gambiae*

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INTRODUCTION

Mosquitoes are regarded as a nuisance and a serious public health concern because their females feed on human blood and so spread diseases including malaria, yellow fever, and filariasis [1]. Malaria infects around 700 million people each year and are responsible for the deaths of about 1 in every 17 people [1].

Successful interaction between female mosquitoes and their hosts is required for effective transmission of mosquito-borne illness [2]. The genus *Anopheles* is well known among the Anophelinae for its role in transmitting malaria and filariasis over the world [1,3]. Malaria, caused by the Plasmodium parasite, is one of the most deadly diseases on the planet [1]. In 2018, WHO predicted 207 million cases of malaria, with 200 million cases (80.0 percent) occurring on the African continent. The degree of urbanization and the distance from vector breeding areas influence the disease's distribution pattern, transmission, and intensity [4]. The quantity, feeding, resting behaviour, and *Plasmodium* infectivity of indigenous *Anopheles* mosquitoes, among other characteristics, define the endemicity of malaria in any given place [5,6].

According to the Federal Ministry of Health in Abuja, at least 50.0 percent of Nigerians suffer from one form or another of malaria, making it the country's most serious health concern [7]. The numerous mosquito breeding grounds, which include nearly any receptacle that collects water, such as tins, cans, old tyres, tree holes, cisterns, open pools, drainage, stream, and ponds, contribute to the high transmission rate and prevalence of malaria [8]. When it comes to malaria prevention, people living in poor rural areas face a slew of challenges, including a lack of awareness of the biology and ecology of the vectors, among other things [8,9].

Malaria vector mapping is critical for malaria prevention and control. This is because other biological parameters of mosquitoes are poorly known in different ecological zones of Nigeria, as well as in most malaria-endemic areas, due to difficulties in morphological identification of certain complex species, which are required in the design of vector control programs and in tackling the prevalence of malaria [10].

Malaria is still the leading cause of death in children in Sub-Saharan Africa, according to the World Health Organization. Every two minutes, a youngster in this region dies as a result of the disease [11]. The research is aimed at investigating the relative abundance of *Anopheles* mosquitoes in three different eco-systems in Nasarawa State, Nigeria.

MATERIALS AND METHODS

Study Area

This study was carried out at Nasarawa State in three different Local Government Areas of 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. 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 27-33^{0}C and 65 - 80 % respectively [12].

Figure 1: Map of Nasarawa State showing the study sites. Nasarawa Geographic Information System (NAGIS).

Study Design

Entomological surveillance was conducted in the Doma Nasarawa Eggon and Karu LGAs 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 commence from the month of November to April with annual rainfall varying from 1,200-1,500mm. The prime period for malaria transmission is six months from the month of May to October [13, 14].

Sample Collection

Centre for Disease Control light trap collection

Centre for Disease Control light traps (baited traps) were 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 18:00hours to 06:00hours per house per night in order to have proxy estimate on the peak biting time. One collector worked from 18:00hours to 24:00hours and was replaced by a second collector both indoor and outdoor from 24:00hours to 06:00hours following the methods of Yohannes and Boelee [15]. 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 8 houses per LGA per month were sampled using the Pyrethrum Spray Collection (PSC) method as described by the WHO [16] 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. Prior to spraying of the rooms from 5:30am to 8:30am 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 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 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; the knocked down mosquitoes were collected using feather weight forceps and then placed in petri dishes or paper cups containing damp cotton wool and filter paper to maintain the physiological status of the mosquitoes. The Anopheline mosquitoes were preserved on damp absorbent paper in a cool box and later identified to the species level by morphological criteria [17, 18, 19, 20].

Morphological and Molecular 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 using morphological keys of Gillies and De Meillion [17], Gillies and Coetzee [20]. After identification, the mosquitoes were preserved in dry labeled eppendorf tube over dry silica gel used for PCR identification. The mosquito identification was carried out at Abt Associates Entomological Laboratory and Insectary, Nasarawa State University, Keffi.

Data Analysis

Data generated from field and laboratory analysis were analyzed using the SPSS software version 22.0 and Excel package. Chi – square ($\chi 2$) test was used to compare the mosquito species at various collection sites and seasons. The relationship between *Anopheles* species and months/season was carried using Analysis of Variance (ANOVA) and Chi – square analyses. All significant difference was defined at 95 % confidence interval.

RESULTS

Spatial species composition and distribution across different eco – settings of Nasarawa State, Nigeria

Spatial species composition and distribution of *Anopheles* mosquitoes across the different eco – settings of Nasarawa State is presented in Table 1a. Six (6) different species of *Anopheles* mosquitoes were encountered in all the three eco – settings during the study period. These are: *Anopheles gambiae, An. funestus, An. nili, An. coustani, An. rufipes*and *An. pharoensis.*

The relative abundance of mosquito vector genera across the eco – settings is presented in Table 1a. 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. Among the collected mosquitoes (15,417 mosquitoes), 9,881 (64.09 %) were anopheline while 5,536 mosquitoes (35.91 %) were culicine. The highest number (5,644 mosquitoes; 36.61 %) of mosquitoes was collected in the Swampy grassland eco – setting (Doma Local Government Area, LGA) while Sparse woodland (Nasarawa Eggon LGA) had the least number (4,245 mosquitoes; 27.53 %) of mosquitoes. Among the collected *Anopheles* mosquitoes (9,881 mosquitoes), over 50 % (50.39 %; 3,006 mosquitoes) were recorded in Sparse woodland (Nasarawa Eggon LGA). This was followed by wooded grassland (Karu LGA) with 44.17 % (3463 mosquitoes) while the Swampy grassland (Doma LGA) had the least (42.64 %; 3,412 mosquitoes). Analysis revealed significant difference ($p<0.05$) in the relative abundance of mosquito genera across the eco – settings.

Seasonal variation in relative abundance of *Anopheles* mosquitoes encountered in the study locations

Analyses revealed seasonal variations in relative abundance of *Anopheles* mosquitoes encountered in the study areas within the eco – settings (Table 1b). A total of 5,665 *Anopheles* mosquitoes (57.24 %) were encountered during the wet season as compared to 4,225 mosquitoes (42.76 %) encountered during the dry season. More *Anopheles* mosquitoes were encountered indoors (62.50 %) during the wet season than outdoors (37.50 %). In dry season, more *Anopheles* mosquitoes were collected indoors (2,571 mosquitoes; 60.85 %) than outdoors (1,654 mosquitoes, 39.15 %). Analysis revealed that there was a significant difference ($p<0.05$) in the population of *Anopheles* mosquitoes encountered in wet and dry seasons within the study areas.

Monthly variation in abundance of *Anopheles* mosquito in the selected eco – settings of Nasarawa State

The monthly variation in relative abundance of *Anopheles* mosquito vector in the selected eco – settings of Nasarawa State is presented in Table 2. Among the Anopheline mosquitoes caught during the study period, the highest number of mosquitoes (1,273 mosquitoes; 12.88 %) were caught in the month of May 2017 followed by June 2017 (1,222; 12.37 %). The least was recorded in the month of February 2017 (534 mosquitoes; 5.40 %). In relation to the eco – settings, the highest number of Anopheline mosquitoes were recorded in Swampy grassland (3,835; 38.81 %) followed by wooded/grassland (3,175; 32.13 %), while the least anopheline mosquitoes were recorded in Sparse woodland (2,871; 29.06 %).

In sparse woodland eco – setting, anopheline mosquitoes were higher in the month of January and February 2017 (32.39 and 32.21 %, respectively) while the least was recorded in the month of May and June 2017 (27.42 and 27.33 %, respectively). Similarly, in wooded/grassland eco – setting, anopheline mosquitoes were peaked (34.27 %) in the month of February 2017 and least (30.05%) in the month of July 2017. The results of monthly dynamics of Anopheline mosquitoes varied significantly ($p< 0.05$) within the swampy grassland eco – setting. Anopheline mosquitoes were higher in the months of April, June and May 2017 (41.56, 41.52 and 41.33 %, respectively) while the least number of anopheline mosquitoes (33.52 %) was recorded in the month of February 2017. Analysis showed significant difference ($p<0.05$) in monthly variation of Anopheline mosquitoes among the selected eco – setting of Nasarawa State.

Table 1a Relative Abundance of Mosquito Genera cross the Eco - Setting

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

$\chi 2$ Cal =120.81; $\chi 2$ tab = 5.99; df = 2

Table 1b: Seasonal Variation of *Anopheles* Mosquitoes encountered in the Study Area

Seasons	Wet Seasons		Dry Seasons		Total	
Locations	Indoor (%)	Outdoor (%)	Indoor (%)	Outdoor (%)	Indoor (%)	Outdoor (%)
Wooded/Grassland (Karu LGA)	1292(36.65)	648(30.55)	925(35.98)	511(30.89)	2217(36.31)	1159(30.70)
Sparse woodland (Nas. Eggon LGA)	3114(32.31)	603(28.43)	782(30.42)	487(29.44)	1924(31.51)	1090(28.87)
Swampy Grassland (Doma LGA)	1101(31.15)	870(41.01)	864(33.61)	656(39.66)	1965(32.18)	1526(40.42)
Total	3535(62.50)	2121(37.50)	2571(60.85)	1654(39.15)	6106(61.70)	3775(38.20)
Grand Total	5565 (57.24)		42215 (42.76)		9881(100)	

$\chi 2$ Cal =71.63; $\chi 2$ tab = 5.99; df = 2.

Table 2: Monthly Variation of the Mosquito Genera in the Selected Eco-Settings of Nasarawa state

Months (2017)	Eco – settings			Total (%)
	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)

$\chi 2$ Cal =29.02; $\chi 2$ tab = 33.92; df = 22

Spatial composition of *Anopheles* mosquito species encountered across the selected eco – settings of Nasarawa State

Table 3 showed the spatial composition of *Anopheles* species encountered across the three selected eco – settings of Nasarawa State. Six (6) species of *Anopheles* vectors were encountered in all the selected eco – settings of Nasarawa State. The various species encountered are; *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 followed by *An. coustani* (19.49 %) while *An. pharoensis* had the least number of species (5.83 %) across the eco – settings. There was a statistical difference ($p<0.05$) in the abundance of *Anopheles* species.

Higher numbers of *Anopheles gambiae* s.l. (46.75 %) while *An. rufipes* had the least (3.39 %) number of *Anopheles* mosquito species recorded 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.

Monthly spatial composition of *Anopheles* species encountered in the study locations

The monthly spatial composition of *Anopheles* species encountered in the three eco – settings is presented in Figure 1. Six (6) species of *Anopheles* mosquito were encountered during the study period. The highest *Anopheles* mosquito population was recorded in the month of May (618±30.0 mosquitoes) followed by the month of June (465±26.0 mosquitoes) while the least *Anopheles* mosquito population was recorded in the month in the month of January (140±10.0 mosquitoes). The composition and distribution of *Anopheles* mosquito species varies significantly ($p<0.05$) on monthly basis.

Anopheles gambiae s.l was the most dominant (111.58±13.59 mosquitoes) species encountered throughout the months of the study period followed by *An. coustani* (51.96±4.61 mosquitoes) while *An. pharoensis* was the least encountered species (15.5±1.61 mosquitoes). Interestingly, all the six (6) species of *Anopheles* mosquito encountered during the study period peaked in the month of May.

Species composition of *Anopheles* mosquitoes from indoor and outdoor collections

Of the 9881 (64.09 %) *Anopheles* mosquitoes caught across the selected eco – settings of Nasarawa State, 6392 (64.69 %) *Anopheles* mosquitoes were caught using CDC method; 6106 (61.80 %) indoors and 3775 (38.20 %) were caught outdoors. Indoors *Anopheles* mosquitoes were higher (65.66 %) in wooded/grassland (Karu LGA) eco – setting followed by sparse woodland (Nasarawa Eggon LGA) eco – setting (63.86 %). While the least (56.27 %) indoors *Anopheles* mosquitoes were recorded in the swampy grassland (Doma LGA) eco – setting. In the same vein, outdoor *Anopheles* mosquitoes were peaked in swampy grassland eco – setting (42.73 %) followed by sparse woodland (36.14 %) while woodland/grassland had the least number of outdoor *Anopheles* mosquitoes (34.32 %). The species composition of *Anopheles* mosquitoes from indoor and outdoor collections across the selected eco – settings of Nasarawa State varied significantly ($p<0.05$) (Table 4).

Table 3: 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

Values with the same superscript within a column are not significantly different at P>0.05. LGA = Local Government Areas

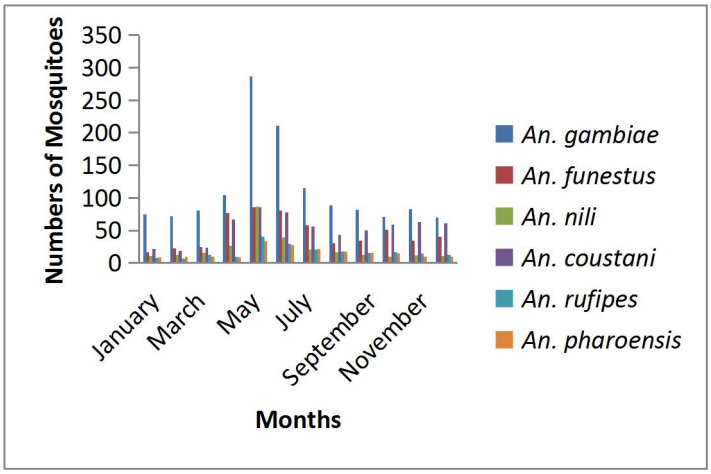

Figure 1: Monthly Spatial Composition of *Anopheles* Species encountered in the Study Areas

Table 4: Species Composition of *Anopheles* Mosquitoes from Indoors and Outdoors Collections across the Selected Eco-settings

Eco – settings	Indoors (%)	Outdoors (%)	Total (%)
Wooded/Grassland	2216 (65.66)	1158(34.32)	3374 (34.15)
Sparse woodland	1924 (63.86)	1089 (36.14)	3013 (30.49)
Swampy Grassland	1966 (56.27)	1528 (42.73)	3494 (35.36)
Total	6106 (61.80)	3775 (38.20)	9981 (100)

χ^2 Cal =72.19; χ^2 tab = 5.99; df =

DISCUSSION

The results of the present study revealed that the populations of *Anopheles* (64.09 %) mosquitoes were more abundant than the Culicines, (46.41 %). This observation could be attributed to the various method of collection as CDC LTs are not specifically made for culicine mosquitoes. The topography of the areas is undulating with some valleys which allow water to be retained that created a lot of water pools that serve as a potential breeding site for the vectors [12]. 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 [21] and Adeleke *et al.* [14].

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, 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 concussive breeding sites for mosquitoes within and near human habitation. 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 revealed 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 Madara *et al*. [22] 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.

The swampy grassland eco-settings had more and abundance of the vectors compare to other selected eco-settings of sparse woodland and wooded grassland as this may be attributed and linked with the swampy areas that has created abundant and potential breeding sites than other eco-settings. 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.* [23] 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. WHO [1] 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*. [24]. 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 in the study areas. This finding is in line with the reports of Marrama *et al.* [25] 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. *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 Himeidan and Kweka [26] who reported that farmlands constitute about 40 % of the mosquito 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. This is in addition to the heterogeneity in Anopheline mosquito species composition at the macro-geographic scale as widely reported by Himeidan and Kweka [26]. They revealed that 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. This finding is also in conformity or agreement with the work of Olayemi *et al*. [27], in Minna and Madara *et al*. [22] in Abuja 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*. [28] and Akunne *et al*. [29] in Akure, Ondo state and 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.

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 in the study areas. 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. This finding is similar to a recent study conducted in three selected areas of Taraba by Lamidi *et al*. [30]. They 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*. [31], 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 could be 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*. [27], and Ebenezer *et al.* [32], 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.

Six (6) species of Anopheline mosquitoes were encountered throughout the study period and in all the eco – settings. Depinay *et al*. [33] put the usual number at more than five within a given area, and this has been confirmed in different localities in Africa [34, 35, 36]. 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.* [37].

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*. [38]. The result of this finding is in conformity to the work of Okwa *et al.* [39], Oguoma and Ikpeze, [40] who in Lagos and Kano respectively, reported that *An. gambiae* was the most predominant species.

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 mosquitoes). *Anopheles gambiae* s.l was the most dominant (111.58±13.59) species encountered throughout the months of the study. The relative abundance of *An. gambiae* s.l in the study areas is also in conformity with other studies in different geo – political zones within Nigeria [40, 41, 42, 43, 44, 45].

Anopheles gambiae s.l was more abundant in the wet months, followed by *An. coustani* and *An. funestus* at the end of the rainy season. These three species seems to complement each other in order to sustain the endemicity of malaria in the sampled towns/villages across the three eco – settings. Faye *et al.* [46] also observed a high variation of *An. gambiae* s.l population in the Sahelian area of Niger Republic. Also, similar findings were reported by Lamidi [47]. Moreover, Ebenezer *et al.* [31] reported that *An. gambiae s.s, An. arabiensis* and *An. funestus s.s* alternate in malaria transmission across the year especially during the rainy period and as such all should be targeted for effective malaria vector control.

Species composition of *Anopheles* mosquitoes collected from indoor and outdoor was also analyzed. The result of this study revealed that most *Anopheles* mosquitoes were caught indoors (68.21%) across the three eco – settings of Nasarawa state. This finding is in conformity with the report of Getachew *et al.* [48], who reported that *Anopheles* mosquitoes were predominantly endophagic and as such tend to reside indoors than outdoors that was shown in the biting rhythms which usually commences at 10 pm as the peak biting period was noticed at 2-4 am for both indoors and outdoors collections across the selected eco-settings in Nasarawa state as this has confirmed the endophagic and exophagic nature of the vectors as the endophagic and endophilic nature of the vectors were eminent which is in conformity with the findings of Oduola *et al.* [49] at Ilorin kwara state North Central Nigeria. This work confirmed that the method used influences the quality and the variety of mosquitoes collected. In this study, the highest number of *Anopheles* mosquitoes were collected using CDC (64.69 %) method than PSC (35.31 %). This is probably due to the multiple attraction stimuli displayed by the method (light) [9].

CONCLUSION

This study established that six (6) species of *Anopheles* mosquitoes were prevalent during the study period; *Anopheles gambiae, An. funestus, An. rufipes, An. coustani, An. nili* and *An. pharoensis* across with *An. gambiae* s.l as the most encountered species in all the three eco – settings. The highest *Anopheles* mosquito species population was recorded in the month of May and June.

RECOMMENDATIONS

On the basis of the above conclusion, the following recommendations are therefore made;

Knowledge of vector species and their correct identification should be sought continuously in Nasarawa State and beyond because it is a prerequisite for a proper understanding of the epidemiology and transmission dynamics of malaria in any given area. Integrated Vector management should be adopted as a control

strategy to curtail the distribution and the proliferation of the vectors across the selected eco-settings which may include Indoor residual spray (IRS), the use of Long Lasting Insecticidal treated Nets (LLIN) and larvicing activities.

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