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Research Article

SPECIES COMPOSITION, DISTRIBUTION, ABUNDANCE AND VECTORIAL CAPACITY OF *AN.* GAMBIAE IN PARTS OF KATSINA STATE, NIGERIA

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ABSTRACT

There is scanty data on the dynamics of *Anopheles gambiae* in Katsina State. Consequently, a study was undertaken from 2009 to 2014 to establish the species composition, distribution and abundance and vectorial capacity of *An.gambiaein* parts of Katsina State. Mosquitoes collected were identified morphologically using morphological keys, then subjected to PCR analysis utilizing standard methods. *An. gambiae*s.s. was the most preponderant, out of the 1069 adults reared from larvae, 972 (89.3%) were *An. gambiae*s.s. followed by *An. arabiensis* with 114 (10.7%). There was no significant difference between *An. gambiaes.s* .and *An. arabiensis* reared from larvae between Zones A, B and C of Katsina State. Also there was no significant difference between the two species ($p>0.05$, F=19). Nine hundred and one 901(95.1%) and 46 42.9%) adult collections were found to be *An. gambiaes.s.* and *An. arabiensis* respectively. The highest number of *An. gambiae*s.s. were from Dandume with 333 and 205 for reared adults and indoor collections respectively. The lowest number of 6 *An. arabiensis* was also recorded at Dandume. There was no significant difference between *An. gambiaes.s* and *An. arabiensis* caught indoors in Zones A, B and C and also no significant difference between the two species ($P>0.05$, F=19). As the number of *P. malaria* increases in *An. gambiae*, it decreases in *P. falciparum.* Chi-Square indicates no significant difference between the Plasmodium species ($p< 0.05$). Even though *An. gambiae* was the most preponderant, there was no significant difference between *An. gambiaes.s.* and *an. Arabiensis.*

Keywords: *An. arabiensis*, *An. gambiaes.s*, Species composition, Vectoral capacity, Reared adults, Katsina State.

INTRODUCTION

The transmission of malaria occurs only within about 40 species even though there are about 60 to 80 species of *Anopheles gambiae* present around the globe. Consequently, it is important to establish the species composition, distribution, abundance, vectorial capacity, ecological and behavioral differences of *Anopheles gambiae* species in Katsina State. Diseases transmitted by mosquitoes have been responsible for killing more people than all the previous World Wars combined (Beerntsen *et al.*, 2000). Worldwide, mosquitoes transmit different nasty diseases like dengue, filariasis and malaria, to more than700 million people annually (Fradin, 1998). In 2006, 35 to 80 million Nigerians were infected with malaria, out of which 1 million people died, most of them children under five years (WHO, 2008).

In sub-saharan Africa, *P. falciparum* is mainly transmitted by *An. gambiae*. Which is the most ubiquitous in Africa as well as having the highest rates of sporozoite development (WHO, 2011). *An. gambiae*s.s. is recognized as the world's most important vector of *P. falciparum* followed by *An. arabiensis.An. gambiae* occur throughout Katsina State (Umar and Nock, 2019a;Umar and Nock, 2019b) and the globe and can survive all weather (Coetzee, and Fontenille, 2004). Even though *An. gambiae* is more preponderant in the wet season and *An. funestus* dominates in the dry seaon (Umar and Ndams, 2018; Umar and Kogi, 2018). However, variations in ecology and bahaviour play a big role in the life of mosquitoes. Knowledge of

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distribution and abundance of mosquitoes is essential for controlling malaria in a particular area (Umar and Nock, 2019a). Members of the *An. Gambiae sensulato* (s.l.) are closely related and morphologically similar and are sympatric (Coetzee, and Fontenille, 2004) but differ in host-biting preference, abundance and vector competence which makes species identification and distribution imperative towards effective control.

Not much is known of the species composition, distribution, and abundance of *Anopheles* and *Plasmodium* species in Katsina State. It is also not known how *Anopheles* species breed and sustain themselves within the different ecological zones and also within the wet and dry seasons. Consequently, the present study has collated information on mosquitoes in terms of species distribution, breeding sites, abundance and the prevalence of malaria in both dry and wet seasons across the three ecological zones of Katsina State. The data will be used to compare *Anopheles* species occurrence and abundance in relation to malaria episodes across the three ecological zones of Katsina State. This study has provide detailed information of the mosquito species composition, their vectoral capacity and malaria prevalence in Katsina State so as to facilitate mosquito control through the use of ITNs, insecticides etc. GPS guided maps produced by this study has identified areas where greatest mosquito and malaria control efforts should be focused on.

MATERILAS AND METHODS

Study Area

Katsina State is 1,696 feet above sea level, it is located between 12°15' N 12_15_N_7_30_E_"12° 25'N - 7.5° 0'E (Figure 1). It has an area of 24,194 km^2, with a population of 3,878,344 million and a population density of 160.3/km^2.

The climate of Katsina State is characterized by two well marked seasons, the rainy season, extending from May to September and the dry season from October to April. The dry season is characterized by harmattan dust between November and February. The maximum amount of rainfall occurs between August and September.

Katsina State's geography is a gently undulating environment. The vegetation is divided into three types: I the northern region (for example, Daura, Zango, Katsina, Jibia, and Mai-Adua) receive the least amount of annual rainfall (25"-28"). Katsina (12o 59" N: 7o 36" E) and Daura (13o 2' 11" N: 8o 9' 4" E) are examples of Sahel savannah vegetation. Even during the wet season, the few river systems in this area dry up. Ajiwa town (7 km) near Katsina has a huge dam, and Jibia and Zabge near Daura have smaller dams. Both dams are utilized for fishing and irrigation. In most of the towns in the zone, modest artificial dams have been built for farming purposes. It is distinguished by extremely hot temperatures (40°C to 47°C) and low humidity. (ii) The middle area (e.g., Dutsinma, Matazu, and Kafur) receives moderate rainfall, ranging from 30" to 35". The vegetation is of the Sudan Savannah variety, and the humidity is mild. In most of the towns in the zone, modest artificial dams have been built for farming purposes. A huge dam, the Zobe dam, is located 3 kilometres outside of Dutsinma and is used for irrigation and fishing. Low temperatures (18°C - 26°C), luxuriant grass cover, and high humidity characterise the southern half (e.g. Funtua, Faskari, etc.) of the guinea savannah. The zone is usually connected with the maximum amount of yearly rainfall, which ranges from 35" to 55". The Katsina State Environmental Protection Agency KTSEPA (2004) provided a detailed account of Katsina State's climate, from which the following description was derived.

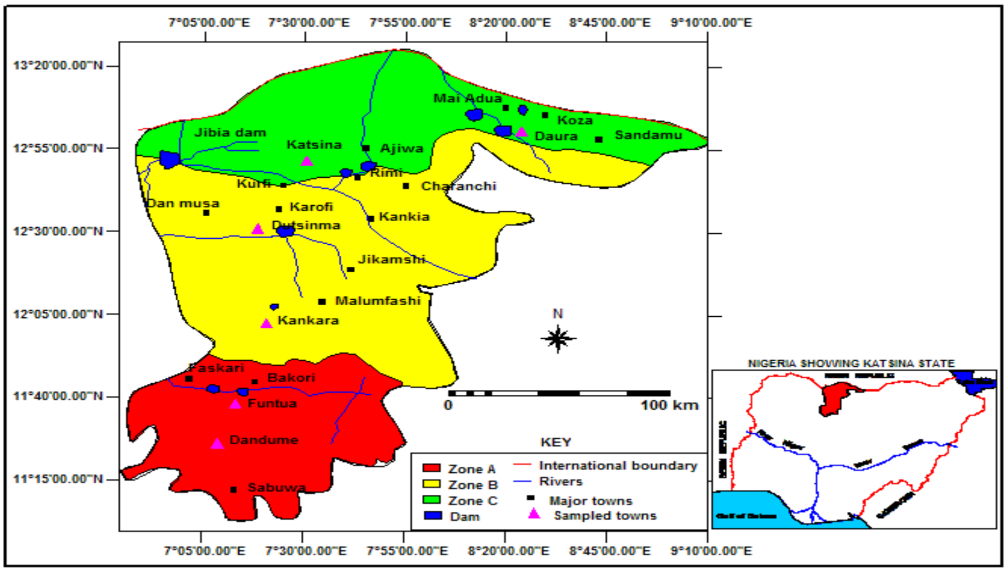

FIGURE 1 : KATSINA STATE SHOWING THE SAMPLED TOWNS AND VEGETATION ZONES

Source : Adapted and Modified from Katsina State Map, Ministry of Lands and Surveys

Figure 1. Mosquitoes analyzed were from two sources.

Mosquitoes analyzed were from two sources: 1) indoor resting adult catches and 2) adults reared from field collected larvae (series). The adult *Anopheles* mosquitoes were first identified using morphological characteristics according to (Coetzee and Fontenille, 2004); Hopkins, 1952).

PCR Discrimination of *Plasmodium* Sporozoites

Anopheles mosquitoes caught indoors were tested using the Vec Test, which involved aliquouts (150 ul) of Anopheles mosquito triturates made from squashed mosquito thoraces using grinding tubes and transferred into the wells of micro-titre plates (Sero-wel; Bibby Sterilin Ltd, Stone Staffs, UK) for testing..

RESULTS AND DISCUSSION

A total of 2,049 mosquitoes were collected across the three ecological zones over the study period (2009-2011), and all were morphologically recognized as anopheline mosquitoes. *An. gambiaes* accounted for 1077 (52.56 percent) of the 1649 adults raised from larval samples (Table 1). *An. gambiae* was the most common species among the 1378 adult mosquitoes collected from indoor adult collections, accounting for 972 (70.54) of them (Table 2& Figure 2). The regional distribution of *An. gambiaes*.s larval populations was found to be variable. Zone A had the most larvae, with 356 (33.05 percent) at Dandume and 169 (15.7 percent) at Funtua, while Zone C had the least abundance, with 99 (9.19 percent) at Daura (Table 1 & Figure 2). Adults, on the other hand, were more prevalent in Zone A at Dandume (214.02 percent) and Funtua (211.71 percent), and were scarce in Zone C at Daura (70.2%). (Table 2,3 & 4). Chi-square and One sample t-test have indicated no significant difference between samples of *An. gambiae* collected within different towns ($p<0.05$). Chi-Square showed no significant difference between species population collected. There was no significant difference in the numbers of larval collections between Zone A (Dandume), Zone B (Dutsinma) and Zone C (Daura) ($p>0.05$, F=10.13). There was no significant difference in indoor collections between Zone A (Dandume), Zone B (Dutsinma) and Zone C (Daura) ($p>0.05$, F=10.13). There was no significant difference in indoor collections between *An. gambiae* and *An. funestus* within Zone A, Zone B and Zone C ($p>0.05$, F=5.05). *Anopheles gambiae* adults caught were the most abundant in all the sampled resting places. Its adults were the most abundant in Zone A with 200 at Kankara and the lowest of 70 in Zone C at Katsina. The highest number of *An. gambiae* collected was 35 in Zone A at Dandume (Table 2). The highest abundance of *An. gambiae* larvae collected in a pond was 17 in Zone B at Dutsinma in September, 2009. Pools and rice farms breeding sites were only active during wet months while ponds and reservoirs were active during both wet and dry months. Fewer number of *An. gambiae* larvae were collected during the dry months of October to May, 2010. The month of July recorded the highest abundance of *An. gambiae* within Zone A with 47 at Dandume. *An. gambiae* have not been collected in the dry months between May and April in Zone C at Katsina and Daura and also in Zone B at Dutsinma and Kankara. *An. gambiae* larvae were not abundant (highest was 8) during the dry months (Figure 5). Upto 17% of reared *An. Gambiae* were collected in June and July (Figure 5). Up to 24% of the *An. Gambiae* collected indoors were collected in June and 18% were collected in August (Figure 5). A PCR based test on the *Anopheles gambiae* reared from larvae showed that *An. gambiae*s.s. was the most preponderant, out of the 1069 adults reared from larvae, 955 (88.75%) were An. *gambiae*s.s. followed by *An. arabiensis* with 122 (11.3%). There was no significant difference between *An. gambiaes.s.* and *An. arabiensis* reared from larvae between Zones A, B and C.

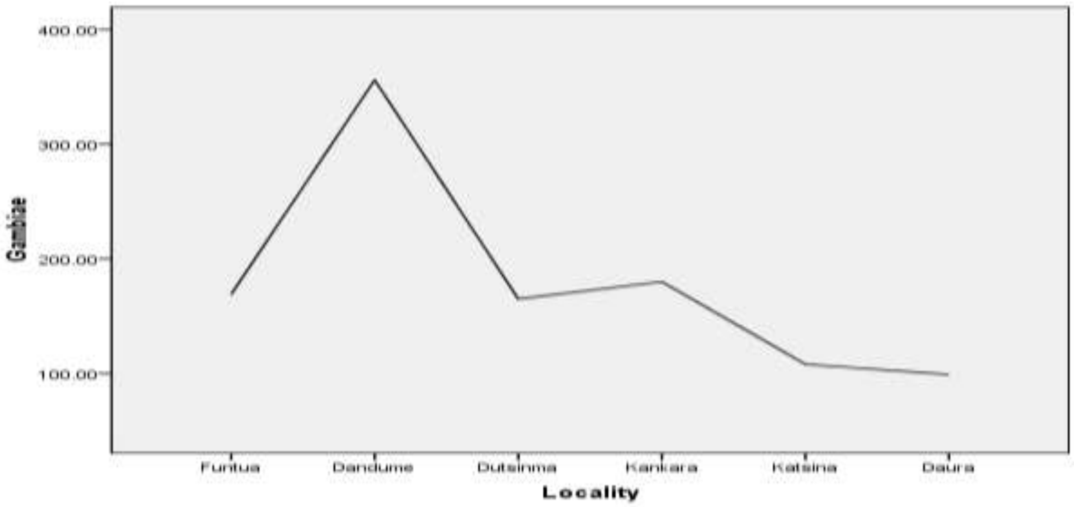

Figure 2. Distribution of An. gambiaeaccording to locality.

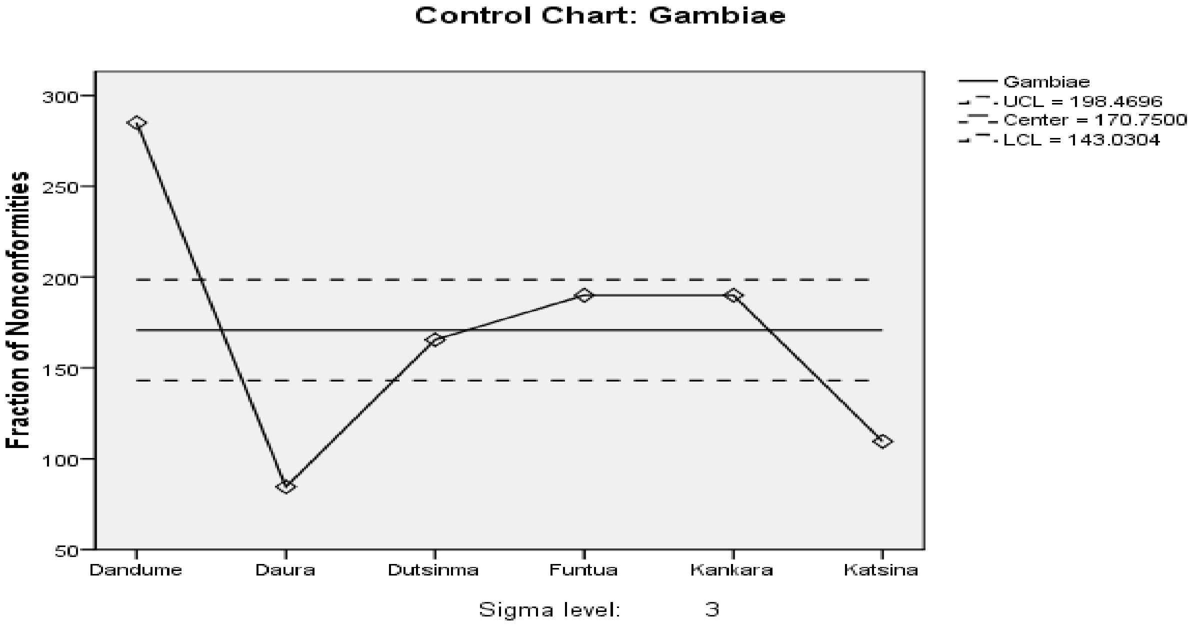

Figure 3. SP Control chart of *An. gambiae* by locality indicating Nonconformities.

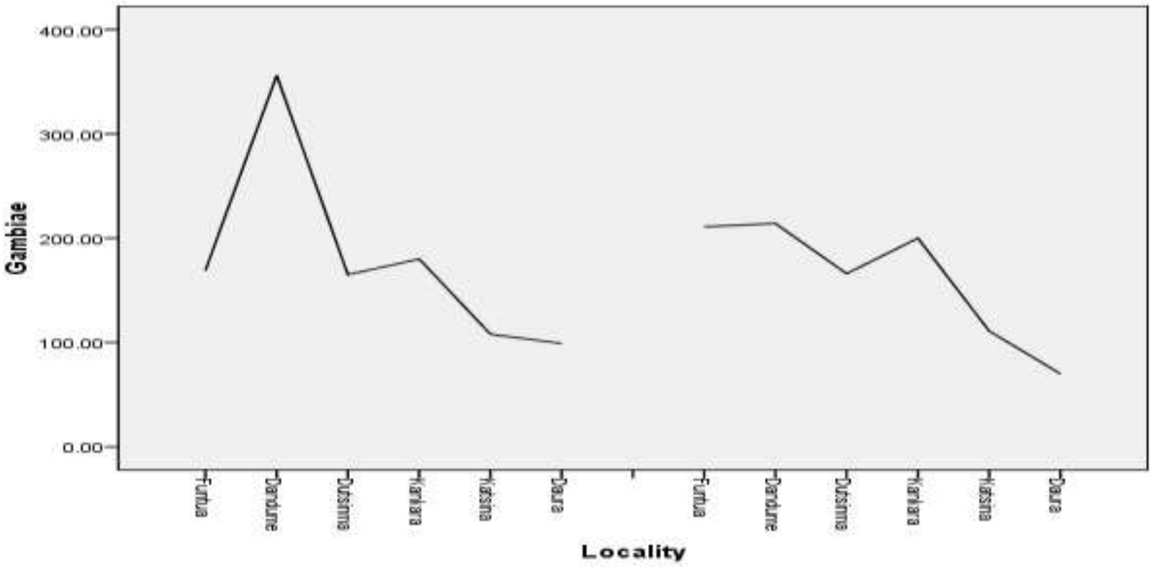

Figure 4. Sequence plot of *An. gambiae* versus locality.

Also there was no significant difference between the two species (*p*>0.05, F=19). Nine hundred and one (97.3%) and 71 (2.7%) adult collections were found to be *An. gambiaes.s.* and *An. arabiensis* respectively. There was no significant difference between *An. gambiaes.s* and *An. arabiensis* caught indoors in Zones A, B and C and also no significant difference between the two species(*P*>0.05, F=19). The highest number of *An. gambiae*s.s. were from Dandume with 333 and 205 for reared adults and indoor collections respectively. The lowest number of 4*An. arabiensis* was also recorded at Daura (Table 1). There was no Pearson Correlations based on One-Sample and Paired-Sample t-Tests. Similarly Chi-Square has also showed no significant difference between the sensustricto, sensulato and *Arabiensis*molecular species (p< 0.05). There was a very high significant difference between *P. falciparum* and *P. malariae* isolated from *An. gambiaes.s.* and *An. arabiensis* within the zones (*p*<0.05, F=161.44). There is a very high significant difference between malaria sporozoites isolated from *An. gambiaes.s*. which was higher than that of *An. arabiensis. An. gambiae*s.s recorded the highest number of *P. falcifarum* at 190 and also the highest *for P. malariae* with 289 (Table 2). In this study, *Anopheles* mosquitoes were found breeding in all the ecological zones of Katsina State. Breeding was predominantly in pools (formed by rain), ponds, cemented reservoirs, overhead tanks and rice farms. The implication is that there will be high preponderance of mosquitoes and high transmission rate. *An. gambiae* were also found in numerous water bodies created by rain in addition to breeding in small water storage containers utilized by people for household chores (Umar and Kogi, 2018).

The water delivery system was inconsistent in all of the cities studied, which explains the widespread usage of water storage tanks to provide water for household chores, irrigation, vehicle washes, block manufacturing, and other construction reasons. Within and near human habitations, these proved to be ideal mosquito breeding grounds. Water storage in cemented and plastic tanks was found to be a major contributor to the abundance of Anopheles mosquitoes in all three study years, particularly during the dry season. Malaria parasites may be transmitted more easily and quickly as a result of this. Zone A had a higher concentration of mosquito breeding sites, which could be due to the fact that it receives more rainfall than the other two zones (Umar and Kogi, 2018). This could explain why Anopheles mosquitoes were so widespread and plentiful in the area. As a result, disease vectored by Anopheles species will spread widely. The presence of major water reservoirs (used for irrigation purposes) in various towns, such as the Sabke dam at Daura, the Ajiwa dam near Kasina, and the Zobe dam at Dutsinma, contributed to the high prevalence of Anopheles species, which easily invaded nearby houses. In Sub-Saharan Africa, 9.4 million people live near dams and irrigation facilities, accounting for 87.9% of all malaria cases worldwide. Mosquitoes can travel up to 5 kilometres from their spawning sites to infest human habitations, according to many writers (Umar and Kogi, 2018). Furthermore, widespread irrigation within the three zones has changed soil qualities, significantly impacting desert physiography, vector abundance, distribution, and vectorial capacity, and causing alterations in *Plasmodium falciparum*-dominated malaria. Several anophelines have been attracted to the three zones due to changes in crop patterns, high surface moisture retention, excessive use of irrigation canals, and inadequate irrigation water handling. The distribution of Anopheles and malaria in Katsina State's three zones is more or less directly tied to the distribution of agricultural irrigation water. As a result, water reservoirs for irrigation should be supplied with motorised aerators that constantly swirl the water, making it inhospitable to mosquito larvae and, as a result, contributing significantly to the reduction of mosquitoes and, by extension, malaria.

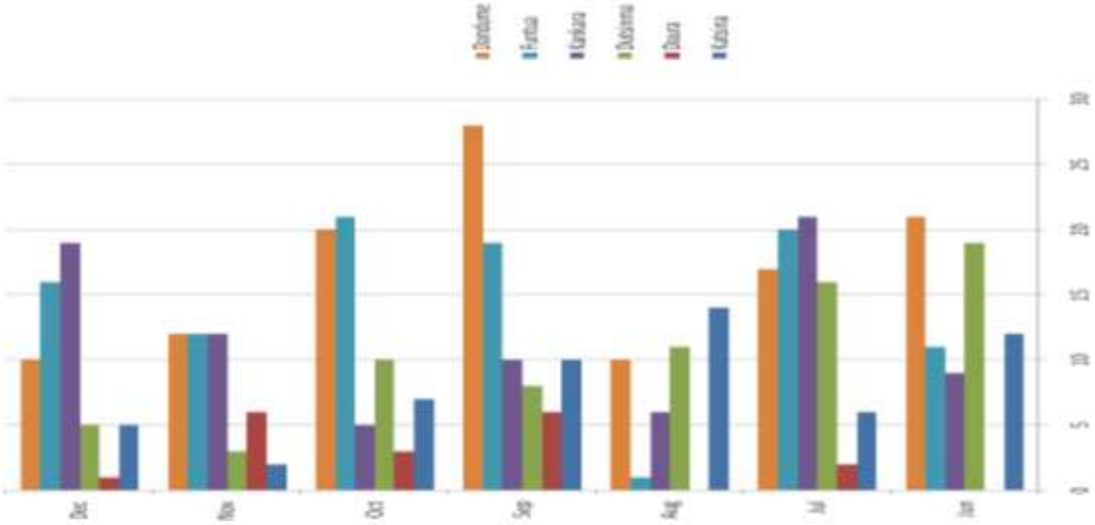

Figure 5. Monthly distribution of indoor adult *An. gambiae*species across sampled towns in 2009.

Table 1: Molecular Charaterisation of *An. gambiae*s.l.

		Adults reared from larvae			Adults collected indoors		
		Anopheles			***Anopheles***		
Zone	Site	Ag. s.l	Ag. s.s	A. ar	Ag. s.l	Ag. s.s	A. ar
Zone C	Katsina	108	89	19	111	99	5
“	Daura	99	79	20	70	53	4
Zone B	Dutsinma	165	148	17	166	155	9
“	Kankara	180	161	19	200	188	11
Zone A	Funtua	169	145	24	211	201	10
“	Dandume	356	333	23	214	205	6
	Total	1077	955(88.67%)	114(10.58%)	972	901(92.70%)	45(4.63%)

In a similar line, heavy rains and farming operations such as irrigation of vast rice fields contributed to the extremely high population of Anopheles species found. Mosquitoes and malaria transmission were quite abundant in irrigated areas and rice fields. This is in line with the findings of (Takken *et al*., 2007), who found that malaria transmission was 150 times higher in irrigated areas than in wild ecosystems, with *An. funestus* accounting for 90 percent of illnesses. This study discovered that regions left fallow after rice harvesting were ideal for mosquito breeding, resulting in significant populations of anophelines. When compared to locations where irrigation was not applied, the malaria transmission season saw significant changes (Umar and Kogi, 2018). In rice farmlands, *Anopheles gambiae* was the dominant species, with farmlands accounting for more than a third of Anopheles larval habitats, confirming farmlands as key contributors to mosquito and malaria prevalence in the three zones. During the current investigation, numerous Anopheles breeding sites were discovered in murky water and exposed to direct sunlight, which is similar with the findings of. Because they are warmer, female Anopheles favour open habitats those are directly under the sun for ovipositor because the warmth minimises the larval and pupal development period (Marrama et al., 2004). There is also less predation and more algae, which provides food for the larvae. Despite the fact that some of the nesting locations were extremely turbid, several Anopheleses were detected. Consequently, the presence of *Anopheles* in turbid and polluted water is an indication that some physical qualities of a water body may not play a role in their proliferation.

Similarly, contrary to popular belief, *An. gambiaes*.l. only breeds in clean, clear water, its larvae were identified in habitats polluted by vegetation, human faeces, murky water, and even oil during the current investigation. This is in line with the conclusions of a recent study. These sites included a sewage pond with organic pollution from human faeces, a contaminated swamp used as a garbage dump, and a polluted swamp used as a garbage dump. It was also discovered that breeding places with a diameter of less than one metre, such as buckets, small plastic tanks, and the like, were more likely to host Anopheles larvae, as long as detritus was present. Despite the presence of Anopheles larvae in big drains, bogs, and puddles, these areas had substantially lower populations of Anopheles larvae. Some of the breeding sites studied had aquatic plants such as Typha species (*Typhaangus tifolia*) and water lilies (Nyrnphaea spp.). Anopheles breeding was aided by these water plants, which slowed the river, blocked water flow, and provided cover and laying places. Few Anopheles larvae were found in marshes during this investigation. This discovery supports previous studies that *An. gambiaes.l.* Likes to breed in transient locations. Though Anopheles mosquitoes are less likely to inhabit swamps if other, more suitable habitats exist, the importance of swamp habitats for mosquito proliferation should not be underestimated, given their large size and role in supplying water for irrigation ditches, rice farms, and other agricultural activities. As a result, proper control measures should be addressed at marshes.

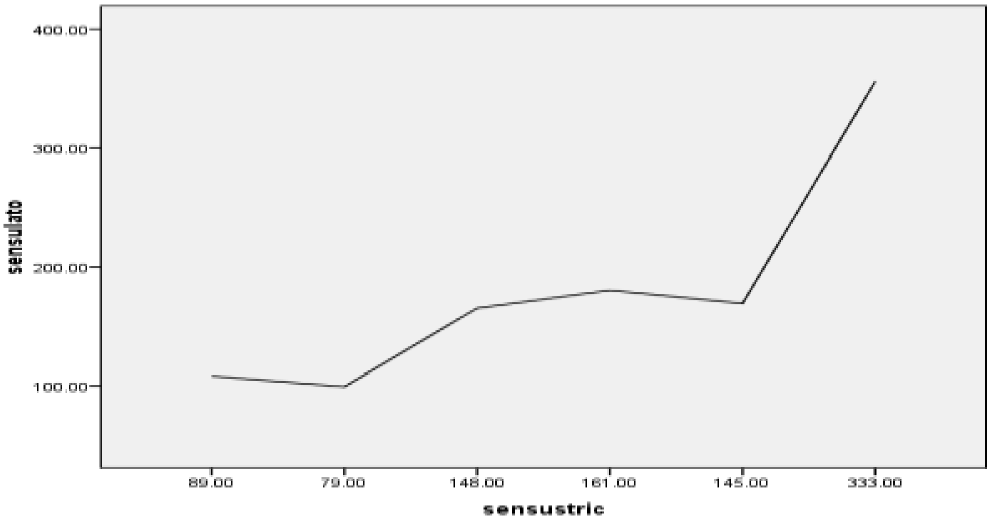

Figure 6. Distribution of sensustrictus against sensulato species of *An. Arabiensis* by Frequency.

Seasonal fluctuations in the population of Anopheles species were observed in this study, which was conducted across the three biological zones of Katsina State and over the seasons. *Anopheline gambiae* was the most synnantrophic and widespread of all the anophelines found in the three zones. The considerable increase of Anopheles mosquitoes gathered was due to the abundance of breeding places generated by the recent rains, which is comparable to the situation in the northern Guinea savannah. At the macro-geographic scale, there is also a lot of variability in the anopheline mosquito species makeup. The link between mosquito population and rainfall varies by district in Kenya, as well as by environmental heterogeneity (Sattler *et al*., 2005). Similarly, during the rainy season, Anopheles predominates because the range and relative abundance of Anopheles gambiae and Anopheles arabiensis are influenced by the amount of yearly rain, annual and wet season temperatures, and dense vegetation, all of which are favourable in Zone A. Furthermore, the presence of optimal breeding places, as well as the oviposition of mosquito eggs by gravid females, as well as their maturation into larvae and ultimately adults, is dependent on rainfall. This is also consistent with the findings of (Tekleheimanot *et al*., 2004). Rainfall supplies the medium for the acquatic phases of the mosquito life cycle, as well as boosting relative humidity and hence the adult mosquito's life span, according to some writers. As a result, the link between mosquitoes, malaria, and rainfall is ascribed not only to increased mosquito breeding activity, but also to increased relative humidity and a higher likelihood of female Anopheles mosquitoes surviving. This fluctuates depending on the circumstances of a given geographic region and mosquito habits in that area. Malaria transmission can only be sustained for around 5 months with 80mm of rain; however, 60mm for the same number of months or 80mm for less than 5 months will be insufficient (Tekleheimanot *et al*., 2004).

The foregoing data is crucial for mosquito management; first, identifying the ecology and distribution of distinct Anopheles species is crucial for assessing mosquito vector abundance and malaria prevalence. Second, *Anopheles gambiaes.l.* is a collection of sympatric mosquito species that are closely related and physically indistinguishable. Thus, information on the distribution and abundance of Table vectors in a targeted area like Katsina State is required for effective malaria control through vector management. Furthermore, individual species within the species complex differ in host-biting preference, abundance, and vector competence, necessitating species-level identification and mapping of mosquito vector distribution in heterogeneous environments for a successful control programme (Coetzee and Fontenille, 2004; Marrama *et al*., 2004; Highton *et al*., 1979; Petrarca *et al*., 1991).

Table 2. Prevalence of *Plasmodium*sporozoites isolated in the identified *Anopheles* spp.

Anopheles species	*Plasmodium* sporozoites identified by Vectest				Total
	P. fal.	*P. mal.*	*P. vivax (210)*	*P. vivax* (247)	
An. gambiaes.s.	190	289	0	0	479
An. arabiensis	35	133	0	0	168
Total	225	422	0	0	647

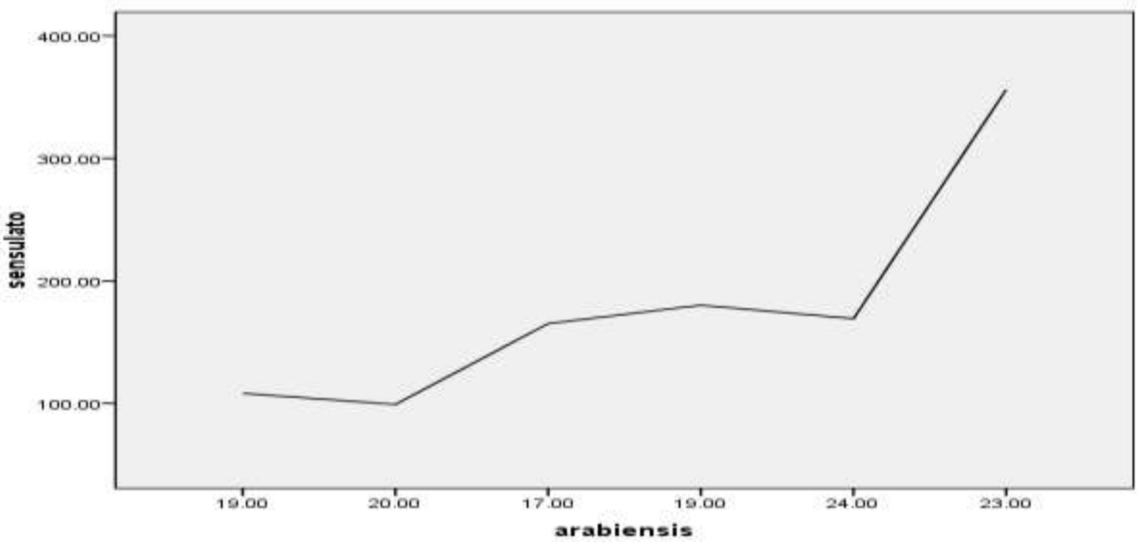

Figure 7. Distribution of *An. Arabiensis versussensulato* species.

The data obtained shows that as one moves from the arid towns of Zone C (Katsina and Daura) to the less arid towns of Zone B (Dutsinma and Kankara), the population density of Anopheles larvae and adults increases, culminating in a dramatic increase in population density of Anopheles in Zone A (Funtua and Dandume) due to abundant rain, which leads to the formation of water bodies such as pools and ponds, In July and August, the amount of rainfall reported resulted in temperatures that were conducive to mosquito multiplication. In fact, larval and pupal development might take as little as 10 days at 30°C (Rueda *et al*., 1990; Tekleheimanot *et al*., 2004). During moderate temperatures, mosquito blood meals and the length of the gonotrophic cycle increased (Martens, 1995). During the study period, more instances of malaria were observed in the study area in July and August. Low humidity also prompted the vectors to feed more frequently in order to compensate for their dehydration. Mosquitoes tend to live longer in appropriate humidity conditions, allowing them to travel further and participate in malaria transmission cycles (Tekleheimanot *et al*., 2004). Malaria transmission is very seasonal when temperature is not a limiting factor, peaking after a period of excessive rainfall. Furthermore, Anopheles species can aestivate as eggs for up to 20 months, with the bulk of the eggs hatching as soon as the rains begin, raising *An. gambiaes*.l. Population density (Jupp *et al*., 1980; Charlwood *et al*., 2000; Kasili *et al*., 2009).

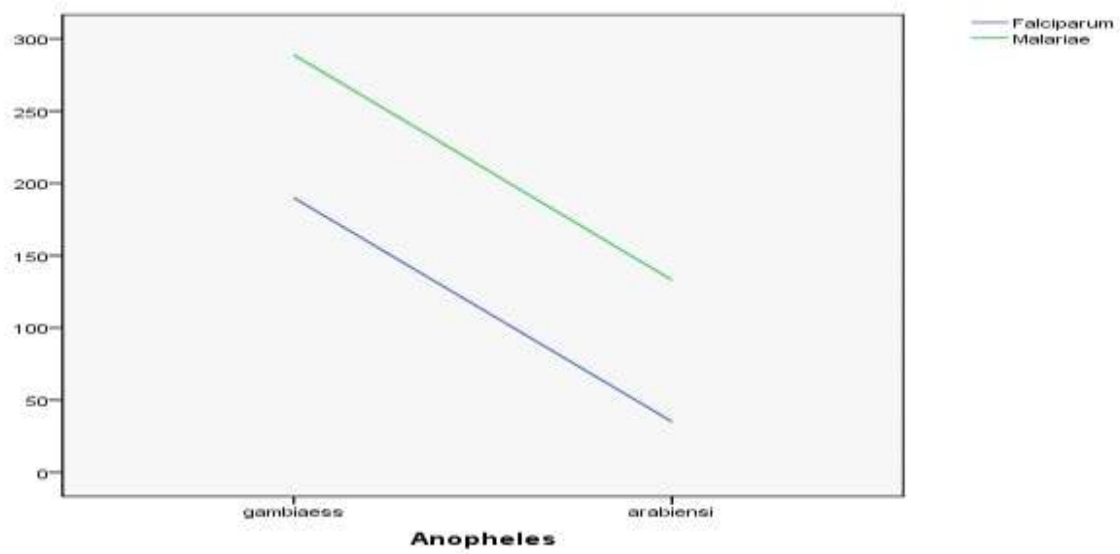

Figure 8. Distribution of *P. falciparum* and *P. malariae*within *An. gambiae*and *An. Arabiensis.*

During the rainy season, *Anopheles gambiaes.s*. was responsible for the majority of malaria transmission, while *An. arabiensis* was responsible for the majority of malaria transmission during the dry season. As a result, the two species appear to work in tandem to maintain malaria endemicity in the towns studied across the three zones. This is analogous to the wide range of *An. gambiaes*.l. Population density in the Republic of Niger's Sahelian region (Faye *et al*., 1997; Lamidi, 2009; Ebenezer *et al*., 2014). As a result, *An.gambiaes.s., An. arabiensis,* and *An. funestuss.s.* alternate in malaria transmission throughout the year (Ebenezer *et al*., 2014; Onyabe and Conn, 2001; Umar and Nock, 2019a; Umar and Ndams, 2018), particularly during the rainy season, and all three should be targeted for effective malaria control. Similarly, the high proliferation rate seen in the aforementioned species could be explained by *An. gambiaeeggs'* endurance to desiccation during the dry season, and the fact that *An. gambiaeeggs* can survive up to 15 days in dry conditions, depending on the kind of soil (Umar and Nock, 2019b). As a result, Anopheles populations explode as soon as the rains begin to fall.

Because malaria transmission is closely tied to mosquito proliferation, more malaria cases are expected in Zone A, which has all of the ideal meteorological conditions for mosquito reproduction. However, no substantial differences in malaria cases were found in the three zones, according to hospital records of malaria transmission. This raises the question of whether malaria prevalence is influenced by factors other than the weather. Yes, malaria transmission is aided by a lack of sufficient drainage, poor sanitation, and the use of adequate insecticide-treated nets, among other factors (Onyabe and Conn, 2001).

CONCLUSION

*Anopheles gambiae*s.s. was responsible for most of the malaria transmission during the wet season while *An.*

arabiensis was responsible for most malaria transmission during the dry season however malaria incidence is seasonal. The two species seem to complement one another in order to sustain the endemicity of malaria in the sampled towns across the three zones. More cases of malaria were recorded in the study area during July and August throughout the period of study.

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