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Original article

SEASONAL ADAPTIVE DISTRIBUTION OF MOSQUITO SPECIES IN RICE FIELDS LARVAL HABITATS IN MINNA, NORTH CENTRAL NIGERIA.

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ABSTRACT

Seasonal adaptive distribution of mosquito species in rice fields was investigated in four widely spaced sites located in Bosso, Maitumbi, Fadikpe and Chanchaga areas of Minna, Niger State. Mosquito larvae were collected from the four sites during the rainy season while soil samples were collected by excavation and flooded with water in plastic containers to allow aestivating eggs and immature to emerge. Immature mosquitoes recovered for both seasons were reared to adults and identified in the laboratory using standard morphological keys. The results revealed three mosquito genera (i.*e Aedes, Anopheles* and *Culex*) species co- existing in rice fields in Minna, with *Culex* been dominant. The distribution of the ten species of mosquitoes occurred in the following order of decreasing abundance during the rainy season; *Culex pipiens pipiens* 651(21.9%)> *Culex quinquefasciatus* 421(14.2%)> *Anopheles gambiae* 400 (13.5%*)> Anopheles funestus* 334 (11.2%)> *Culex restuans* 297 1(10.0%)> *Anopheles maculipalpis* 187(6.3%)> *Anopheles quardrimaculatus* 178(6.0%)> *Aedes dorsalis* 173 (5.8%)> *Aedes aegypti* 169 (5.7%)> *Aedes vexans* 162 (5.5%). While that of dry season was Cx*. pipiens pipiens* 78(30%)> *An. gambiae* 6(23%)> *Cx. quinquefasciatus* 34 (13%*)> An.funestus* 32 (12.3%)> *Ae. aegypti* 20 (7.7%)> *An. maculipalpis* 10 (3.8%)*> An. quadrimaculatus* 9(3.4%)*> Cx. restuans* 8(3.1%)> Ae*. dorsalis* 6(2.3%)> Ae *vexans* 4(1.5%). Findings further revealed a negative correlation between *Aedes* vs *Anopheles* and *Anopheles* vs *Culex* mosquitoes in rainy season. But a positive correlation was exhibited between the three mosquito genera during the dry season. Statistically however, there was significant difference ($P > 0.05$) in the distribution of mosquito species in the studied areas in both seasons. Thus, there is an urgent need for an effective mosquito larvicidal programme for vector control in rice-fields in Minna, for sustainable rice production.

Key words: Mosquitoe, Rice, Habitat, Adaptive distribution,

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INTRODUCTION

Mosquitoes are insect arthropods belonging to the Order *Diptera* and Family *Culicidae* with 3 sub families, namely; *Anophelinae, Culicinae,* and *Toxorhynchitinae.* About 43 genera and over 3,500 species of mosquitoes have already been described [1]. Mosquitoes exploit different Kinds of lentic aquatic habitats for breeding, but rice fields are amongst the most productive sites for mosquitoes. Rice agro- ecosystem perfectly fits the ecological requirement of mosquito vectors and specifically suitable for the pioneer species, members of the *Anopheles gambiae* complex [2]. Water quality of aquatic habitats is an important determinant of female mosquito oviposition and successful larval development [3]. Changes in physicochemical characteristics of Rice field water may create conditions that are either favourable or unfavourable to breeding success.

Mosquitoes are distributed throughout the world. Some species exist at altitudes of >14,000 feet, while others can inhabit mines that are 3,760 feet below the sea level [2]. Species range in latitudes northward from the Tropics to Arctic regions and southward to the end of the continents. A wingless species have been reported to exist in Antarctica, while many species do exist in the remote desert [2]. However, majority of mosquitoes are found in the tropics and subtropics. The warmer temperatures in the tropics allow them to be more active and the rainfall provides them with aquatic sites for larval and pupal stages.

Increased rice production inevitably results in expansion of mosquito larval habitats. About a quarter of the 60 odd *Anopheles* species listed as important vectors of human malaria breed in Rice fields [2]. Furthermore, Rice fields also produce important mosquito vectors of human Filariasis and Viral diseases.

The relative abundance of mosquitoes breeding in Rice field varies extensively by season and spatially. This variation has been attributed to the different rice cultural practices [4].

Mosquitoes sometimes go into their own form of off season aestivation as the rainy season winds down. Depending on the species and sometimes climate, mosquitoes can successfully survive the unfavourable dry period in the egg, larval or adult stage. The resumption of direct development in the resting or diapausing eggs is commonly influenced by a variety of environmental factors such as the rise in temperature and oxygen levels or exposure to light ([5]; [6]). In some cases, specific abiotic factors such as seasonal changes in physicochemical characteristics and biochemistry of the host soil can stimulate the resumption of direct development.

The diverse mosquito species occurring in African Rice agro- ecosystems have been scarcely studied, despite the strong link between irrigated rice cultivation and mosquito-borne diseases [7]. This no doubt left farmers with little or no knowledge of the potential health hazards' associated with mosquitoes arising from flooded rice fields. However, the knowledge of mosquito species, occurrence and seasonal adaptive distribution should be an essential component of vector ecology and a guiding principle to the formulation and implementation of integrated vector management programme.

MATERIALS AND METHODS

Study Area

The study was carried out in Minna, the Capital of Niger State, Nigeria. Minna, is located within longitude 6°33'E and latitude 9^0 37'N, covering a land area of 88km^2 with an estimated human population of 1.2 million. The area has a tropical climate with mean annual temperature, relative humidity and rainfall of 30.20^{0}C, 61.00% and 1334.00mm, respectively. The climate presents two distinct seasons; a rainy season between May and October, and a dry season between November and April. The study covers four rice fields in four widely spaced sites located in Fadikpe, Bosso, Maitumbi and Chanchaga areas of the city. The ecotype of all these four sites is that of Fadama wetland rice agro-ecosystem with temporary stagnant fresh water pools of various sizes constituted by rains.

Mosquito Larval Collection and Rearing

Mosquito larvae were collected by dipping (using a dipper of 1.5 liters capacity) at depths of not more than 5cm at the various sampling stations between 08:00- 10:00 hours on each collection day. Collected larvae were transferred into large plastic buckets (5 litres size) to transport live larvae from the field to the laboratory. The larvae were subsequently reared in white plastic bowls (2 litre size) in the laboratory of the Department of Biological Sciences, Federal University of Technology Minna. Rearing was done according to the methods described by [8] and [9]. At the end of the day, emerging adults were counted and recorded.

Identification of Mosquito Species

The adult mosquitoes were demobilized with carbamate insecticides (Raid(R) and carefully removed from the rearing bowls with a pair of forceps and identified under microscope, using standard morphological and Taxonomic keys, ([10]; [11]; [12]).

Collection of Soil Samples to obtain Dry Season Aestivating Mosquitoes

At the onset of the dry season (November) when all stagnant rain pools in the sampling sites (rice fields) had dried off, soil samples were collected by excavation at a shallow depth of about 5cm, 10cm and 15cm using local farm tools at each sampling station in the four sites. About 0.75kg of soil samples were transferred into plastic bowls and flooded with 2 litres of borehole water to form a water layer – soil depth of about 5cm in the bowls. The experiment was conducted in the laboratory of the Department of Biological Sciences, Federal University of Technology, Minna, Nigeria.

Data Analysis

Data obtained were analyzed using SPSS Software (Version 20). The results were analyzed using one-way ANOVA, and Duncan multiple range test was employed to separate their means, and $P<0.05$ was considered significant. The relationships between Mosquito distribution in dry and rainy seasons were compared and correlated using Paired Sampled t-test to determine the degree of association between the variables.

RESULTS

Table 1 presents detailed results of adaptive spatial distribution of mosquito species breeding in rice fields during the rainy season. Ten mosquito species from three *genera* were encountered each of which made up more than 5% of the total mosquitoes collected in the rainy season. Of the three *genera*, *Culex* were the dominant mosquitoes with 1,369

(46%) followed by *Anopheles* 1,099 (37%) and then *Aedes* 504 (17%) out of the total 2,972 mosquitoes collected. However, the frequency of occurrence of the ten species occurred in the following order of decreasing abundance: *Culex pipiens pipiens* 651(21.9%)> *Culex quinquefasciatus* 421(14.2%)> *Anopheles gambiae* 400 (13.5*%)*> *Anopheles funestus* 334 (11.2%)> *Culex restuans* 297 1(10.0%)> *Anopheles maculipalpis* 187(6.3%)> *Anopheles quardrimaculatus* 178(6.0%)> *Aedes dorsalis* 173 (5.8%)> *Aedes aegypti* 169 (5.7%)> *Aedes vexans* 162 (5.5%). The distribution of mosquito species in rice fields varied considerably in Minna. *Aedes* mosquitoes occurred more frequently in Chanchaga, with low presence in Bosso, Maitumbi and Fadikpe.

Statistically, the distribution and relative abundance of eight out of the ten mosquito species was significantly different (P<0.05) among the four rice fields larval habitats. This is however not true with *Aedes aegypti* and *Aedes vexans* as their distribution and relative abundance do not varied significantly (P<0.05) among rice fields with Chanchaga having the highest frequency of occurrence of both *Aedes dorsalis* and *Aedes vexans*

Table 1: Distribution of Mosquito Species (Mean ±SE) in Rice fields during the Rainy Season

Mosquito species	FADIKPE	BOSSO	MAITUNBI	CHANCHAGA	AGGREGATE
Aedes aegypti	23.00±3.00[ab]	18.00±0.30[b]	18.00±2.00[b]	26.00±5.00[a]	21.25±1.85
Aedes dosalis	18.00±2.00[b]	20.00±2.00[ab]	22.50±0.50[ab]	26.00±2.00[a]	21.62±1.31
Aedes *vexans*	20.50±3.50[a]	19.00±2.00[a]	20.50±2.00[a]	21.50±0.50[a]	50.00+-2.14
Anopheles gambiae	53.50±5.50[a]	42.00±1.00[b]	50.00±3.00[ab]	51.50±0.50[ab]	50.00±2.14
Anopheles funestus	40.00±1.00[ab]	45.00±1.00[a]	44.50±3.50[a]	37.50±2.50[b]	41.75±1.46
Anopheles quardrimaculatus	19.50±0.50[b]	26.00±0.00[a]	25.00±1.00[a]	18.50±0.50[b]	22.25±1.35
Anopheles maculipalpis	22.00±2.00[ab]	32.50±1.05[a]	15.50±0.50[b]	23.50±0.50[ab]	23.38±3.06
Culex pipiens pipiens	75.00±9.00[b]	77.50±2.50[b]	83.50±2.50[ab]	94.50±4.50[a]	82.63±3.48
Culex quinquaefasciatus	52.00±6.00[a]	48.50±3.50[ab]	54.00±3.00[a]	56.00±2.00[a]	52.63±1.81
Culex restuans	39.00±4.00[a]	35.50±2.50[b]	39.50±1.50[a]	34.50±0.50[b]	37.13±1.25

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

Table 2 shows adaptive spatial distribution of mosquito species aestivating in rice fields in Minna during the dry season. The results obtained in this study showed similar trends to the one obtained during the rainy season. A total of 261 mosquitoes were collected. Ten species were encountered and they occurred in the following order of decreasing abundance: *Cx. pipiens pipiens* 78(30%)> *An. gambiae* 6(23%)> *Cx. quinquefasciatus* 34 (13%*)*> *An. funestus* 32 (12.3%)> *Ae. aegypti* 20 (7.7%)> An*. maculipalpis* 10 (3.8*%)> An. quadrimaculatus* 9(3.4%)> *Cx. restuans* 8(3.1%)> Ae*. dorsalis* 6(2.3%)> Ae *vexans* 4(1.5%).

The aestivation of mosquito species in the different breeding habitats is variable. For instance, *Aedes vexans* was not encountered in Bosso and Maitumbi just as *Anopheles quadrimaculantus* and *Culex restuans* were not found in

Chanchaga and Maitumbi respectively. However, *Culex pipiens pipiens, Anopheles gambiae*, and *Anopheles funestus* occurred more abundantly in Chanchaga. Generally, *Aedes dorsalis* and *Anopheles quadrimaculatus* occurred in very low proportions in all the breeding habitats.

The distribution of *Aedes* species were not significantly different (P>0.05) in the four rice fields except for *Aedes aegypti.* However, the densities and seasonal adaptive distribution of *Anopheles and Culex* species showed no significant difference (P>.0.05) between the studied rice fields except for *Anopheles funestus* and *Culex quinquifasciatus.*

Table 2: Adaptive Distribution of Mosquito Species (Mean ±SE) Aestivating in Rice fields in Minna during the Dry Season

Mosquito species	FADIKPE	BOSSO	MAITUNBI	CHANCHAGA	AGGREGATE
Aedes aegypti	1.17±0.17 [a]	0.67±0.21 [b]	0.50±0.22[b]	1.50±0.56 [a]	0.96±0.18
Aedes dosalis	0.17±0.17 [a]	0.17±0.17 [a]	0.17±0.17 [a]	0.50±0.22 [a]	0.25±0.09
Aedes *vexans*	0.33±0.21 [a]	0.00±0.00 [a]	0.33±0.00 [a]	0.33±0.21 [a]	0.17±0.08
Anopheles gambiae	2.50±0.34 [ab]	1.83±0.40 [b]	2.00±0.63 [b]	3.66±0.67 [a]	2.50±0.29
Anopheles funestus	1.00±0.26 [a]	1.50±0.34 [a]	1.00±0.26 [a]	1.83±0.31 [a]	1.33±0.16
Anopheles quardrimaculatus	0.33±0.21 [ab]	0.83±0.30 [a]	0.50±0.22 [ab]	0.00±0.00 [b]	0.42±0.11
Anopheles maculipalpis	0.33±0.21 [ab]	0.33±0.21 [ab]	0.17±0.17 [b]	0.67±0.21 [a]	0.37±0.10
Culex pipiens pipiens	3.83±1.01 [a]	2.83±0.75 [ab]	2.33±0.71 [b]	4.00±1.59 [a]	3.25±0.52
Culex quinquaefasciatus	1.83±0.60 [a]	1.67±0.33 [a]	1.67±0.31 [a]	1.00±0.37 [b]	1.42±0.21
Culex restuans	0.66±0.21 [a]	0.17±0.17 [b]	0.00±0.00 [b]	0.40±0.24 [ab]	0.30±0.09

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

Table 3 shows the correlation analysis of the relationship between distribution of mosquitoes in rice fields during the rainy and dry seasons. During the rainy season, *Anopheles* mosquitoes correlated negatively with *Aedes* and *Culex*, while *Aedes* correlated positively with *Culex*. All such correlations were however, strong. But for dry season aestivating mosquitoes*, Aedes* correlated positively and strongly with *Anopheles* and *Culex*, and a weak positive correlation also exist between *Anopheles* and *Culex.*

Table 3: Correlation between the distribution of mosquito species in rice field during rainy and dry seasons

Variables Combination	Seasonal Period	
	Rainy season	Dry season
Aedes Vs Anopheles	-0.866*	0.694
Aedes Vs Culex	0.738	0.819*
Anopheles Vs Culex	-0.612	0.355

* indicates strong correlations.

DISCUSSIONS

Ten species of mosquitoes were encountered with considerable variation in their distribution among the sampled Rice fields in Minna. Result of this study demonstrated co-existence of *Aedes, Anopheles* and *Culex* mosquito larvae in the same rice field aquatic habitats. This confirms an earlier work by [13] who found pests and vectors of *Anopheline* and *Culicine* mosquito species in association with rice field habitats.

The major concern about Rice field is that it may serve as breeding sites for potential mosquito vectors for all seasons. Unfortunately, the major species of mosquitoes (i.e., *Aedes, Anopheles* and *Culex)* that are capable of transmitting diseases are found coexisting in the rice agro ecosystem of Minna. In a similar research, [14] reported a list of 60 species of mosquitoes that have been found positive for west Nile virus to include rice fields species such as *Ps. Columbiae, An. crucians, An quadrimacultus, Cx. erraticus* and *Cx salinarius*.

Mosquito breeding activities in conventional larval habitats in Minna is heterogeneous, with the swamps been the most active source of mosquito production [15]. [13] reported that proximity and number of host animals, water quality, presence and absence of water current, degree of shading and plant composition and the density and height of crops are factors that encourage oviposition by female mosquitoes. The rice fields in Minna provides good breeding sites for mosquitoes as they provide water with organic content, nearby pastures (with mammal host), shade and plant biomass for protection against predators, thereby increasing the survival rate of adult mosquitoes.

The distribution of mosquito species in Rice fields in Minna revealed that, *Culex* species was dominant among the three mosquito *genera*, with *Culex pipiens pipiens* taking the lead. This affirms the results of some previous works ([15]; [16]). The abundance and distribution of *Anopheles* species in Minna was second only to *Culex* with *Anopheles gambiae* taking the lead similar to the findings of [17] in Abeokuta, Nigeria and [18] elsewhere in Serbia. However, studies on mosquito diversity in Imo state, South east Nigeria, provides contradictory information as [19] reported the abundance and distribution of mosquito species in the following order of decreasing abundance: *Anopheles gambiae* (39.6%)> *Anopheles funestus* (18.5%)> *Culex quinquefasciatus* (13%) >*Anopheles Pharoensis* (19%)> *Aedes aegypti* (8.5%)> *Culexx Pipien fatigans* (6%)> *Anopheles rhodesiensis* (2.49%)> *Culex trigripe* (2%). Perhaps, polluted gutters and drainages that empty into wetland rice fields, in Minna provided preferential breeding sites for *Culex* mosquitoes, as [15] earlier reported that *Culex* mosquitoes are known to prefer polluted water for breeding. However, *Anopheles* mosquitoes thrive very well in these rice fields, making their abundance second only to *Culex*. The relationship between the three mosquito genera (i.e, *Aedes, Anopheles* and *Culex)* and the diseases they transmit is not established in this work, but [20] and [15] previously incriminated *Anopheles* mosquitoes in malaria transmission in Minna, North Central Nigeria.

However, there were no previously published reports on the distribution of mosquito species in Minna rice fields to provide information for comparison. Meanwhile, the distribution and relative abundance of *Culex* and *Anopheles* mosquitoes were not significantly different (P>0.05) among the rice fields larval habitats. Thus, confirming the findings of [20].

The result of this study shows that both the three mosquito genera (i.e *Aedes, Anopheles* and *Culex*) aestivated in the rice fields during the dry season, thereby constituting an active dry season refugia reservoir of mosquito-vectors in the city. This result can be juxtaposed to some extent, with the findings of [21] who posited that egg aestivation is typical for *Ochlerotatus, Aedes* and *Psorophora,* while *Anopheles* and *Culex* undergoes larval and adult aestivation respectively. The findings further confirmed the work of [22], who evaluated the contribution of aestivating mosquitoes to the persistence of Anopheline malaria vectors in the Sahel and revealed that aestivating mosquitoes constituted the main source of the population of vectors after the 6-7 months of long dry season.

The correlation analysis of the relationships between the abundance of mosquitoes in rice fields during the rainy season shows that *Anopheles* mosquitoes correlated negatively with *Aedes* and *Culex,* while *Aedes* correlated positively with *Culex.* But for dry season aestivating mosquitoes, *Aedes* correlated positively and strongly with *Anopheles* and *Culex* as well as a positive correlationt between *Anopheles* and *Culex.* This implies that, an increase in the population of *Anopheles* mosquitoes, decreases the abundance of *Aedes* and *Culex* during the rainy season, and this explains why malaria fever is more prevalent than any other mosquito-borne diseases during the rainy season. On the contrary, there is the possibility of equal prevalence of mosquito-borne diseases in the dry season, because the abundance of all the three mosquito types increased simultaneously during the dry season.

CONCLUSION

The rice-fields in Minna are active rainy season breeding and dry season refugia sites for the three principal mosquito vector genera. While *Culex* species dominated the mosquito collections, *Anophiline* malaria vectors also thrived in this habitat type, with its attendant public health threat in the area. Inter-genera competition for breeding during the rainy-season favoured the anophiline mosquitoes, suggesting superior adaptive plasticity of malaria vectors in the area. Thus, there is an urgent need for an effective mosquito larvicidal program for vector control in rice-fields in Minna, for sustainable rice production.

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