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Aedes (Stegomyia) Mosquitoes in the Ashanti Region of Ghana: Implications for Yellow Fever Paucity

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Abstract
A research was carried out to map *Aedes* mosquito vectors of Yellow Fever (YF) in 4 localities (KNUST, Ejisu, Angola and Akropong) in the Ashanti Region of Ghana to identify and catalogue the various species of *Aedes* mosquitoes that may occur in the Region. This is to ascertain possible factors (both physical and biological) that may influence the population densities of *Aedes* mosquitoes and the possible reasons for the paucity of YF in the Region. Several species of *Aedes* mosquitoes were encountered and identified. Of all the mosquito species identified, *Aedes aegypti* was the predominant (81%). This was followed by *Aedes vittatus* (3.3%) and *Toxorhynchites brevipalpis* (3.1%). The bulk of the other mosquitoes apart from *Aedes* and *Toxorhynchites brevipalpis* was only 9.5%. The research analyzed the output of elliptical profile model generated for 4 *Aedes* vectors (n=2,7492) and 4 sample locations. Analysis of the model output reveals that the standard deviational ellipse is significantly better able to predict the linear distribution of *Aedes* populations within the geographical region. The relationship between the orientation of the elliptical profiles and the mean linear orientation of the corresponding quarters was assessed to reveal a moderate but significant association. These findings demonstrate that the sample locations vis-à-vis pH concentration impact on the distributions of *Aedes* within the geographical area and supports the ecological variability within the sample locations.
Keywords: Yellow Fever, *Aedes* mosquitoes, *Toxorhynchites brevipalpis*, pH Range, GIS

1. Introduction

Aedes mosquitoes are creating problems all over the world and people are dying from Yellow Fever (YF) disease. Several strategies - physical, chemical, cultural and biological - are required to confront this problem. In line with this, the current research was carried out to study and map out *Aedes* (Stegomyia), vectors of YF in the Ashanti region of Ghana.

About 90% of an estimated 200,000 annual cases of YF occur in Africa, where outbreaks are common (WHO 2003, WHO 2011). The disease is endemic throughout West Africa (Boyce 1911) and in Ghana, records of the number of cases (morbidity) and deaths (mortality) for the past 40 years confirm that this is so. Yellow fever epidemics in Ghana occur almost entirely north or south of the belt (Scott 1965) and are considered to be the urban type (Agadzi, Boakye et al. 1984). The disease recurs every 10-12 years and mostly during the rainy season (Scott 1965).

Yellow fever causes degeneration of the tissues in the liver and kidneys. Symptoms include chill, headache, pains in the back and limbs, fever, vomiting, constipation, reduced flow of urine which contains a high level of albumin and jaundice. Yellow fever often proves fatal and attacks both male and female. The disease may present two distinct epidemiological patterns, namely, the urban type and the jungle or sylvan type.

In the classical urban type of Yellow Fever, man serves both as the natural vertebrate reservoir and amplifier and, therefore, the source of infection to susceptible mosquitoes. The domestic mosquito *Aedes aegypti* which breeds predominantly in small collections of water in the vicinity of human dwellings is virtually the exclusive natural vector. In the jungle or sylvan type Yellow Fever with particular reference to Africa, the YF virus is maintained by natural cycle involving wild arboreal primates *Cercopithecus* and *Colobus* monkeys, and mosquitoes. The most important mosquitoes involved in this type of Yellow Fever cycle are *Aedes* (Stegomyia) *africanus* (Theobald) and *Aedes* (Stegomyia) *simpsoni* (Theobald). *Aedes africanus* is known to bite monkeys readily (Headow and Dick, 1948) and is dominant forest canopy mosquito (Smithburn and Haddow

1949) which maintains Yellow fever cycle with non-human primate hosts and occasionally cause Yellow fever outbreaks when it bites man.

It is known that of all the Yellow Fever epidemics which developed in Ghana in 1977 to 1979 and 1983 (Agadzi, Boakye et al. 1984; Addy, Minami et al. 1986; Baffoe 1987) 2007, 2011 (WHO, 2012), none were recorded in the Ashanti Region. From 1990s to date there were no Yellow Fever cases (WHO 2005; WHO 2007, 2013). An earlier work on YF in Ghana between 1900-1960 shows the same report (Scott 1965).

The objectives of this research were to identify and map out the distribution of *Aedes* mosquitoes in selected localities within and surrounding University Campus as a target for control measures, determine the pH concentration and predatory activities on *Aedes* mosquitoes in the region and explain possible contributory factors associated with Yellow Fever in the wild.

2. Description of the Study Area

Apart from the KNUST, Anloga, Akropong and Ejisu were selected as the study areas because of ecological variations, the urban nature of Kumasi and the proximity of the rural towns to the University campus. However, the bulk of the work in the Kumasi area was concentrated on the University campus and Anloga, a suburb.

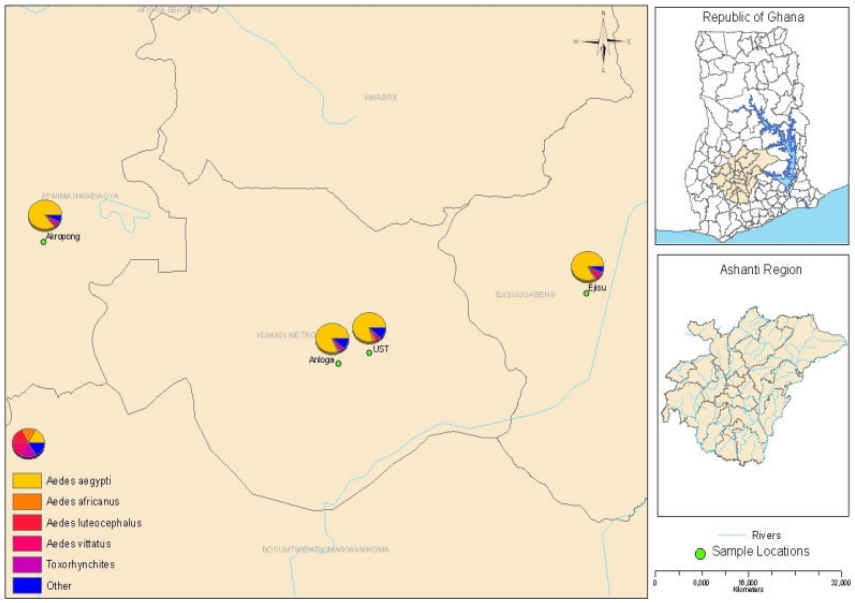

Figure 1: Map of the study area (KNUST, Anloga, Akropong and Ejisu) showing the type of mosquito species in the various locations.

2.1 The Kumasi Area

The area is on a low plateau of about 300 metres above sea level. The plateau is dissected by a number of streams, for example Subin River, Denyame River, Kwadaso River, Aboabo River and Sisai River so that on the plateau are ridges which form the main built-up areas. The immediate banks of the streams are marshy and some have been drained and developed. In Ashanti Region however, the main rivers are Afram and the Ofin River which is the boundary.

Between Central Region and Ashanti region, Lake Bosumtwi is in South-East of Kumasi and the Volta Lake extends into its eastern part. Also the Pra River is the boundary between Ashanti and Eastern Region.

There is the Ashanti section of the Koforidua-Mampong escarpment, and also in the sougthern parts are some highlands (Boateng 1970). The land slopes from about 300 metres in the north to 150 metres in the south. There are several hills and ranges which stand above the general level in some places. Some of these hills rise between 500 and 850 metres above sea level. Two of the most prominent of these ranges are the Adansi mountains, extending south-westwards from the Lake Bosumtwi and the range between Nsuta and Bibiani, 40 kilometres west of Kumasi. The North-east to Southwest trend which is repeated by almost all the other ranges in the region appears to correspond to the direction of folding in ancient geological times (Boateng 1970). The present ranges seem to be largely the result of prolonged erosion working on rocks of varying hardness.

Kumasi is located in the centre of the southern part of Ghana and because of its location several roads converge on it from Accra, Atebubu, Sunyani, Bibiani, Dunkwa and Cape Coast. It is also the converging point of the 2

main railway lines in Ghana, namely the Western line from the Sekondi-Takoradi and the Eastern line from Accra.

The climate is semi-equatorial type. Rainfall is about 145 centimetres (1450 millimetres) per annum and provides ideal condition for deciduous forest. Rainfall is not evenly distributed. There are some months with heavy rainfall and others little. The two rainfall seasons are: March to July and September to November. The seasons are separated by relatively dry periods. The long dry period starts from December to February and the short dry period of July and August. Rainfall is variable annually, seasonally and monthly. Rainfall can be torrential and especially in the evening. The weather is generally cloudy in the rainy season and fine in the dry seasons and in the mornings.

The maximum average annual temperature is 21^0C. The highest temperature is experienced between February and March when the average is about 32.2^0C. The minimum temperature is mainly in December and January when it is 19.4^0C and 20.0^0C respectively and in August when it is about 20.5^0C.

Kumasi experiences the harmattan from December to early February when the weather is dry and hazy. It is also cool in the night.

Vegetation is semi-deciduous type with some of the trees shedding their leaves at different times so that the forest appears evergreen throughout the whole year. There is very little sign of the original vegetation in the Kumasi area, and much of it having given way to Farms.

2.2 The University Campus (KNUST)

The campus is situated on 17.92 square kilometres piece of undulating land about 6.4 kilometres from Kumasi along Accra-Kumasi Road. The campus has modern buildings interspersed with lawns and tropical flora such as *Poincitia regia* Boj (Flambouyant) *Peltophorum pterocarpum* Backer (Rust tree) *Largestroema speciosa* Linn. (Queen flower), *Roystoneo regia* (Royal palm); *Tectona grandis* Linn. (Teak) *Magnifera indica* Linn (Mango). In addition to this is a 10 acre Botanical garden which gives the area the semblance of a forest. Examples of trees in the Botanical garden are: *Chlorophora. Excelsa* A. Shev. (Doum) *Bombax buonopozense* P. Beav; *Piptadeniastrum africacum* Hook *Musanga cecropioides* R, Br. and *Khaya grandifoliola.* C. DC.

The dominant trees that provide tree holes on the campus are *Poincinia regia* Boj (Flamboyant) *Pithecellobium saman* Benth (Rain tree) also provide a few trees holes. Other common trees scattered on the campus are: *Mechelia champaca* L. (Champaca); *Termindia catapa* Linn (Indian almond) *Magnifera indica* Linn. (Mango); Elaeis *guineensis* Jacq (Oil palm); *Psidium guajava* Linn and *Persea gratissima* Gaertn (Avocado pear). The banks of several streams flowing across the compound have been developed into irrigated farmlands, where vegetables such as lettuce, cabbage and melons are cultivated.

2.3 Anloga

A suburb of Kumasi is found 3.2 kilometres South-East of Kumasi. The area is about $0.5km^2$ and an elevation of 259.00-274.30 metres above sea level. Most of the tress have been destroyed in this area. Breeding grounds for mosquitoes are simply water receptacles, lorry tyres, drains and abandoned fish ponds. The soil is clay in texture.

2.4 Ejisu

It is a town of about 18 kilometres East of Kumasi. This area is 1.28 km^2 and the elevation is 274.30–289.50 metres above sea level. The vegetation is semi-deciduous forest with patches of derived savannah. The trees are scattered and provide few tree-holes suitable for mosquito breeding. In the various homes, there are many water receptacles which provide breeding grounds for mosquitoes. The soil is well drained over granite. The valley bottoms are clayey. The people are predominantly farmers, growing such cash crops as cocoa, and food crops like cassava, plantain and cocoyams.

2.5Akropong

A town of about 16 kilometres North-West of Kumasi. The area is about 0.64 km^2, and the elevation is 213 – 228.6 metres above sea level. Vegetation immediately around the town is derived savannah with elephant grass, *Panicum maximum* Jacq and spear grass P. *Deflexum schum*. There are few scattered trees especially flamboyant trees

Poincinia regia Boj and water receptables and drains in the town also provide breeding grounds for mosquitoes. The valley bottoms are clayey and acidic.

3. Materials and Methods

3.1 Identification of the Aedes Mosquitoes

Both adults and larvae of the *Aedes* mosquitoes were identified (Huang Yiau-Min & Ward 1981; MMCA 2002; Rueck 2004). Confirmatory tests for the species were made by identifying the second filial generation of the mosquitoes (both larvae and adults). Other mosquitoes collected during the study were identified (Hopkins 1952) and (Huang Yiau-Min & Ward 1981; MMCA 2002; Rueck 2004).

3.2 Mosquitoes in the Study Areas

Depending on the type of breeding ground, a siphon, a Pooter (aspirator), ladle or a Sweep net was used to collect some water sample to fill a 120 millilitre specimen bottle.

Specimens were taken from a wide range of receptacles such as tree-holes, lorry tyres, water tanks, household water containers, irrigation canals, crab-holes, rock pools, ground pools and ponds. The pH values of these receptacles were recorded.

Once a week, 20 specimens were randomly collected from various localities within the University campus. At least one specimen was taken from any of the following places: The botanical Garden, the irrigated farmland, Hall of Residence, Junior Staff Residence, an orange orchard, the Medical School premises and the Swampy areas. Another 20 specimens each were collected from Anloga, Akropong and Ejisu.

3.3 Feeding Preferences of Toxorhynchites brevipalpis

Experiment on the feeding preference of *Toxorhynchites* was made on the second instar larvae of *Aedes aegypti, Culex decens* and *Anopheles gambiae* mosquitoes, as preys.

Ten (10) fourth instar *Toxorhynchites* larvae were placed in 10 separate bottles of 120 millilitre capacity each. Exactly 20 larvae of each of the 3 mosquito species (as preys) were added to the bottles containing *Toxorhynchites* and left for 24 hours.

At the end of the 24 hour period, the numbers and types of mosquito larvae eaten or killed were counted. The killed or eaten larvae were constantly replaced by fresh ones and the experiment which was replicated 10 times was continued for 21 days and pH recorded

3.4 Field Studies of Toxorhynchites brevipalpis

Records of *Toxorhynchites* encountered on the field both on the KNUST campus and other Districts were recorded; but intensive field survey of *Toxorynchites* larvae was made on the KNUST campus in April, May and June 2012.

The temperature and pH of the stagnant water were determined by using thermometers, and pH meters respectively.

The distribution and predatory activities of the minor predators such as *Culex* (Lutzia) *trigripes*, Notonecta, Nepa sp. (Water scorpion), Hydrometra (Water stick), Belostoma (giant water bug) and Lispa (anthomyid fly), were observed but not studied.

3.5 Analysis of Data

The data were analysed statistically using analysis of variance, X^2 (Chi-sqared) and the F-test significance according to Hair *et al*; (1998). The least significance difference test (L.S.D) was further used to determine possible significance difference among means.

In order to assess the spatial heterogeneity in the estimated relationships between the dependent and independent variables, Geographical Weighted Regression (Fotheringham *et al*, 2002) analysis was run on the data by dividing the year into quarters (disaggregation) to predict the level of pH per location and also run the total of the data against pH and presented *in* Table 1.

Table 1 Analysis of Variance for pH values per location

ResidualSquares	0.57379278524				
EffectiveNumber	2.00819475716		NAME	VALUE	DESC_
Sigma	0.53672781942		Bandwidth	6.95015944663	
AICc	-5849.27709297000		ResidualSquares	0.74452760307	
R2	0.73769472675		EffectiveNumber	2.00897011382	
R2Adjusted	0.60492331136		Sigma	0.61150711195	
Dependent Field	0.00000000000	PH_LEVEL	AICc	-5342.70147783000	
Explanatory Field	1.00000000000	1QTOTAL	R2	0.65964452431	
			R2Adjusted	0.48716669993	
			Dependent Field	0.00000000000	PH_LEVEL
			Explanatory Field	1.00000000000	4QTOTAL
NAME	VALUE	DESC_			
Bandwidth	6.95015944663				
ResidualSquares	0.45124731365		NAME	VALUE	DESC_
EffectiveNumber	2.00888968600		Bandwidth	6.95015944663	
Sigma	0.47605776542		ResidualSquares	0.46115478438	
AICc	-5393.17584519000		EffectiveNumber	2.00891669488	
R2	0.79371551376		Sigma	0.48125875576	
R2Adjusted	0.68919177689		AICc	-5376.76429876000	
Dependent Field	0.00000000000	PH_LEVEL	R2	0.78918638428	
Explanatory Field	1.00000000000	2QTOTAL	R2Adjusted	0.68236344229	
			Dependent Field	0.00000000000	PH_LEVEL
			Explanatory Field	1.00000000000	TOTAL

NAME	VALUE	DESC_
Bandwidth	6.95015944663	
ResidualSquares	0.44746766897	
EffectiveNumber	2.00887427945	
Sigma	0.47405801050	
AICc	-5402.56599335000	
R2	0.79544335133	
R2Adjusted	0.69179748939	
Dependent Field	0.00000000000	PH_LEVEL
ExplanatoryField	1.00000000000	3QTOTAL

A linear transformation was then applied to the random variables to create a new random variable which was used in the directional distribution (SD Ellipse) model (Fotheringham 2002).

4.0 Results

4.1 Identification of the Aedes Mosquitoes:

The mosquito species identified during the research in the study area were as follows: *Aedes* (Stegomyia) *aegypti*. Linnaeus; *Aedes* (stegomyia) *africanus* Theobald; *Aedes* (Stegomyia) *luteocephalus* Newstead; Aedes

(stegomyia) *vittatus* Bigot. The other mosquitoes identified were as follows: *Culex* (Culex) *decens* Theobald, *Culex (Culex) thalassius,* Theobald, *Culex* (Lutzia) *tigripes* Grandpre, *Anopheles gambiae* S.I and *Toxorhynchites brevipalpis* Theobald.

4.2 Mosquitoes Collected in the Study Area

A list of the various mosquitoes and the pH of their respective habitats is presented in Table 2

Table 2: Comparison of monthly Larval mosquito species in four localities (Anloga, Ejisu, KNUST, Akropong) in the Ashanti Region showing population of various mosquito species and the pH of their respective habitats.

Month	Mosquito spp.	Anloga	Ejisu	KNUST	Akropong	pH values	pH range	Totals	% monthly total
Jan	*Aedes aegypti*	23	12	4	3	6.3	6-7	42	62
	Ae africanus					7.5	7-8	0	0
	Ae luteocephalus					7.6	7-8	0	0
	Ae vittatus		5			8.3	8-9	5	7
	Toxorhynchites	2	1			6.8	6-10	3	4
	Other mosquitoes	15		2	1	7.2	6-8	18	26
	TOTALS	40	18	6	4			68	
Feb	*Aedes aegypti*	78	28	177	36	6.5	6-7	317	61
	Ae africanus	21	18	5	3	7.5	7-8	47	9
	Ae luteocephalus					7.6	7-8	0	0
	Ae vittatus	8	21	6	9	8.4	8-9	35	7
	Toxorhynchites	12				7.5	6-10	45	9
	Other mosquitoe	22				7.0	6-8	74	14
	TOTALS	141						520	
Mar	*Aedes aegypti*	623	850	1236	438	6.5	6-7	3147	88
	Ae africanus	10	7	23		7.5	7-8	40	1
	Ae luteocephalus		13			7.5	7-8	13	0.4
	Ae vittatus		120	7		8.5	8-9	127	3
	Toxorhynchites	36	25	33	18	8.2	6-10	112	3
	Other mosquitoes	25	31	166	26	7.3	6-8	248	7
	TOTALS	694	1046	1465	482			3575	
April	*Aedes aegypti*	208	309	997	150	6.5	6-7	1664	74
	Ae africanus	12	23	57	14	7.4	7-8	106	4.7
	Ae luteocephalus			9		7.5	7-8	9	0.4
	Ae vittatus		55	9		8.6	8-9	64	2.8
	Toxorhynchites	18	31	43	15	8.3	6-10	107	4.7
	Other mosquitoes	77		188	29	7.0	6-8	294	13
	TOTALS	315	418	1303	208			2244	
May	*Aedes aegypti*	404	530	1161	293	6.5	6-7	2388	86
	Ae africanus		17	28		7.5	7-8	45	2
	Ae luteocephalus					7.5	7-8	0	0
	Ae vittatus		21	23		8.5	8-9	44	1.6

	Toxorhynchites	**27**	19	30	12	8.7	6-10	88	3.2
	Other mosquitoes	**35**	15	108	31	7.5	6-8	189	6.8
	TOTALS	466	602	1350	336			2754	
June	*Aedes aegypti*	913	1045	1828	609	6.6	6-7	4395	87
	Ae africanus	15	36	61		7.3	7-8	112	2.2
	Ae luteocephalus			3	9	7.5	7-8	12	0.2
	Ae vittatus			57		8.3	8-9	57	1.1
	Toxorhynchites	51	36	48	25	8.9	6-10	160	3.2
	Other mosquitoes	71	21	183	13	6.8	6-8	188	5.7
	TOTALS	1050	1138	2180	656			5024	
July	*Aedes aegypti*	609	893	2055	532	6.5	6-7	4089	82.4
	Ae africanus	8	15	149	12	7.5	7-8	184	3.7
	Ae luteocephalus			4	3	7.8	7-8	7	0.1
	Ae vittatus		61	171	28	8.3	8-9	260	5.2
	Toxorhynchites	24	13	26	21	8.5	6-10	84	1.7
	Other mosquitoes	51	68	185	31	7.0	6-8	335	6.8
	TOTALS	692	1050	2590	627				
August	*Aedes aegypti*	728	850	1153	620	6.5	6-7	3351	76
	Ae africanus	21	12	75	6	7.5	7-8	114	2.6
	Ae luteocephalus					7.5	7-8	0	0
	Ae vittatus	32	73	83	46	8.5	8-9	234	5.3
	Toxorhynchites	53	17	35	28	8.8	6-10	133	3.0
	Other mosquitoes	91	125	264	76	7.0	6-8	556	12.7
	TOTALS	925	1077	1610	776			4388	
Sept	*Aedes aegypti*	815	683	1294	531	6.5	6-7	3323	77
	Ae africanus		12	86		7.5	7-8	98	2.3
	Ae luteocephalus	41			25	7.5	7-8	66	1.5
	Ae vittatus		56	57	16	8.5	8-9	129	3.0
	Toxorhynchites	31	12	42	17	9.3	6-10	102	2.4
	Other mosquitoes	165	124	270	21	7.1	6-8	580	13.5
	TOTALS	1052	887	1749	610			4298	
Oct	*Aedes aegypti*	318	416	590	215	6.4	6-7	1539	79.6
	Ae africanus			17		7.3	7-8	17	0.9
	Ae luteocephalus		31			7.5	7-8	31	1.6
	Ae vittatus	21		22	18	8.5	8-9	61	3.2
	Toxorhynchites	35	8	31	10	9.1	6-10	84	4.3
	Other mosquitoes	49	16	137		7.1	6-8	202	10.4
	TOTALS	423	471	797	243			1934	
Nov	*Aedes aegypti*	53	31	28	106	6.5	6-7	218	77
	Ae africanus			1		7.8	7-8	1	0.3

	Ae luteocephalus					7.6	7-8	0	0
	Ae vittatus	12	3	1	5	8.5	8-9	21	7.4
	Toxorhynchites	3	5	7	1	9.2	6-10	16	5.7
	Other mosquitoes	20		6		7.2	6-8	26	9.2
	TOTALS	88	39	43	112			282	
Dec	*Aedes aegypti*	36	**25**	14	53	6.6	6-7	128	58
	Ae africanus					7.5	7-8	0	0
	Ae luteocephalus					7.5	7-8	0	0
	Ae vittatus	5			5	8.5	8-9	10	4
	Toxorhynchites	1	**2**	2		9.1	6-10	6	3
	Other mosquitoes	23	**17**	17	28	7.3	6-8	77	35
	TOTALS	65	**44**	44	86			221	
GRAND TOTALS	*Aedes aegypti*	4808	**5672**	10537	3586	6.5	6-7	24603	81
	Ae africanus	87	**140**	502	35	7.5	7-8	764	2.5
	Ae luteocephalus	41	**44**	16	37	7.6	7-8	138	0.5
	Ae vittatus	78	**415**	436	118	8.5	8-9	1047	3.3
	Toxorhynchites	293	**177**	302	168	8.6	6-10	2887	3.1
	Other mosquitoes	644	**432**	1543	268	7.1	6-8	940	9.5
	TOTALS	5951	**6880**	13336	4212			30379	100

Aedes aegypti is the predominant (81%) and widely distributed mosquitoes in the 3 districts. This is followed by *Aedes vittatus* (3.3%) and *Toxorhynchites* (3.1%.). The bulk of other mosquitoes (apart from *Aedes* and *Toxorhynchites)* in all the districts add up to 9.5%. *Aedes vittatus* is mainly found in rock pools at UST campus. It persists throughout the year just as *Aedes aegypti* and *Toxorhynchites brevipalpis.*

The highest density of mosquitoes occurred between June and September when about 60.3% of the total insects were collected. With an average number of 16.5% the month of June, was the period of the greatest number of insects, while January with a percentage of 0.2% recorded the least number of insects. *Aedes aegypti, Ae vittatus* and *Toxorhynchites* were the most widely distributed and occur almost thoughout the year. The respective pH ranges and the various mosquito habitats were as follows: *Aedes aegypti* pH 6-7, *Aedes africanus* pH 7-8 *Aedes luteocephalus* pH 7-8; Aedes vittatus 8-9; *Toxorhynchites* pH 6-10. Other mosquitoes (mainly *Culex*) pH 6-8. *Aedes aegypti* appears to prefer acidic to neutral media while *Aedes africanus* prefer neutral to alkaline media. *Ae luteocephalus* prefer neutral to alkaline media. *Ae vittatus* prefers alkaline medium and *Toxorhynchite* can survive in both acidic and alkaline media.

In order to assess the spatial heterogeneity in the estimated relationships between the dependent and independent variables, Geographical Weighted Regression (Fotheringham *et al*, 2002) analysis was run on the data by dividing the year into quarters (disaggregation) to predict the level of pH per location and also run the total of the data against pH.

A linear transformation was then applied to the random variables to create a new random variable which was used in the directional distribution (SD Ellipse) model (Figure 2). The quarterly data was uniform but after aggregating the data for the directional distribution, it was different. This shows that aggregation and disaggregation are not linear transformation; and answers the question of Simpson's Paradox.

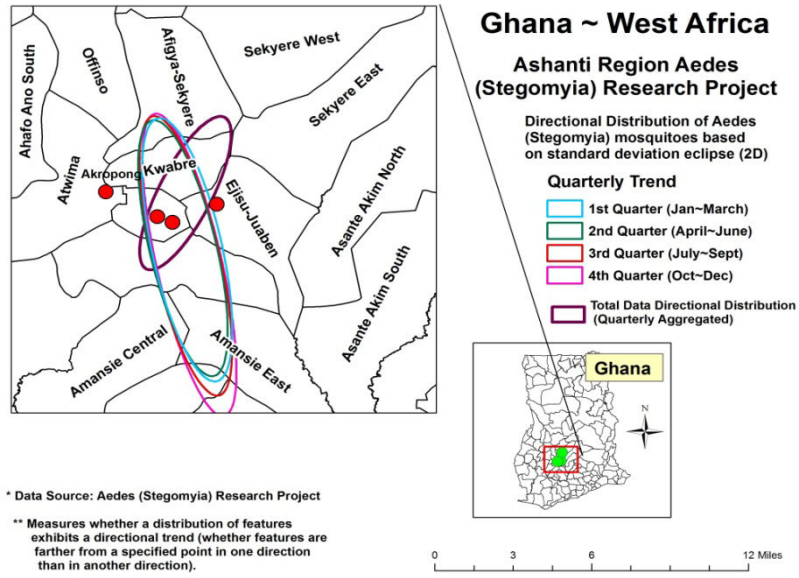

Figure 2 Directional Distribution of Aedes (Stegomyia) mosquitoes based on standard deviation eclipse (2D)

The data further suggests that, the physical site location has a deterministic effect on the density and distribution of Aedes *(Stegomyia)*. Although there was a slightly significant association between the dependent and independent variable upon disaggregation, it was limiting and there is a 1% likelihood ($p < 0.01$) that the dispersed pattern could be the result of random chance (Fig 3)

Figure 3 Average Nearest Neighbor Distance

Table 3 shows daily consumption of three types (breeds) of mosquitoes (*Aedes Aegypti, Culex decens,* and *Anopheles gambiae)* by *Toxorhynchites brevipalpis*. From this table, it is clear that *Toxorhynchites* prefers to feed on *Aedes Aegypti* to both *Culex decens* and *Anopheles gambiae.* The average daily consumption of the three brreds of mosquitoes by *Toxhorhynchites* for week 1 are 29.14 for *Aedes aegypti,* 11.29 for *Culex decens* and 12.43 for *Anopheles gambiae*. In week 2 the *Toxorhynchites* preferred to feed on the average 18.43, 6 and 9 *Aedes*, *Culex* and *Anopheles gambiae* mosquitoes respectively. The situation is the same in week 3; it preferred on the average 23.57 *Aedes*, 9.43 *Culex* and 11.14 *Anopheles* daily in week 3

Table 3: Feeding Preferences of *Toxorhynchites brevipalpis* on *Aedes aegypti*, *Culex decens* and *Anopheles gambiae*

Weeks	Days of expt	*Aedes aegypti*		*Culex decens*		*Anopheles gambiae*		Totals
		Total	**Mean**	**Total**	**Mean**	**Total**	**Mean**	
1	1	35	3.5	18	1.8	13	1.3	66
	2	27	2.7	8	0.8	12	1.2	47
	3	19	19	7	0.7	10	1.0	36
	4	38	3.8	14	1.4	15	1.5	67
	5	31	3.1	15	1.5	17	1.7	63
	6	26	2.6	12	1.2	8	0.8	46
	7	28	2.8	5	0.5	12	1.2	45
Total		204	29.1	79	11.3	87	12.4	370
2.	8	10	1.0	8	0.8	6	0.6	24
	9	17	1.7	3	0.3	5	0.5	25
	10	16	1.6	5	0.5	12	1.2	33
	11	21	2.1	3	0.3	8	0.8	32
	12	**25**	**2.5**	**7**	**0.7**	**12**	**1.2**	**44**
	13	19	1.9	8	0.8	9	0.9	36
	14	21	2.1	8	0.8	11	1.1	40
Total		129	18.4	42	6.0	63	9.0	234
3.	15	23	2.3	9	0.9	14	1.4	46
	16	15	1.5	10	1.0	8	0.8	33
	17	18	1.8	5	0.5	7	0.7	30
	18	31	3.1	12	1.5	15	1.6	51
	19	19	1.9	7	0.7	8	0.8	34
	20	33	3.3	8	0.8	13	1.3	54
	21	26	2.6	15	1.5	12	1.2	53
Total		165	23.6	66	9.4	78	11.1	309
GRAND TOTALS		**498**	**23.7**	**187**	**8.9**	**228**	**10.9**	**913**

We conduct further statistical test to verify the claim that *Toxorhynchites* prefers *Aedes aegypti* to *Culex* and *Anopheles*.

To formulate our test, we let u_1 denote the mean number of *Aedes* mosquitoes consumed by *Toxorhynchites* daily, u_2 denote the mean number *Culex* consumed daily and u_3 denote the mean number *Anopheles* consumed daily.

To be specific, we test the null hypothesis

H_0: $u_1 = u_2 = u_3$;"there is no feeding preference for *Aedes*, *Culex* or *Anopheles* by *Toxorhyncites*" against the alternate Hypothesis

H_1: $u_i = u_j$, for at least $i \neq j$; "There is feeding preference for *Aedes*, *Culex* or *Anopheles* by *Toxorhynchites*"

Two-way Anova for our data using matlab package gives the following table

ANOVA TABLE

SOURCE	SS	DF	MS	F	PROB>F
columns	2726.38	2	1363.19	70.43	0
Rows	441.52	2	220.76	11.41	0.0001
Interaction	102.67	4	25.67	1.33	0.2721
Error	1045.14	54	19.35		
Total	4315.71	62			

We note that the columns represent the three breeds of mosquitoes namely, *Aedes*, *Culex* and *Anopheles* and rows represent weeks.

Now, the p-value of columns $p = 0 < 0.05$, so we fail to accept H_0 at 5% level of significance and conclude that there is feeding preference for *Aedes aegypti*, *Culex decens* or *Anopheles gambiae* by *Toxorhynchites*.

As p-value = 0.0001 < 0.05, we fail to accept the claim that there is no feeding preference for the three breeds of mosquitoes by *Toxorhynchites* over the three weeks.

However, the p-value for interaction p = 0.2721 > 0.05, so we accept the claim that there is no interaction between daily feeding preference for *Aedes*, *Culex* and *Anopheles* by *Toxorhynchites*.

We went on to find the particular breed of mosquitoes preferred by *Toxorhynchites*. Constructing a 99% joint confidence interval for difference in means u_1-u_2, u_1-u_3, u_2-u_3 we obtain [11.20, 18.42], [9.29, 16.52] and [-5.52, 1.72] respectively. Since 0 is not included in the first two intervals, we reject the claims "*Toxorhynchites* have equal feeding preference for *Aedes* and Culex", and "*Toxorhynchites* have equal feeding preference for *Aedes* and *Anopheles*" at 1% level of significance.

However, the last interval [-5.52, 1.72] includes 0, so we fail to reject H_0, the claim

"*Toxorhynchites* have equal feeding preference for *Culex* and *Anopheles*" at 1% level of significance.

Furthermore, we find the particular breed of mosquitoes more preferred by *Toxorhynchites*.

We test the null Hypothesis:

H_0: $u_1 = u_2$ "*Toxorhynchites* have equal feeding preference for *Aedes Aegypti* and *Culex decens*"

against the alternate hypothesis:

H_1: $u_1 > u_2$ "*Toxorhynchites* insects prefer *Aedes Aegypti* to *Culex decens* as food"

and the null hypothesis:

H_0: $u_1 = u_3$ "*Toxorhynchites* have equal feeding preference for *Aedes Aegypti* and *Anopheles gambiae*".

against the alternate hypothesis:

H_i: $u_1 > u_3$ "*Toxorhnchites* prefer *Aedes Aegypti* to *Anopheles gambiae*"

Using one tail-test, we obtain the calculated test statistics

$$T^* = \frac{23.7142 - 8.9048}{\sqrt{19.35} \times \sqrt{\frac{1}{21} + \frac{1}{21}}} = 10.9093$$

Since T* = 10.91 ≥ 2.423, we reject H_0 at 1% significance level, and conclude that *Toxorhynchites* prefers

Aedes aegypti to *Culex decens* as food.

Similarly, we have for the second test the calculated the test statistic

$$T^* = \frac{23.57 - 11.14}{\sqrt{19.35} \times \sqrt{\frac{1}{21} + \frac{1}{21}}} = 9.2628$$

Since T* = 9.2628 > 2.423, we fail to accept H_0 and conclude that *Toxorhynchites* prefers to feed on *Aedes aegypti* to *Anopheles gambiae*.

5.0 Discussions

Although it was not possible to survey all possible breeding places, it was necessary to locate most of the *Aedes* mosquito sites as accurately as possible so that circumstances favouring mosquito population may be known. The survey did not confine itself to the traditional domestic breeding places only, but also took into consideration the problem posed by warehouses, tyre dumps, rock pools and the installations of modern buildings.

Of all the mosquitoes identified, only *Aedes* (Stgegomyia) *vittatus* Bigot and *Toxorhynchites brevipalpis* Theobald were not recorded previously in the Ashanti Region. *Toxorhynchites* was the most widely distributed mosquito found and has a range of pH 6-10 in all the habitats investigated. The wide pH range of *Toxorhynchites* (pH 6.0 – 10.0) probably gives it a great advantage in colonizing varied habitats as a predatory agent for *Aedes* mosquito species and possibly the advantage of less competition among themselves and therefore enhances the control of *Aedes* mosquitoes in the wild. *Toxorhynchites* are known to survive long periods with little or no sustenance (food) (Dedge, 1964). Their ability to withstand starvation and desiccation permits this genus to survive through long dry spells without food in the region and demonstrates their effectiveness as biological control agents in the wild.

The Culex mosquitoes, (*C. decens, C. tarsalis)* were found in all the localities surveyed but were most numerous at Anloga, KNUST and Ejisu; KNUST registering the highest number (1088). This is probably because of the polluted drains which are favourable breeding grounds for Culex mosquitoes. The pH range for the Culex mosquitoes was pH 6-8.

Anopheles was found everywhere but dominant at KNUST probably because of the ponds, marshy areas and irrigated canals which normally favour the breeding of Anopheles gambiae mosquitoes (Goma, 1966) and the pH range was pH 6-7. Although in the 4 localities studies, *Aedes*, aegypti (81%) was the most dominant, *Toxorhynchites* (3.1%) was the most widely distributed in the study area.

The data further suggests that, the physical site location has a deterministic effect on the density and distribution of *Aedes* (Stegomyia). Although there was a slightly significant association between the dependent and independent variable upon disaggregation, it was limiting and there is a 1% likelihood ($p < 0.01$) that the dispersed pattern could be the result of random chance.

The distribution of the *Aedes* (Stegomyia) exhibit a shape and orientation that is not consistent with the underlying data points. The directional distribution (SD Ellipse) model accounts for these effects by utilizing basic geographical principles of central tendency and spatial diffusion.

The research analyzed the output of elliptical profile model generated for 4 *Aedes* vectors (n=27492) and 4 sample locations. Analysis of the model output reveals that the standard deviational ellipse is significantly better able to predict the linear distribution of *Aedes* populations within the geographical region. The relationship between the orientation of the elliptical profiles and the mean linear orientation of the corresponding quarters was assessed to reveal a moderate but significant association

6.0 Conclusion

These findings demonstrate that the sample locations vis-à-vis pH concentration does impact on the distributions of *Aedes* within the geographical area and supports the ecological variability within the sample locations. The fact that *Toxorhynchites brevipalpis* has a predatory preference for *Aedes aegypti* as compared to other *Aedes* mosquito species, a wide ecological variation and PH range indicates that it could also control *Aedes* aegypti in the wild. However more data are required for confirmation.

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REFERENCES

Addy, P. A. K., K. Minami, *et. al;* (1986). "Recent Yellow Fever Epidemics in Ghana (1969-1983)." East African Medical Journal 63(6): 422-434.

Agadzi, V. K., A. Boakye, *et. al;* (1984). "Yellow Fever in Ghana." Bulletin of the World Health Organization 62(4): 577-583.

Baffoe, A. W. (1987). Report on Yellow Fever Surveillance in the Brong Ahafo, Upper East, Upper West, Northern, Ashanti and Volta Region of Ghana. Accra, Ministry of Health, Epidemiology Division (Entomology Unit).

Boateng, E. A. (1970). A Geography of Ghana. Cambridge, Cambridge University Press.

Boyce, R. (1911). Corresspondence relating to a recent outbreak of Yellow Fever in West Africa C. O. C. D. HMSO.

Edward, F. W. (1951). Mosquitoes of the Ethiopian Region. London, British Museum of Natural History.

Fotheringham, A. S. B., C; and Charlton, M.E. (2002). Geographically Weighted Regression: the Analysis of Spatially Varying Relationship. Chichester, John Wiley.

Hopkins, G. H. E. (1952). Mosquitoes of the Ehiopian Region 1 Larval bionomics of mosquitoes and taxonomy of Culicine Larvae. London, British Museum of Natural History.

Huang Yiau-Min & Ward, R. A. (1981). "A pictoral Key for the identification of the Mosquitoes associated wityh Yellow Fever in Africa " Mosquito Systematics 13(2): 138-148.

MMCA (2002). Michigan Mosquito Manual Michigan Department of Agriculture 109 pp.

Rueck, L. (2004). Picktorial keys for the identification of mosquitoes (Diptera;Culicidae) associated with Dengue virus Transmission. auckland, NZ, Magnoria Press.

Scott, D. (1965). Epidemic Disease in Ghana. London, Oxford University Press.

Smithburn, K. C. and A. J. Haddow (1949). "The Susceptibility of African Wild Animals to Yellow Fever in Monkeys." American Journal of Tropical Medicine 29: 389-408.

WHO (2003). "Yellow Fever vaccine." Weekly Epidemiological Record 78: 349-360.

WHO (2005). "Progress in the control of Yellow Fever in Africa." Weekly Epidemiological Record 80(80): 49-60.

WHO (2007). "Assessment of Yellow Fever epidemic risk - a decision-making tool for preventive immunization campaigns." Weekly Epidemiological Record 82: 153-160.

WHO (2011). Yellow Fever fact Sheet No: 100 January 2011

WHO (2013). Yellow Fever in Ghana. Global alert Response – Disease Outbreak news