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Ecology of mosquitoes of Midwestern Nigeria

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Background & objectives: The ecology and distribution of various mosquito species is important in the determination of mosquito vector abundance and associated diseases prevalence. The distribution of various mosquito genera in natural and artificial habitats and their relative species abundance was studied between August 2002 and July 2003 in three foci (Uromi, Ekpoma and Auchi) comprising the Esan and Etsako regions of Midwestern Nigeria.

Methods: Sampling was carried out by the method of Hopkins (1952) by dipping using a pipette or ladle depending on container types. Pooled contents of smaller containers were sampled with a pond net. All breeding sources of mosquito larvae were grouped into five (5) depending on their nature, constitution and the physiochemical properties. Artificial mosquito cultures were also carried out in four different container types; plastics, metal cans, earthenware pots and bamboo strips, in parts of two different macro habitats subdivided into area of high human activities (AHHA) and areas of derived/secondary vegetation (ADSV). Environmental temperatures, rainfall and relative humidity were monitored during the study.

Results: The present study revealed 17 mosquito species belonging to three genera (*Anopheles, Culex* and *Aedes*) which are potential vectors of four human diseases in the areas surveyed. A total of 736 mosquito larvae were encountered in artificial sources and 568 larvae were harvested from natural sources. Pools, plastics and metal cans were the predominant artificial sources of mosquito larvae.

Conclusion: The contribution of human activities and increasing environmental modification to the breeding of human disease vector mosquitoes is of importance and selective vector control measures including larviciding are recommended particularly before onset of rainy season.

Key words Disease vectors – ecology – macro habitats – micro habitats – mosquitoes – Nigeria

Some aspects of human ecology greatly influence mosquito distribution[1], species relative abundance and their survival[2]. All mosquitoes breed in water more often quiescent. Often mosquito species groups, subgenus and genus have their own preferred habitat based on locations and conditions of the water body[3]. Hopkins[4] has classified such locations to include; ground pools—including small lakes, and weedy edge of swamps, springs, rivers, ditches and hoof prints. The composition of mosquito fauna of a pool is influenced by the temporary or permanent nature of the pools. Rock pools form a distinct class distinguishable into true rock pools and rock edged pools.

Small containers are often inhabited by a relatively consistent fauna included in this group are tree holes, including cut or bored bamboos, artificial containers including discarded tins, bottles, motor vehicle tyres and tubes, barrels, closed tanks, earthenwares of varying sizes and rain water drains. Also included are water collections in depression of fallen leaves, plant axils, leaf-axils, crab holes in banks of streams and seashores which are not too saline.

The physiochemical compositions of the water bodies are complicated and determine their condition and fauna composition. They include salts, dissolved inorganic and organic matter, degree of eutrophication, turbidity and presence of suspended mud. Others include presence or absence of plants, temperature, light and shade, hydrogen ion concentration, presence of food substances (living or dead), presence of predacious mosquito larvae, fishes, other insects, crustaceans and arachnids.

The purpose of this study carried out between August 2002 and July 2003 was to determine the various mosquito larva species, their seasonal distribution and relative abundance in natural and artificial habitats in three foci (Uromi, Ekpoma and Auchi) of Midwestern Nigeria.

Attempts were also made in the study to relate mosquito larva species abundance to human activities (macro habitats) and to preferred artificial breeding micro habitats. The main emphasis in the course of the investigations was on *Anopheles* species, a lot of information was also gathered on the relative abundance and breeding site preferences of culicine mosquitoes, parts of which are presented in this paper.

Material & Methods

The study areas were the Esan and Etsako regions of Edo State, Nigeria, located between approximately latitude 05º 44'N–07º 34'N and longitude 05º 04'E – 06º 43'E covering an estimated area of 20,000 km^2 with a projected population of 2.7 million people by 2002 (at a 3.17% growth rate from 1991 population census)[5,6].

After a preliminary survey two macro habitats were chosen, subdivided into areas of derived/secondary vegetation (ADSV) and areas of high human habitation (AHHH). Their subdivisions, detailed description of these areas and the various artificial mosquito culture methods and their standardisation are given elsewhere[7].

Natural and artificial breeding sources of mosquito species were grouped into five based on sources, containers and material types as follows : (i) plastic drums and containers, automobile tyres and tubes; (ii) metal cans, metal containers and abandoned automobile roof tops; (iii) clay pots /earthenware containers; (iv) pools—ground pools, rock pools, ditches and swamps; and (v) plant and animal shells, leaves stalk, leaf husks (maize), tree holes and bamboo stumps. Sampling of the various groups was done according to the method of Nwoke *et al* [8] and Hopkins[4].

Larval collection and standardisation: Larvae from smaller containers were collected by means of a ladle, or using a pipette depending on types of containers. Bigger and more elaborated pipettes were used for larger containers and pools. Pipettes made of glass cylinder about an inch in diameter had to its top attached a rubber bulb frame motor horn, the other end is narrowed by means of a cork. The tiny end of the glass tube is attached a six inches of rubber tubing as described by Hopkins[4].

This dipping method is highly recommended because of its relative ease[9]. In each large container like drums, 10 dips in different parts of the water were made and taken to constitute a sample. The contents of smaller containers of the same group in a compound or area were carefully pooled together into a plastic dish and sampled with a pond net. The larvae and pupae found were put into a plastic bucket containing a little water from the container and the rest poured back into their original containers. Samples collected were labeled according to the types of containers, the macro habitat and ecological foci. About 5 ml of water from the containers was also randomly collected aseptically into clean sterile specimen containers for physiochemical analysis. Identification and scoring of mosquito larvae were done with the aids of published keys of Hopkins[4] by comparing mosquito parts and identification features with published keys[10-12]. Mosquito species identification becomes easy using this method with practice. Larvae that could not be identified were bred to adults and then identified.

Climatic & metereological data: There are two distinct seasons in Midwestern Nigeria—a dry harsh harmattan season with low relative humidity, high environmental temperatures of 28–36°C with scanty or no rainfall (December–March) followed by a wet rainy season with abundant rainfall and flooding (April–October), with high relative humidity and lower environmental temperatures. The vegetation from coastal swamps along the River Niger, ranges between Ilushi and Warri delta areas. The rain forest area encompasses Uromi and Ekpoma with associated thick vegetation and a guinea savannah area ranging from Agbede to Auchi towns. Mean monthly environmental temperature, relative humidity and rainfall were monitored during the study. The mean monthly environmental temperatures ranged between 18°C and 39°C. The lowest environmental temperatures were observed between the months of July and September (19–29°C), while mean monthly temperatures for the months of October 2002 through January to July 2003 ranged from 30–39°C. The mean monthly relative humidity ranged between 21 and 84%. Mean monthly relative humidity was highest in the wet months of June–September (range 60–84%) and lowest in the dry months of November–February (range 21–23%). The mean monthly rainfall ranged from 0–294. The lowest rainfalls were observed between the months November and February. The highest monthly rainfall occurred between the months of March and October with a peak in July/August. The mean monthly distribution and relative abundance of *Anopheles, Culex* and *Aedes* mosquito species in the study is shown in Fig. 1.

Statistics: Mosquito species abundance were depicted in graphs, bar charts and differences in distribution of mosquito larvae in various habitats, locations and ecological foci were subjected to statistical analysis by student's *t*-test to determine their levels of significance.

Results

The present results demonstrated a total of 17 different mosquito larva species in a sampling of artificial and natural sources in the study area. Mosquito larva species harvested belonging to three genera were potential vectors of four human diseases. Fourteen different mosquito larva species were harvested in artificial sources amounting to 736 mosquito larvae with

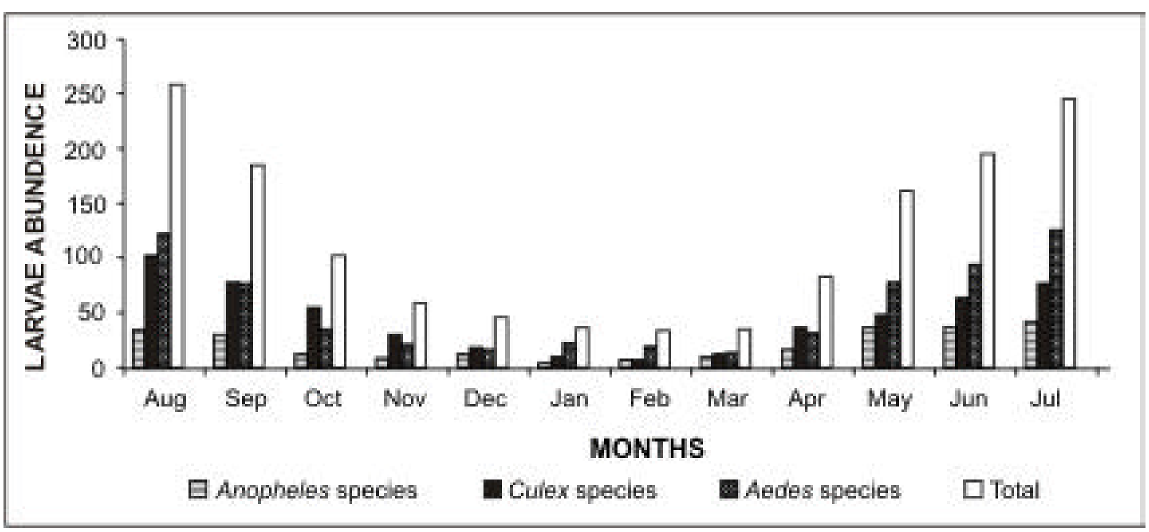

Fig. 1: Monthly distribution of *Anopheles, Culex, Aedes* and three mosquito genera larvae in the study (Aug 2002 to Jul 2003)

Table 1. Mosquito larva species in a sampling of artificial and natural sources in the study area

S. No.	Mosquito larva species	Natural sources (Receptacle types)	No.	Artificial sources (Container types)	No.	Total (General)	% in study area
1.	*An. pseudopunctipennis*	Pools, tree holes, leaves stalk and bamboo stumps	28	Plastic drums/containers, metal cans, clay pots and bamboo sticks	110	138	11.2
2.	*An. gambiae*	Pools, shells and tree holes	159	-do-	126	285	23.1
3.	*An. funestus*	Rock holes and leaves stalk	14	-do-	20	34	2.8
4.	*Ae. aegypti*	Pools, plants, shells and tree holes	41	Pools, rock holes, plants and animal shell, plastics, metals and earthenware containers	150	191	15.5
5.	*Ae. albopictus*	Leaves stalk, plant and animal shells	34	Automobile tyres and tubes	17	51	4.1
6.	*Ae. simpsoni*	Tree holes and leaves stalk	26	—	–	26	2.1
7.	*Ae. palpalis*	Plants and animal shells	16	Pools, puddles and metal cans	28	44	3.6
8.	*Ae. africanus*	Tree holes and plant shells	13	—	–	13	1.1
9.	*Ae. vittatus*	—	—	Plant and animal shells, pools and puddles	27	27	2.2
10.	*Ae. unlingeatus*	—	—	Pools, metals, plastics and bamboo sticks	18	18	1.5
11.	*Ae. luteocephalus*	Tree holes and leaves stalk	36	—	—	36	2.9
12.	*Cx. (p) fatigans*	Pools and plant shells	56	Pools, metals, plastics and earthenware containers	98	154	12.5
13.	*Cx. (p) quinquefasciatus*	—	—	Domestic runoffs, pools, metals and plastic containers	62	62	5.0
14.	*Cx. (p) pipiens*	Pools and leaves stalk	41	Metal cans, plastic cups, bamboo sticks	20	61	4.9
15.	*Cx. decens*	Leaves stalk and plant shells	34	Earthenware, metal and plastic containers	38	72	5.5
16.	*Cx. albovitrolus*	—	—	Earthenware, metal and plastic containers	15	15	1.2
17.	*Cx. perfuscus*	—	—	Pools and metal cans	8	8	0.6
	Total					1235	100

three *Anopheles* species accounting for 256 (34.8%), five *Aedes* species accounting for 240 (32.6%) and six *Culex* species accounting for another 240 (32.6%) of larvae harvested (Table 1).

There were 12 different mosquito species of the above three genera which were harvested in natural receptacles. These included three *Anopheles* species amounting to 201 (40.4%), six *Aedes* species amounting to 180 (23.3%) and three *Culex* species amounting to 131 (26.3%) of larvae harvested in natural habitats. There was a significant difference between larval abundance in natural and artificial habitats ($p < 0.01$).

Container types/receptacles related distribution of mosquito species showed plastic drums, bowls/containers, automobile tyres and tubes to support more sources of water used for mosquito larvae breeding in the area. A total of 568 (42.2%) mosquito larvae harvested belong to three genera—*Anopheles, Culex* and *Aedes* spp. Mosquito genera abundance in the study shows *Aedes* spp 654 (45.5%) to be most abundant followed by *Culex* spp 536 (37.3%) and *Anopheles* spp 248 (17.2%). There is a significant difference in the abundance of the three mosquito genera encountered in the study ($p < 0.05$).

Plastic wares had a significantly high breeding of *Aedes* and *Culex* species than that of *Anopheles* spp ($p < 0.05$). Clay pots and other earthenwares bred 264 (19%) of larva species encountered. Clay pots were more preferred breeding sites for *Anopheles* spp than *Culex* and *Aedes* spp. Ground pools and rock holes bred 167(12.4%) of larva encountered. These were preferred breeding sites for *Anopheles* spp (*An. gambiae* and *An. funestus*) and *Aedes* spp including *Ae. vittatus*.

Plants and animal shells, tree holes and leaves stalk-bred 101(7.5%) of larvae harvested. *An.pseudo-punctipennis* and *An. funestus* were among anopheline species encountered, while *Aedes* spp included *Ae. albopictus, Ae. palpalis, Ae. africanus* and *Ae. luteocephalus*.

The distribution of mosquito breeding material/sites in the three foci studied showed the university town of Ekpoma to have a higher distribution of these materials especially the plastic containers, metal cans/containers and construction associated ground /mud pools.

The relative abundance of *Anopheles* larvae species harvested during the study is depicted in Fig. 2. The mean monthly rainfall distribution, temperature and relative humidity were monitored at station 0606, lat 677 long 122, GMT 0.06 Irrua, Nigeria. This station is central and relatively equidistant from the three foci studied. The annual abundance of mosquito genera from comparative artificial cultures set up in two macro habitats (AHHA and ADSV) using four different

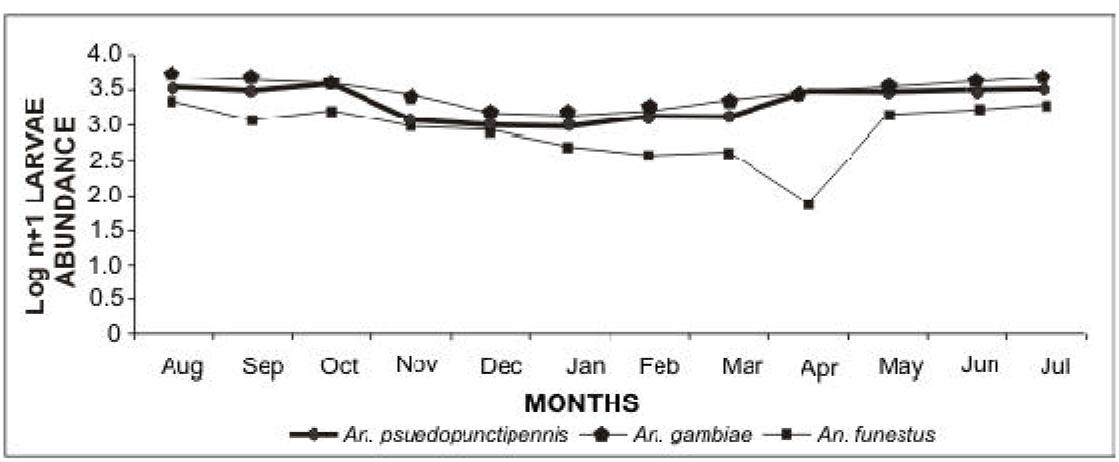

Fig. 2: Relative abundance of *Anopheles* larvae species harvested during the study

micro habitats (plastics, metal cans, earthenware containers and bamboo stumps) in the study, showed that AHHA accounted for 56,759 different larvae and ADSV 64,158 respectively. There was a significant difference between the mosquito larvae harvested from AHHA and ADSV ($p < 0.01$).

Discussion

Mosquito species use different natural and artificial habitats as sources of water for oviposition and breeding. These breeding sites are numerous in parts of Midwestern Nigeria due to varied human activities, poor economic conditions; low literacy levels, poor sanitation level and indiscriminate disposal of discarded household materials. The resultant effect is abundance of pools, ponds, puddles, water collections in tins, bowls, drums, clay pots and earthenware containers of varying sizes used for domestic water collection due to failure of regular water supply system. Their various other domestic uses include those used as cooking pots, drinking pots, food and beverages fermentation bowls, etc. These poor behavioural attitudes and practices are also responsible for indiscriminate disposal of household wastes, abundant number of abandoned construction sites and domestic runoffs. The containers also widely used for varying domestic activities especially cassava fermentation in the area supported breeding of culicine mosquitoes; this confirms an earlier report by Iwuala[13].

Seventeen different mosquito species were encountered in the sampling of artificial and natural sources in the study; 14 of these were harvested in artificial sources, seven of these were encountered in pools and rock holes including four *Aedes* spp *(Ae. albopictus, Ae. palpalis, Ae. unlingeatus* and *Ae. vittatus)* and three *Culex* spp *(Cx. albovitrolus, Cx. perfuscus* and *Cx. decens)*. *Culex (p) quinquefasciatus* was also harvested in sewage effluents, domestic runoffs and gutters. These were mostly in urban and semi-rural environments of the study area. *Anopheles* spp harvested in artificial sources include *An. pseudopunctipennis*, a closely related sibling of the American *An. punctipennis*. *An. pseudopunctipennis* is a major malaria vector in the forest parts of Midwestern Nigeria including Uromi, Ekpoma and Irrua. *An. gambiae* is a potential vector of yellow fever, arboviruses in general and as well the most important vector of malaria in the study area. *An. funestus* is also a malaria vector in the savannah parts of the study area. This species has been reported as the major malaria vector in the guinea savannah of northern Nigeria[9]. All three *Anopheles* spp encountered in the study are potential vectors of malaria, the most endemic parasitic disease in the study area.

Culex spp disease vectors encountered in the study include *Cx. (p) fatigans, Cx. (p) quinquefasciatus* and *Cx. (p) pipiens* which are known vectors of bancroftian filariasis and *Cx. decens* a potential vector of arboviruses in general. *Ae. aegypti, Ae. simpsoni, Ae. africanus, Ae. vittatus* and *Ae. luteocephalus* are potential vectors of yellow fever, while *Ae. aegypti* and *Ae. albopictus* are potential vectors of arboviruses in general.

Mosquito species related to natural breeding sites in the study were trees and rock hole breeders mainly *Ae. vittatus*.. While rock holes, pools, leaves stalk, plants and animal shells bred all *Anopheles* spp encountered. Pools, puddles and tree holes bred various *Culex* spp.

The relative abundance of *Anopheles* spp in both natural and artificial breeding sources indicates a higher potential for malaria transmission. Despite increasing awareness of malaria control measures in the area the disease remains most prevalent due to vector abundance and high vector potential.

A combination of lower parasite abundance and vector potential may be responsible for a far less disproportionate transmission rates for yellow fever, arboviruses and bancroftian filariasis. Previous outbreaks of yellow fever in Nigeria tend to occur in epidemic forms. Deforestation and a possible lack of the infective simian monkeys necessary in the transmission chain tend to have been the source of respite in the study area as the potential mosquito vectors are in abundance in the study area. More mosquito larvae were harvested in artificial than natural sources in this study indicating the importance of human activities, environmental modification, attitudes and practices on mosquito vector borne diseases transmission.

Plastic containers and drums bred the three mosquito genera encountered in this study, it is relatively more preferred by *Aedes* and *Culex* spp than *Anopheles* spp. The preponderance of plastic containers, automobile tyres and tubes may be due to the cheaper cost of plastic wares, second-hand (Tokumbo) tyres imported from Europe and a general poor waste disposal culture in Nigeria. This is commonly associated with predaceous *Aedes tigritis* in second-hand tyre markets and depots in Eastern Nigeria (Nwoke 2004 unpublished).

Previous reports[7,14,15] have shown earthenware material supported breeding of various mosquito species specially *Anopheles* spp in parts of Nigeria. In this study earthenware materials remain a favourable breeding habitat for *Anopheles* species specially *An. gambiae* and *An. pseudopunctipennis.* The contribution of clay pots and other earthenware materials to malaria endemicity in parts of Nigeria is yet to be properly elucidated.

Clay pots are widely used for cooking purpose as it keeps food warm for a longer period than aluminium pots. These are also used for storing drinking water specially in cool corners of houses as it is less subjected to environmental temperature changes and keep water cool for longer period where the inhabitant do not have or like the use of refrigerators. Other common uses include for fermentation of cassava and are also often littered around some street junctions containing food particles and other fetish substances used for sacrifices where they often have water collected in them. The physiochemistry of earthenware containers makes them one of the most preferred habitats by *Anopheles* spp in the study area. The indiscriminate disposal of these pots, plastic materials and tins and their domestic uses are contributing factors to difficulty in the control of mosquito.

The contribution of ground pools and rock pools to the breeding of mosquito species is well documented[4,8]. In this study also *An. gambiae*, and *An. funestus* were found breeding in ground and rock pools respectively. Not much is being done in the control of mosquito breeding in such places. In tree holes, mosquitoes encountered were mainly *Anopheles* and *Aedes* spp. The often recommended tree holes filling is not seen to be practiced any where in the study area.

More mosquito breeding sites and disposed wares containing water were recorded in the university town of Ekpoma, due to indiscriminate disposal of tins, cans, and plastic containers used for food and procuring cooking ingredients by students, workers and other inhabitants of the town. Also increased human development efforts associated with a lot of building construction activities is accountable for increasing the number of possible breeding sites in the study area.

A combination factors of abundant rainfall, tropical temperatures and a high relative humidity account for mosquito breeding throughout the year in the study area. Availability of water collections with suitable fauna, flora and physiochemical composition is a limiting factor to mosquito oviposition and breeding. A long duration of wet months (March–October), abundant breeding sites in a variety of domestic water collections, pools and construction sites increase mosquito vector abundance and vectorial capacity. Tropical temperatures encourage mosquito breeding by optimising the duration of its gonotrophic cycle. The optimal gonotrophic cycle of *Anopheles* spp in tropical countries like Nigeria is 3–4 days (unpublished report) which differs from a 5–7 days cycle recorded by Hitchcock[16] in Maryland, U.S.A. Extremes of temperatures and pH are however lethal to aquatic stages of mosquitoes, especially for larvae. High relative humidity as observed in the study, reduces desiccation from harsh environmental temperatures on mosquito breeding water collections.

The combination of favourable environmental temperatures, rainfall and high relative humidity are responsible for a higher number of mosquito larvae harvested at the onset of rainfall in April peaking in July/August and ending through a gradual fall in October. More *Aedes* and *Culex* mosquitoes species were recorded in the dry months of November to March than *Anopheles* species. It is common knowledge in the study area that there is usually an upsurge in reported cases of malaria; the most common mosquito vector borne disease in Nigeria during the wet months probably due to vector abundance. This support the work of Saloko[17] that incidence of malaria cases among school-aged children in some rural communities in Nigeria may be as high as 100%.

The contribution of human activities and increasing environmental modifications in the area to the breeding of mosquito vectors is of particular importance to efforts at mosquito vector control and selected measures including larviciding of breeding sites are among recommended measures to be implemented annually particularly a month before the onset of rainfall in the area to reduce the menace of mosquito vector borne diseases.

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