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Full Length Research

Studies of the Biological and Physicochemical Contents of Rock Pool Breeding Habitats of Mosquitoes: A Case Study of the University of Abuja Main Campus

OSHO Nafisat
Department of Biology,
University of Abuja,
Federal Capital Territory, Nigeria
Email: nafisatosho@gmail.com

HARUNA Newman Ojogbane
Department of Mathematics,
Federal University of Technology,
Minna, Nigeria.
Email: newmanenyoojo@gmail.com

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Abstract: Entomological surveys were conducted to determine the biological and physicochemical parameters influencing mosquito breeding in rock pools in University of Abuja Main Campus. A total of 4 study area were sampled for mosquito larvae using soup ladle dipper (0.105L). Three different species of mosquitoes where found during the survey which is Ae.aegypyi, Ae.vittatus, Cx. Ingrami. Ae.aegypti was found abundant in the four study sites. Biota and physicochemical (depth, temperature, pH, total dissolve solid, total suspended solid, turbidity, hardness, dissolve oxygen, biochemical oxygen demand, nitrate and alkalinity) parameters of the pools were determined. ANOVA showed that the abundance of mosquito larvae differed significantly with pH of each study area ($p<0.05$). The abundance of mosquito larvae did not differ significantly with depth, surface area, total suspended solid, hardness and turbidity of the rock pools ($p>0.05$). Epidemiologically, the mosquito species encountered are potential vectors of human and animal diseases, hence rock pools should be inspected to incriminate vectors and be incorporated in mosquito control strategies.
Keywords: Mosquitoes: Rock Pool Habitat: Temperature: PH; Ae.aegypyi: Ae.vittatus: Cx Ingrami.
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1.0 Introduction of the Study

Mosquitoes are probably the most notoriously undesirable arthropods with respect to their ability to transmit pathogens that cause human diseases such as malaria, dengue, yellow fever, filariasis, viral encephalitides and other deadly diseases. In several parts of the world, the indirect effect of malaria and other mosquito-borne diseases accounted for more deaths as well as reduced production following work losses *(Rueda, 2008).* Emergence of new vector-borne disease entities and the resurgence of old ones are caused by several factors, which are ecological changes that increase vector densities, such as climate, immunity status of humans, human and potential vector population densities and the presence of suitable reservoir amongst others (Adebote *et al*., 2006). The increase in economic activities, tourism and human migration have led to more cases of the movement of both disease vectors and the pathogens they carry thereby increasing the biodiversity of mosquitoes around the world *(Manguin & Boete, 2010).*

Diversity of mosquito breeding environment stems from innate preferences shown by different taxa to the locations and conditions of various aquatic habitats (Adebote *et al*., 2008). Oviposition preferences of adult females and the ability of immature stages of mosquitoes to adapt to both biotic and abiotic environmental conditions of a given aquatic habitat determine the abundance and distribution of immature mosquitoes (Dejenie *et al*., 2002). Mosquitoes have diverse habits that allow them to colonize different kinds of environments. The immature stages of mosquito are thus found in a variety of aquatic habitats including ponds, streams, ditches, swamps, marshes, temporary and permanent pools, rock holes, tree holes, crab holes, lake margins, plant containers (leaves, fruits, husks, tree holes, bamboo internodes), artificial containers (tyres, tin cans, flower vases, bird feeders), and other habitats *(Rueda, 2008).* They can thrive in a variety of water conditions such as freshwater, brackish water and or any water quality (clear, turbid or polluted), except in marine habitats with high-salt concentration. Part of the problems militating against effective and sustained control of mosquitoes and the diseases transmitted by them is the overt advantages available to mosquitoes to breed in diverse aquatic media that are naturally occurring and or the creation of human activities. Rock pools are small bodies of water that undergo recurrent, variable wet-dry phases, making them temporary intermittent pools *(Levas, 2006).* The relatively small nature of rock pools and the few macroscopic biota constituents make it easier to determine their community structure. Rocky outcrops have a profound influence on the distribution and abundance of biodiversity worldwide (Lindenmayer *et al*., 2008). Such environments are well documented as biological hotspots which often support unique biotic communities and high levels of endemism. The composition of mosquito fauna of a pool is influenced by its temporary or permanent nature. The highly variable rock pool environment, with continuously changing abiotic and biotic conditions, therefore continuously tests the tolerance limits of the inhabitants (Jocque *et al*., 2010). The physicochemical compositions of 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. Other hydrologic factors that affect pre-imaginal mosquito populations in water are the 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 (Okogun *et al*., 2005). However, Huggett & Griffiths (1986) attempted to relate the communities occurring in rock pools with the extremes of salinity, hydrogen ion concentration, light and temperature occurring within them. They concluded that temperature was the most important of these parameters. Daniel & Boyden (1975) investigated diurnal variations in water pH, carbon dioxide, salinity, as well as temperature and oxygen concentration within intertidal rock pools and concluded that temperature and oxygen concentrations showed the greatest variation that were particularly important in controlling community structure.

The biological and physicochemical attributes of aquatic environments may alter adult mosquito vector competence (Kengluecha *et al*., 2005). Although aquatic habitats of mosquitoes encompass a broad and complex spectrum, the rock pools comprise a distinct group with unique ecological properties *(*Vezzani, 2007*)*. Rock pools form a distinct class distinguishable into true rock pools and rock edged pools (Okogun *et al*., 2005). Pool structure is determined by a complex set of biological and physical factors that interact to develop a patchy habitat (Wallenstein *et al*., 2010). Interactions between climate and geology (e.g. limestone, sandstone, granite) generally determine the morphology and hydrology of rock pool habitats, with hydro periods ranging from several days up to the whole year. Pool volume is usually small, resulting in strongly fluctuating environmental conditions, low conductivity and wide variations in pH (from 4.0 to 11.0) and temperature (from freezing point to 40°C) often with well-marked diel cycles (Wallenstein *et al*., 2010). Rock pools usually form in shallow depressions in the rock *(*Ranta, 1982*)*. Rock pools in general are oligotrophic systems open to nutrient inputs and outputs (Jocque *et al*., 2010). Even a brief rain shower may, depending on the topography, fill a rock pool to overflowing. They are mosaically distributed habitats characterized by unpredictable changes in their water contents *(*Ranta, 1982). Enrichment happens mainly through bacterial degradation of dead aquatic organisms, faeces from large (terrestrial) vertebrates and organic material blown in. Immediately after filling, dissolved nitrogen and phosphorus concentrations may be quite high, but decline quickly because of nutrient uptake by organisms and a reduced rate of nutrient supply from the sediment (Jocque *et al*., 2010). The algal composition in rock pools exhibit a marked gradient in many places, with green algae dominating pools that occur higher on the shore, whereas brown and red algae are dominant at lower shore levels, where common species from the adjacent subtidal communities occur (Wallenstein *et al.*, 2010). In rock pools, Metaxas & Scheibling (1993) showed that competitive hierarchies involving 3 species of Daphnia can lead to competitive exclusion. Rock pools harbour freshwater communities and are located higher on the shore between the rocky intertidal and terrestrial habitat. Because of the comparatively small spatial dispersal capacity of mosquito larvae, larval control is the principal and most effective tool for mosquito-borne disease management (Siobhan *et al*., 2009). However, in other to critically audit the environment for the sources of mosquito that may be involved in disease transmission include searches of aquatic habitats in rock pools amongst several other breeding sites and determination of factors that support habitation (Adebote *et al*., 2008). The biological and physicochemical factors affecting the breeding of mosquitoes in rock pool habitats have been the subject of rather little ecological interest and research. This could be attributed to the relative inaccessibility of these productive mosquito habitat types that should be given priority in mosquito abatement programmes. Few attempts have also been made to describe the distribution patterns of rock pool biotas in relation to any suspected influence of physicochemical conditions to which the pools are subject and how these in turn affect species composition and relative abundance of pre-imaginal mosquitoes. Typically, in areas where mosquito breed in rock pools, not every pool is often colonized by juvenile stages to the extent that several apposed pools could be devoid of mosquito while few other neighboring pools have high density of larvae. Such disjointed larval colonization has not been fully investigated to unravel its ecologic undertone and potential applicability in control.

2.0 Review of Literature

Mosquitoes

Mosquitoes are members of a group of about 3,500 species of small flies within the family Culicidae (from the Latin *culex* meaning "gnat"). The word "mosquito" (formed by *mosca* and diminutive *–ito*) is Spanish and Portuguese for "little fly". Mosquitoes have a slender segmented body, one pair of wings, one pair of halteres, three pairs of long hair-like legs, and elongated mouthparts (Siobhan *et al*., 2009). The mosquito life cycle consists of egg, larva, pupa, and adult stages. Eggs are laid on the water surface; they hatch into motile larvae that feed on aquatic algae and organic material.

The adult females of most species have tube-like mouthparts (called a proboscis) that can pierce the skin of a host and feed on blood,which contains protein and iron needed to produce eggs. Thousands of mosquito species feed on the blood of various hosts vertebrates, including mammals, birds, reptiles, amphibians, and some fish; along with some invertebrates, primarily other arthropods. This loss of blood is seldom of any importance to the host (Adebote *et al*., 2008). The mosquito's saliva is transferred to the host during the bite, and can cause an itchy rash. In addition, many species can ingest pathogens while biting, and transmit them to future hosts. In this way, mosquitoes are important vectors of diseases such as malaria, yellow fever, Chikungunya, West Nile, dengue fever, filariasis, Zika and other arboviruses. By transmitting diseases, mosquitoes cause the deaths of more people than any other animal taxon: over 700,000 each year. It has been claimed that almost half of the people who have ever lived have died of mosquito-vectored disease, but this claim is disputed, with more conservative estimates placing the death toll closer to 5% of all humans (Adebote *et al*., 2008).

Morphology of Mosquitoes

As true flies, mosquitoes have one pair of wings, with distinct scales on the surface. Their wings are long and narrow, as are their long, thin legs. They have slender and dainty bodies of length typically 3–6 mm, with dark grey to black coloring. Some species harbor specific morphological patterns. When at rest they tend to hold their first pair of legs outward. They are similar in appearance to midges (Chironomidae), another ancient family of flies. *Tokunagayusurikaakamusi*, for example, is a midge fly that look very much alike mosquitoes in that they also have slender and dainty bodies of similar colors, though larger in size. They also have only one pair of wings, but without scales on the surface. Another distinct feature to tell the two families of flies apart is the way they hold their first pair of legs - mosquitoes hold them outward, while midges hold them forward (Adebote *et al*., 2008).

Figure 2.1: Life Cycle of Mosquito

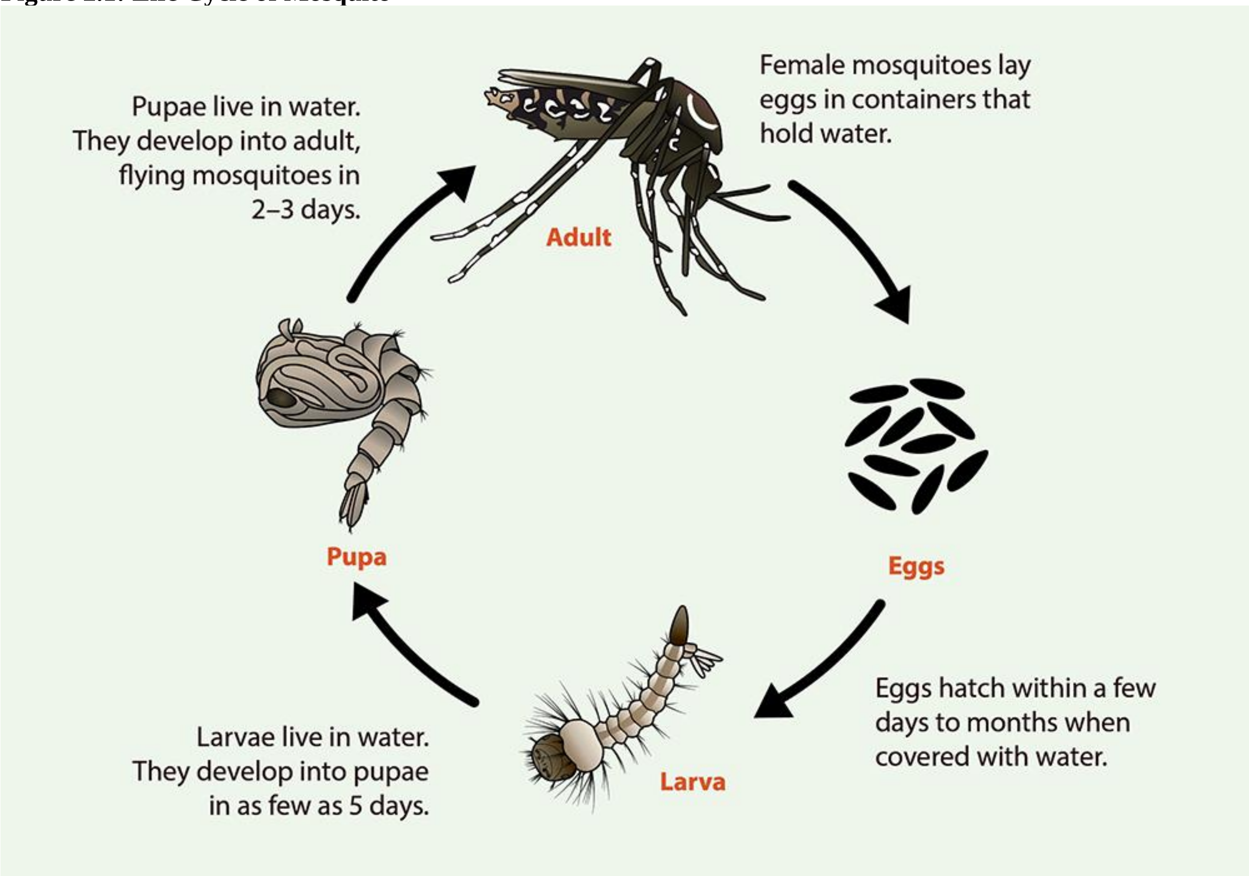

Plate 1: Life cycle of Mosquitoes (Shuaibu & Shuaibu, 2016)

2.1.1 Overview of the Study

Like all flies, mosquitoes go through four stages in their life cycles: egg, larva, pupa, and adult or imago. The first three stages—egg, larva, and pupa—are largely aquatic. Each of the stages typically lasts 5 to 14 days, depending on the species and the ambient temperature, but there are important exceptions. Mosquitoes living in regions where some seasons are freezing or waterless spend part of the year in diapause; they delay their development, typically for months, and carry on with life only when there is enough water or warmth for their needs. For instance, *Wyeomyia* larvae typically get frozen into solid lumps of ice during winter and only complete their development in spring. The eggs of some species of *Aedes* remain unharmed in diapause if they dry out, and hatch later when they are covered by water (Ojikutu & Kolo, 2011). Eggs hatch to become larvae, which grow until they are able to change into pupae. The adult mosquito emerges from the mature pupa as it floats at the water surface. Bloodsucking mosquitoes, depending on species, sex, and weather conditions, have potential adult lifespans ranging from as short as a week to as long as several months. Some species can overwinter as adults in diapause (Ojikutu & Kolo, 2011).

2.1.2 Breeding

In most species, adult females lay their eggs in stagnant water: some lay near the water's edge while others attach their eggs to aquatic plants. Each species selects the situation of the water into which it lays its eggs and does so according to its own ecological adaptations. Some breed in lakes, some in temporary puddles. Some breed in marshes, some in salt-marshes. Among those that breed in salt water, some are equally at home in fresh and salt water up to about one-third the concentration of seawater, whereas others must acclimatize themselves to the salinity. Such differences are important because certain ecological preferences keep mosquitoes away from most humans, whereas other preferences bring them right into houses at night (Ojikutu & Kolo, 2011). Some species of mosquitoes prefer to breed in phytotelmata (natural reservoirs on plants), such as rainwater accumulated in holes in tree trunks, or in the leaf-axils of bromeliads. Some specialize in the liquid in pitchers of particular species of pitcher plants, their larvae feeding on decaying insects that had drowned there or on the associated bacteria; the genus *Wyeomyia* provides such examples — the harmless *Wyeomyiasmithii* breeds only in the pitchers of *Sarraceniapurpurea*.

However, some of the species of mosquitoes that are adapted to breeding in phytotelmata are dangerous disease vectors. In nature, they might occupy anything from a hollow tree trunk to a cupped leaf. Such species typically take readily to breeding in artificial water containers. Such casual puddles are important breeding places for some of the most serious disease vectors, such as species of *Aedes* that transmit dengue and yellow fever. Some with such breeding habits are disproportionately important vectors because they are well-placed to pick up pathogens from humans and pass them on. In contrast, no matter how voracious, mosquitoes that breed and feed mainly in remote wetlands and salt marshes may well remain uninfected, and if they do happen to become infected with a relevant pathogen, might seldom encounter humans to infect, in turn (Ojikutu & Kolo, 2011).

2.1.3 Eggs and Oviposition of Mosquitoes

Mosquito habits of oviposition, the ways in which they lay their eggs, vary considerably between species, and the morphologies of the eggs vary accordingly. The simplest procedure is that followed by many species of *Anopheles*; like many other gracile species of aquatic insects, females just fly over the water, bobbing up and down to the water surface and dropping eggs more or less singly. The bobbing behavior occurs among some other aquatic insects as well, for example mayflies and dragonflies; it is sometimes called "dapping". The eggs of *Anopheles* species are roughly cigar-shaped and have floats down their sides. Females of many common species can lay 100–200 eggs during the course of the adult phase of their life cycles. Even with high egg and intergenerational mortality, over a period of several weeks, a single successful breeding pair can create a population of thousands (Ojikutu & Kolo, 2011).

Some other species, for example members of the genus *Mansonia*, lay their eggs in arrays, attached usually to the under-surfaces of waterlily pads. Their close relatives, the genus *Coquillettidia*, lay their eggs similarly, but not attached to plants. Instead, the eggs form layers called "rafts" that float on the water. This is a common mode of oviposition, and most species of *Culex* are known for the habit, which also occurs in some other genera, such as *Culiseta* and *Uranotaenia*. *Anopheles* eggs may on occasion cluster together on the water, too, but the clusters do not generally look much like compactly glued rafts of eggs. In species that lay their eggs in rafts, rafts do not form adventitiously; the female *Culex* settles carefully on still water with its hind legs crossed, and as it lays the eggs one by one, it twitches to arrange them into a head-down array that sticks together to form the raft (Ojikutu & Kolo, 2011).

Aedes females generally drop their eggs singly, much as *Anopheles* do, but not as a rule into water. Instead, they lay their eggs on damp mud or other surfaces near the water's edge. Such an oviposition site commonly is the wall of a cavity such as a hollow stump or a container such as a bucket or a discarded vehicle tire. The eggs generally do not hatch until they are flooded, and they may have to withstand considerable desiccation before that happens. They are not resistant to desiccation straight after oviposition, but must develop to a suitable degree first. Once they have achieved that, however, they can enter diapause for several months if they dry out. Clutches of eggs of the majority of mosquito species hatch as soon as possible, and all the eggs in the clutch hatch at much the same time. In contrast, a batch of *Aedes* eggs in diapause tends to hatch irregularly over an extended period of time. This makes it much more difficult to control such species than those mosquitoes whose larvae can be killed all together as they hatch. Some *Anopheles* species do also behave in such a manner, though not to the same degree of sophistication (Shuaibu & Shuaibu, 2016).

2.1.4 Larvae of Mosquitoes

The mosquito larva has a well-developed head with mouth brushes used for feeding, a large thorax with no legs, and a segmented abdomen. Larvae breathe through spiracles located on their eighth abdominal segments, or through a siphon, so must come to the surface frequently. The larvae spend most of their time feeding on algae, bacteria, and other microbes in the surface microlayer (Shuaibu & Shuaibu, 2016). Mosquito larvae have been investigated as prey of other Dipteran flies. Species such as *Bezzianobilis* within the family Ceratopogonidae have been observed in experiments to prey upon mosquito larvae. They dive below the surface when disturbed. Larvae swim either through propulsion with their mouth brushes, or by jerky movements of their entire bodies, giving them the common name of "wigglers" or "wrigglers". Larvae develop through four stages, or instars, after which they metamorphose into pupae. At the end of each instar, the larvae molt, shedding their skins to allow for further growth.

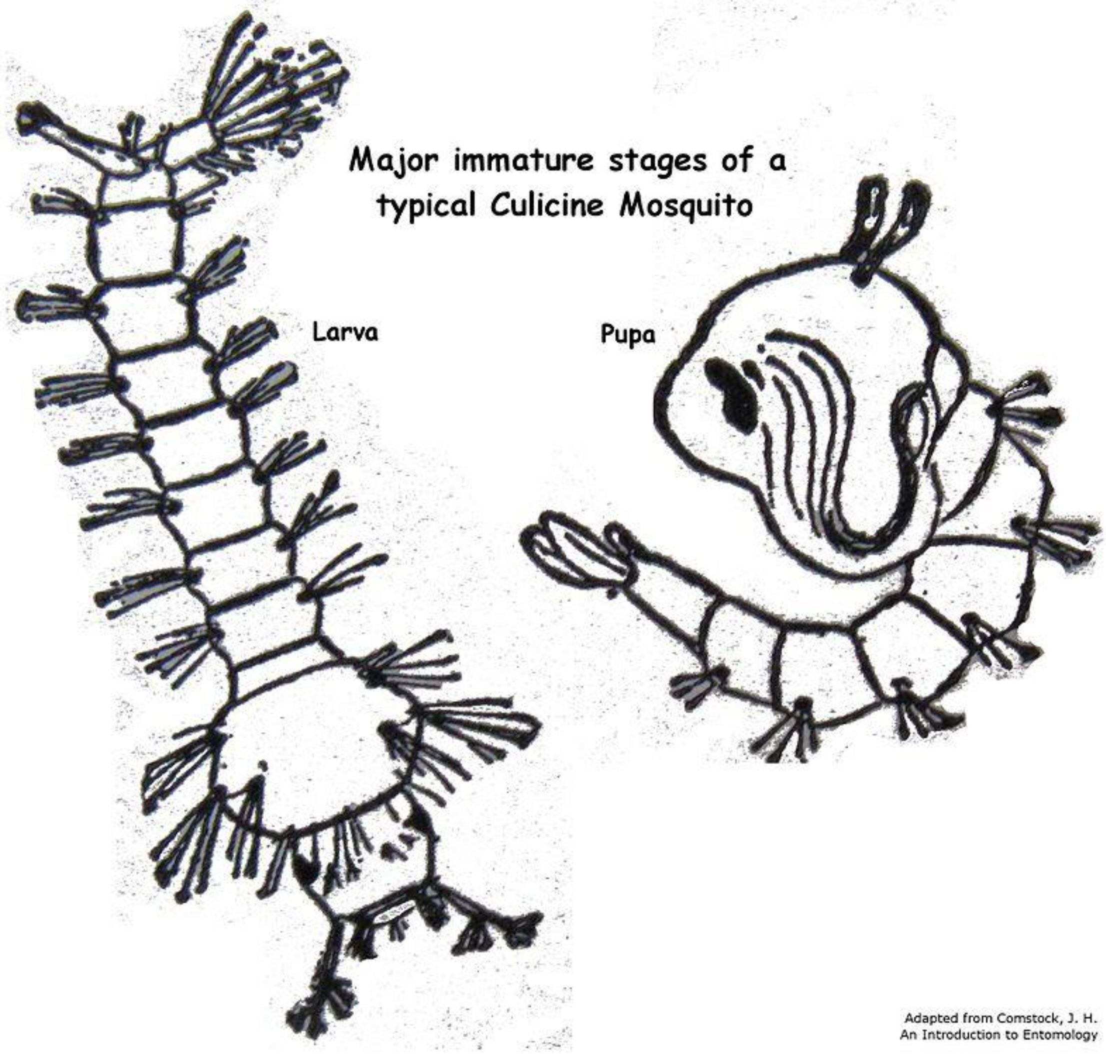

Plate 2: Larva and Pupa of Mosquito (Shuaibu & Shuaibu, 2016)

2.1.5 Pupa of Mosquitoes

As seen in its lateral aspect, the mosquito pupa is comma-shaped. The head and thorax are merged into a cephalothorax, with the abdomen curving around underneath. The pupa can swim actively by flipping its abdomen, and it is commonly called a "tumbler" because of its swimming action. As with the larva, the pupa of most species must come to the surface frequently to breathe, which they do through a pair of respiratory trumpets on their cephalothoraxes. However, pupae do not feed during this stage; typically they pass their time hanging from the surface of the water by their respiratory trumpets. If alarmed, say by a passing shadow, they nimbly swim downwards by flipping their abdomens in much the same way as the larvae do. If undisturbed, they soon float up again. After a few days or longer, depending on the temperature and other circumstances, the dorsal surface of its cephalothorax splits, and the adult mosquito emerges. The pupa is less active than the larva because it does not feed, whereas the larva feeds constantly (NSWQ, 2007).

2.1.6 Adult of mosquitoes

The period of development from egg to adult varies among species and is strongly influenced by ambient temperature. Some species of mosquitoes can develop from egg to adult in as few as five days, but a more typical period of development in tropical conditions would be some 40 days or more for most species. The variation of the body size in adult mosquitoes depends on the density of the larval population and food supply within the breeding water (Sikoki & Veen, 2004). Adult mosquitoes usually mate within a few days after emerging from the pupal stage. In most species, the males form large swarms, usually around dusk, and the females fly into the swarms to mate. Males typically live for about 5–7 days, feeding on nectar and other sources of sugar. After obtaining a full blood meal, the female will rest for a few days while the blood is digested and eggs are developed. This process depends on the temperature, but usually takes two to three days in tropical conditions. Once the eggs are fully developed, the female lays them and resumes host-seeking. The cycle repeats itself until the female dies. While females can live longer than a month in captivity, most do not live longer than one to two weeks in nature. Their lifespans depend on temperature, humidity, and their ability to successfully obtain a blood meal while avoiding host defences and predators. The length of the adult is typically between 3 mm and 6 mm. The smallest known mosquitoes are around 2 mm (0.1 in), and the largest around 19 mm (0.7 in). Mosquitoes typically weigh around 5 mg. All mosquitoes have slender bodies with three segments: a head, a thorax and an abdomen (Sikoki & Veen, 2004).

The head is specialized for receiving sensory information and for feeding. It has eyes and a pair of long, many-segmented antennae. The antennae are important for detecting host odors, as well as odors of breeding sites where females lay eggs. In all mosquito species, the antennae of the males in comparison to the females are noticeably bushier and contain auditory receptors to detect the characteristic whine of the females (NIS, 2007). The compound eyes are distinctly separated from one another. Their larvae only possess a pit-eye ocellus. The compound eyes of adults develop in a separate region of the head. New ommatidia are added in semicircular rows at the rear of the eye. During the first phase of growth, this leads to individual ommatidia being square, but later in development they become hexagonal. The hexagonal pattern will only become visible when the carapace of the stage with square eyes is molted (Sikoki & Veen, 2004).

The head also has an elongated, forward-projecting, stinger-like proboscis used for feeding, and two sensory palps. The maxillary palps of the males are longer than their proboscises, whereas the females' maxillary palps are much shorter. In typical bloodsucking species, the female has an elongated proboscis. The thorax is specialized for locomotion. Three pairs of legs and a pair of wings are attached to the thorax. The insect wing is an outgrowth of the exoskeleton. The *Anopheles* mosquito can fly for up to four hours continuously at 1 to 2 km/h (0.6–1 mph), traveling up to 12 km (7.5 mi) in a night. Males beat their wings between 450 and 600 times per second. The abdomen is specialized for food digestion and egg development; the abdomen of a mosquito can hold three times its own weight in blood. This segment expands considerably when a female takes a blood meal. The blood is digested over time, serving as a source of protein for the production of eggs, which gradually fill the abdomen (NIS, 2007).

2.3 Distribution of Mosquitoes

Mosquitoes are cosmopolitan (world-wide): they are in every land region except Antarctica and a few islands with polar or subpolar climates. Iceland is such an island, being essentially free of mosquitoes. The absence of mosquitoes in Iceland and similar regions is probably because of quirks of their climate, which differs in some respects from mainland regions (NIS, 2007). At the start of the uninterrupted continental winter of Greenland and the northern regions of Eurasia and America, the pupa enters diapause under the ice that covers sufficiently deep water. The imago emerges only after the ice breaks in late spring. In Iceland however, the weather is less predictable. In mid-winter it frequently warms up suddenly, causing the ice to break, but then to freeze again after a few days. By that time the mosquitoes will have emerged from their pupae, but the new freeze sets in before they can complete their life cycle. Any an autogenous adult mosquito would need a host to supply a blood meal before it could lay viable eggs; it would need time to mate, mature the eggs and oviposit in suitable wetlands. These requirements would not be realistic in Iceland and in fact the absence of mosquitoes from such subpolar islands is in line with the islands' low biodiversity; Iceland has fewer than 1,500 described species of insects, many of them probably accidentally introduced by human agency.

In Iceland most ectoparasitic insects live in sheltered conditions or actually on mammals; examples include lice, fleas and bedbugs, in whose living conditions freezing is no concern, and most of which were introduced inadvertently by humans (Sikoki & Veen, 2004). Some other aquatic Diptera, such as Simuliidae, do survive in Iceland, but their habits and adaptations differ from those of mosquitoes; Simuliidae for example, though they, like mosquitoes, are bloodsuckers, generally inhabit stones under running water that does not readily freeze and which is totally unsuited to mosquitoes; mosquitoes are generally not adapted to running water. Eggs of species of mosquitoes from the temperate zones are more tolerant of cold than the eggs of species indigenous to warmer regions. Many even tolerate subzero temperatures. In addition, adults of some species can survive the winter by taking shelter in suitable microhabitats such as buildings or hollow trees (Aina & Adeleye, 2016).

2.4 Physicochemical parameter of Mosquito Rock Pool Habitat

2.4.1 pH: pH is a measure of acidity or alkalinity of water; pH is an important limiting factor for aquatic life as well as for domestic uses. Pure distilled water is neutral with a pH of 7. It is expressed in a scale which ranges from 1 to 14. The geology and soils of the catchment largely determine the pH of stream waters under base flow conditions. Photosynthesis by aquatic plants and algae can cause significant variations in pH Excessive growth of algae and in-stream aquatic plants can lead to elevated pH at certain times of the day (Aina & Adeleye, 2016).

2.4.2 Dissolved Oxygen (DO): The amount of oxygen in water to a degree shows its overall health. Dissolved Oxygen (DO) is a measure of quantity oxygen in milligrams per liter present of water. Dissolved Oxygen saturation is vital for aquatic organisms. Sewage effluent, decaying aquatic vegetation, contaminated storm water discharges and wastewater from human activities all reduce DO levels as they are decomposed by micro-organisms present in river water. River water that has adequate levels of DO can usually sustain a diverse aquatic community. In general, DO level of 3 mg/L are stressful to most aquatic organisms. Water with low DO from 0.5-2 mg/L is considered hypoxic and waters with less than 0.5 mg/L are anoxic (NIS, 2007).

2.4.3 Biochemical Oxygen Demand (BOD): BOD is a measure of the amount of oxygen used by biological and chemical processes in a stream of water over a 5-day. BOD is calculated by measuring the oxygen level of the water on collection and then 5 days after storage in the dark at a constant temperature of 200 C. The difference between DO and BOD is the demand or consumption of oxygen by chemical and biological process. The BOD is measured in milligram per liter of water. Unpolluted and natural waters should have a BOD of 5 mg/L or less (NSDWQ, 2007).

2.4.4 Electrical Conductivity (EC): Electrical Conductivity (EC) is a measure of the ability of water to pass electric current through it in water is affected by the presence of dissolved solids such as chloride, nitrate, sulphide, phosphate, sodium, magnesium, calcium, iron and aluminium (Aina & Adeleye, 2016). Electrical Conductivity also is affected by water temperature with warmer the water, the higher would be the EC. On the other hand streams that run through areas with clayey soils tend to have higher conductivity because of presence of materials that ionize when washed into water. The basic unit of measurement of EC is micro mho per centimetres or micro Siemens per centimetre. Distilled water has EC in a range of 0.5 to 3µmho/cm. The conductivity in rivers ranges from 100 to 1000 µmho/cm (Sikoki & Veen, 2004).

2.4.5 Nitrogen as Nitrate: Nitrate generally occurs in trace quantities in river water. Nitrate is a nutrient for plant growth that dissolves in water. Common sources of nitrate include commercial and manure based fertilizers, waste water treatment plants and faulty septic systems. Nitrate affects the health of fish, plants and other life in rivers. The drinking water should have a nitrate level of 45-100 mg/L (Aina & Adeleye, 2016).

2.4.6 Total Coli Form Bacteria: Total Coli-forms (TC) are not likely to cause illness, but their presence indicates that your water supply may be vulnerable to contamination by more harmful microorganisms. The main sources of these pathogens are through improperly treated septic and sewage discharges, leaching of animal manure, storm water runoff, domestic animals or wildlife. The total coliform count can be done by Most Probable Number (MPN) per 100 ml of water. The TC count should be in a range of 50-500 MPN/100 ml in drinking water (Sharma, 2007).

2.4.7 Faecal Coliform Bacteria: Like Total Coli-form, Fecal Coli-forms (FC) are the sources of pathogenic or disease causing bacteria and viruses. The disease causing organisms are accompanied by other common types of non-pathogenic bacteria found in animal intestines, such as faecal coli-forms bacteria, Enterococci bacteria and Escherichia coli (E.Coli) bacteria. The fecal coli-form count should be 150 MPN/100ml in primary contact like swimming. For drinking purposes, the FC count should vary from 0-700 MPN/100ml (Shuaibu & Shuaibu, 2016).

2.4.8 Chemical Oxygen Demand: The Chemical Oxygen Demand (COD) is used to measure the amount of organic compounds in water. COD can be related empirically to BOD, organic carbon or organic matter. COD is an index of organic content of water because the most common substance oxidized by dissolved oxygen in water is organic matter having a biological origin; that is dead plant and animal waste. The concentration of COD is more in the bottom of water due to more organic matter in the bottom than the surface layer of water (Ekeh & Sikoki, 2003).

2.4.9 Nitrogen as Ammonia: Ammonia is one of the most important water pollutants in the aquatic environment because it is highly toxic and ubiquity in surface water. It is the result of microbiological activity which causes reduction of nitrogen containing compounds in water. It may be due to sewage and industrial pollution and the consequent possible presence of pathogenic microorganisms in the waters. In aqueous solution, ammonia can be of two chemical forms $NH4+$, which is ionized and less toxic and $NH3$, which is unionized and more toxic (Kristens, 2011).

2.4.10 Total Alkalinity expressed as Calcium Carbonate: Total alkali is the measurement of all bases in the river water and can be thought of as the buffering capacity of water, or its ability to resist change in pH. The most common and important base is carbonate. Total alkalinity is expressed as milligrams per litre (mg/L) of calcium carbonate ($CaCO3$). Waters that have moderate to high levels (50 mg/L or greater) of total alkali usually have a neutral to slightly basic pH. The pH is more stable and does not change greatly throughout the day because the presence of carbonates and bicarbonates neutralize, or "buffer," the carbon dioxide and other acids in the water (Aina & Adeleye, 2016).

2.4.11 Total Hardness expressed as Calcium Carbonate: Total hardness is the measurement of divalent cations (+2 ions) in the water and, like total alkalinity, is expressed as milligrams per litre (mg/L) of calcium carbonate ($CaCO3$). When limestone and dolomite dissolve in water, one half of the molecule is calcium (the "hardness") and the other half is the carbonate (the "alkalinity"), so most of the times they are equal. One of the most obvious signs of water hardness is a layer of white film left on the surface of showers. The concentration of calcium ions (Ca^{2+}) in freshwater is found in a range of 4 to 100 mg/L (10–250 mg/L of calcium hardness as $CaCO_3$). Seawater contains calcium levels of 400 mg/L Ca^{2+} (1000 mg/L of calcium hardness as $CaCO_3$) (Ojitikwu & Kolo, 2011).

3.0 Methodology of the Study

Study Area

This research was carried out in the University of Abuja permanent site with four locations, around the school. They included Faculty of Science (on latitude 10° 57.7' N and longitude 7° 39.3' E at an elevation of 111.56 m above the surrounding), Convocation ground (on latitude 11° 07.211' N and longitude 7° 42.659' E at an elevation of 19 m above the surrounding), Girls Hostel (on latitude 11° 04.980' N and longitude 7° 39.416' E at an elevation of 10 m above the surrounding) and Senate Building (on latitude 11° 04.597' N and longitude 7° 40.475' E at an elevation of 32 m above the surrounding). The four location have several depressions that collect water during the rainy season which constitute effective rock pool breeding microhabitats for mosquitoes. These rock pools were examined for mosquito breeding between April and May 2021.

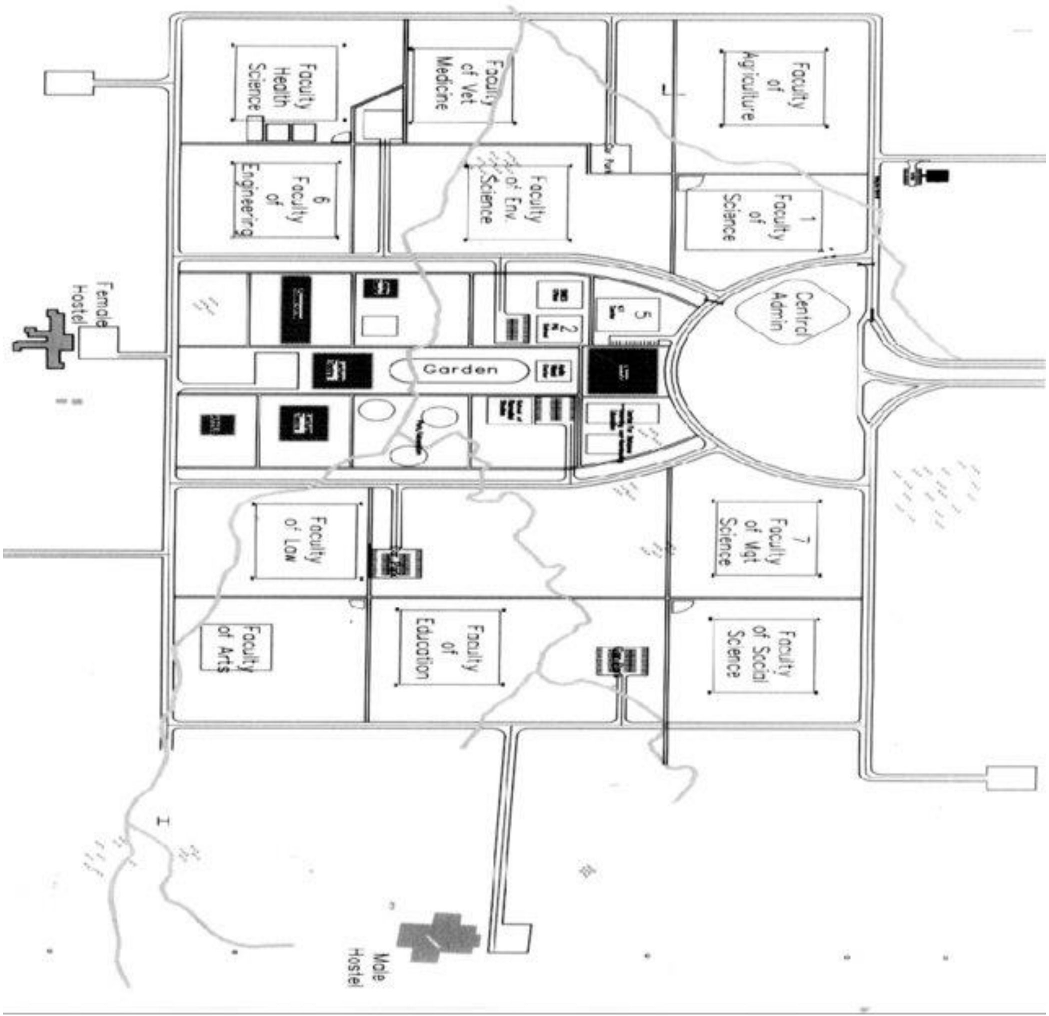

Plate 1: Map of University of Abuja Showing Study Area (Adeyemo *et al.*, 2008)

3.1 Sampling Technique:

Ten dips of the water in every other rock pool was obtained with a plastic soup ladle dipper (0.105 L capacity) 11. The water was collected in a white plastic bowl and carefully observed for the presence of pre-imaginal mosquitoes. Culicine larvae collected was concentrated in a sieve and carefully picked with dropping pipette into labeled specimen bottles, the water drained and 70% alcohol preservative added. Anopheline larvae was collected alive in plastic bottles and reared to adults in the laboratory in small plastic bowls (11x 11x 5.5 cm) on a diet of bakers' yeast.

3.2 Determination of Physicochemical Parameters of Rock Pools:

Depths of water in rock pools were obtained by lowering a metre rule to the bottom of the pools at three locations and the mean depths recorded. The surface areas of rock pools were determined from length and width measurements with a metre rule. The pH, electrical conductivity, total dissolved solids and temperature of water in each rock pool was determined by means of a HANNA HI 991300 pH/ EC/TDS/Temp meter.

3.3 Species Identification:

Mosquitoes collected was identified to species and counted under the x50 magnification of a stereo-microscope using pictorial keys for culicines, and anophelines. Dominant aquatic macrophytes were uprooted from rock pools and identified to species at the Herbarium Unit of the Department of Biological Sciences, University of Abuja, Nigeria by a botanist in the department.

3.4 Statistical Analysis of the Study

Pearson correlation analysis was done to establish relationships amongst the physicochemical parameters of water, in rock pools, and abundance of species of mosquito breeding therein. One-way analysis of variance (ANOVA) was employed to test for significant differences in the relative abundance of mosquitoes amongst locations; using least significant difference to separate means that differ significantly.

4.0 Result of the Study

Result obtained in table 1 indicates that Faculty of Science have a total number of 25 *Ae. aegypti*,9 *Ae.vitattus* and 1*Cx. Ingrami*. Convocation ground also has 15*Ae. aegypti*,0 *Ae.vitattus* and 0*Cx. Ingrami.* Girls Hostel have 10 *Ae. aegypti*,0 *Ae.vitattus* and 0*Cx. Ingrami.* Senate Building has 5 *Ae. aegypti*,0 *Ae.vitattus* and 2*Cx. Ingrami.*

Table 1: Species of mosquito breeding in rock pools around University of Abuja perm Site

Location	***Ae. aegypti* (%)**	***Ae.vitattus* (%)**	***Cx. ingrami* (%)**
Faculty of Science	25 (0.5)	9(1)	1(0.5)
Cov Ground	15 (0.3)	0(0)	0(0)
Girls Hostel	10 (0.2)	0(0)	0(0)
Senate Building	5 (0.1)	0(0)	1(0)
Total	55 (1.1)	9(0)	2(0.5)

Results in Table 1 indicated that *Ae. aegypti* was more prevalence in the four study area, followed by *Cx. Ingrain* and then *Ae.vitattus*

Table 2: Range of physicochemical parameters of rock pools supportive of mosquito species breeding around University of Abuja.

Species	pH	Temp (^{0}C)	TDS (ppm)	Depth (cm)
Faculty of Science	4.32	28	0-172	14
Female Hostel	6.85	27.3	14-82	15.5
Senate Building	7.99	26.8	10-125	18
Cov Ground	7.44	29.0	11-121	19

Result in table 2 indicates that's Faculty of Sciencehas a pH of 4.32, temp of 28^{o}C, total dissolved Oxygen (TDS) of 0-172 and Depth of 14cm. Female Hostelalso have a pH of 6.85, followed by temp of 27.3^{o}C, TDS is 14-82ppm and depth of 15.5cm and then Senate Buildingwith pH of 7.99, followed by Temp of 26.8^{o}C, TDS of 10-125ppm and a depth 18cm, and then Convocation ground with a pH of 7.44, followed by temperature of 29.0^{o}C, TDS of 11-121ppm and a depth of 19cm.

Table 3: Occurrence of microbiota species in varying types of mosquito breeding habitats within University of Abuja perm Site

Biota Species	F. Sci.	C. Ground	G. Hostel	S. Building
Cyperusdendatus	9(3)	-	-	2(1)

Heterantheracallifolia	-	-	3(1)	-
Ludwigiadecurrens	-	-	-	-
Murdannia simplex	2(1)	6(1)	-	-
Scirpusuninodis	4(2)	-	5(2)	4(1)

(—) absence of microbiota; positive samples are given in parenthesis.
F. Sci. = Faculty of Science, C. Ground = Convocation Ground
G. Hostel = Girls Hostel, S. Building = Senate Building

None of the microbiota taxa had constant frequency occurrence (FR% > 51%) in the mosquito breeding habitats during the study period. *Scirpusuninodis* have the highest frequency among the 4 study area, while *Heterantheracallifolia* have the lowest.

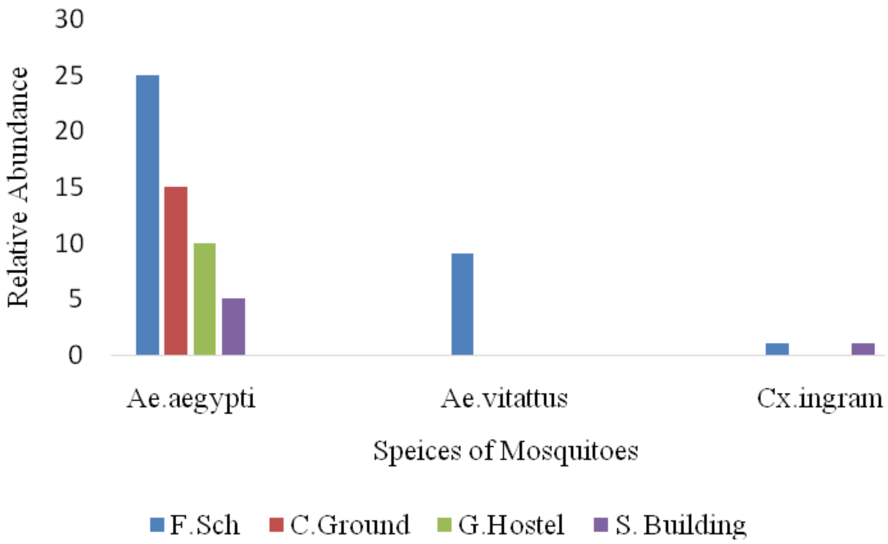

Fig 1: Relative Abundance of Mosquitoes Species found within the rook pool side

5.1 Discussion of the Study

Discrete microhabitats for breeding mosquitoes exist in rock pools and each pool constitutes an independent replicate for determining the ecology of mosquito species. A distinct and predictable disturbance to the fauna that colonise these rock pools is seasonal drying. This was evident at the preliminary stage of this study at the onset of the rainy season in May, when the depressions were devoid of water and could not then serve as effective mosquito breeding habitats. The volume of water in the pools was usually small. *Ae. aegypti* is the dominant species of mosquito breeding in rock pools around University of Abuja, Nigeria. Results show that the species is catholic in its choice of breeding microhabitat in rock pools and was the least affected by the physicochemical conditions of the rock pools. *Ae. egypti* is widely distributed in Africa and has been associated with breeding principally in rock pool habitat (Adeyemo *et al*., 2008, Auta *et al*., 2016). Together with *Ae. aegypti*, *Ae. vittatus* is a potential yellow fever vector in northwestern Nigeria, adjacent to the study area, and in several foci in Africa (Auta *et al*., 2016). Considering the high yellow fever epidemic risk posture of the University of Abuja environment, due to elevated *Ae. vittatus* larval indices (Akindele *et al*., 2013), the current findings of high populations of larval *Ae. aegypti* in rock pools within the same area has further exacerbated the risk factor. Senate building, Girls Hostel and Faculty of Science are surrounded by human habitations stationed within flight range of these pool-breeding mosquitoes. *Ae. aegypti* could thus be amongst the species that constantly create biting nuisances on humans in the area; since it has been caught at human bait in some villages northwest of Nigeria (Adeyemo *et al*., 2008). As such, rock pools did not constitute a breeding habitat for malaria vectors in University of Abuja, Nigeria. It is plausible that the species are zoophilic and obtain their blood meals readily from the large number of cattle and small domestic ruminants owned by nomadic Fulani herdsmen camping at the foot of University of Abuja premises. *Cx. ingrami* is also a medically unimportant zoophilic species. The dominant aquatic macrophytes co-inhabiting mosquito microhabitat within University of Abuja included *Cyperusdenudatus*, *Heterantheracallifolia*, *Ludwigiadecurrens*, *Murdannia simplex* and *Scirpusuninodis*. In this study, it was revealed that the more diversified the availability of rock pools, the less are the relative abundance and mean number of larval mosquitoes per pool. This is an indication that density related pressure could regulate population of larvae, especially with few rock pools. Depending on the availability of rock pools, oviposition by adult mosquitoes is communal when few pools are available and dispersed in the presence of several pools.

Conclusion of the Study

In conclusion, this study identified three species of mosquito breeding in rock pools around University of Abuja Nigeria. Amongst these *A. egypti* a potential yellow fever vector in the area was predominant. Therefore, for effective prevention of epidemic yellow fever, attention should be focused on the control of mosquitoes breeding in rock pools. In the face of epidemic yellow fever outbreak, rock pools should be inspected to implicate vectors and launch suitable control measures. The study concludes that the Government should share mosquitoes net for students staying on Campus. The School Management should inspect and incriminate rock pool habitats in the University and educate students on the dangers of rock pool habitats. The students should always protect themselves against these vectors of animal and human diseases.

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