DISTRIBUTION, BITING BEHAVIOUR, AND PRODUCTIVITY OF BREEDING SITES OF *CULEX* MOSQUITOES IN BADEGGI, NIGER STATE, NIGERIA

BY

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ABSTRACT

Culex mosquitoes are vectors of public and veterinary health importance as well as nuisance biters that are found widely spread all over the world. This study evaluated the distribution, biting behaviour and productivity of breeding sites of *Culex* mosquitoes in Badeggi, Niger State, Nigeria. Centre for Disease Control (CDC) light traps were used for the collection of adult mosquitoes while the larval mosquitoes were collected using a standard World Health Organisation (WHO) dipper (350 ml). Larval and adult *Culex* mosquitoes collected were identified morphologically using a standard pictorial key. Water samples were also collected and analyzed to determine the physicochemical parameters of the breeding sites (Rice field and Pond). A total of 2848 adult *Culex* mosquitoes were collected. Five species were encountered which include, *Culex quinquefasciatus* (52 %), *Culex salinarius* (24 %), *Culex tritaeniorhynchus* (17 %), *Culex restuans* (5 %) and *Culex nigripalpus* (2 %). Low biting activites was recorded between the hours of 6-7 pm and 5-6 am while the peak of biting activities was recorded between the hours of 7-9 pm. In the months of January-March, mosquitoes bit more outdoors (14 mosquitoes per night) compared to indoors (6 mosquitoes per night), in July-October, they bit more outdoors (13 mosquitoes per night) even though a considerable number bit more indoors (11 mosquitoes per night), while in the months of November-December, they bit more indoors (26 mosquitoes per night) compared to outdoors (14 mosquitoes per night). Prominent physicochemical parameters determined include; Temperature, pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Total Dissolved Solid (TDS), Total Alkalinity (TA) and Total Hardness (TH). Statistically significant difference ($p<0.05$) occurred between mean pH (6.74±0.26 and 6.99±0.19), EC (258.88±22.77 us/cm and 415.75±150.81 us/cm), TA (103.63±10.79 mg/L and 124.13±20.61 mg/L), TH (78.25±10.62 mg/L and 111.50±22.58 mg/L) and TDS (100.72±31.04 mg/L and 143.72±46.37 mg/L) of rice field and pond. A Mean±SD total of 8.67±5.68 of larval mosquitoes/dip were collected, 5.48±3.72 mosquitoes/dip from pond while 3.19±1.96 mosquitoes/dip from rice-field. In conclusion, *Culex quinquefasciatus* is the principal *Culex* mosquito in Badeggi, variation occurred in the biting period and location of *Culex* mosquitoes. There was no significant difference in the productivity between rice field and pond. This knowledge of the active biting period and site preference should guide the deployment of appropriate control tools e.g. long lasting insecticide, treated bed nets, against these mosquito vectors.

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ABBREVIATIONS

APHA-	American Public Health Association
BOD-	Biological Oxygen Demand
Ca-	Calcium
CDC LT-	Centre for Disease Control Light Trap
CDC-	Centre for Disease Control
CHIKV-	Chikugunya Virus
Cl-	Chlorine
DENV-	Dengue Virus
DO-	Dissolved Oxygen
EC-	Electrical Conductivity
KI-	Potassium Iodide
KOH-	Potassium Hydroxide
LF-	Lymphatic Filariasis
LSM-	Larval Source Management
MBIDs-	Mosquito-borne Infection Diseases
MBR-	Mosquito Biting Rate
NO_3-	Nitrate
pH-	Hydrogen Ion Concentration
PO_4-	Phosphate
RVFV-	Rift Valley Fever Virus
TA-	Total Alkalinity

TDS-	Total Dissolve Solid
TH-	Total Hardness
WHO-	World Health Organization
WNV-	West Nile Virus
YFV-	Yellow fever Virus
ZIKC-	Zika Virus

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Mosquitoes are slender biting insects of the Order Diptera; sub-order Nematocera and Family Culicidae that are cosmopolitan in nature except in Antarctica (Mullen *et al*., 2009). In warm and humid tropical regions, various mosquito species are active for the entire year, but in temperate and cold regions, they hibernate or enter diapause (Fang, 2010). As reported by Joseph *et al*. (2013), these mosquitoes exploit almost all types of lentic aquatic habitats for breeding. The larval stage of these mosquitoes have been found to thrive in aquatic bodies such as fresh or salt water marshes, mangrove swamp, rice fields, grassy ditches, small temporary rain pools, edge of streams and rivers. The distribution of mosquito activity can be highly variable even in the same geographical area (Martha *et al*., 2013).

Mosquitoes are well known group of insects, which transmit many dreadful diseases causing serious health problems to human beings. The female biting habit during their search for blood meal shortly before oviposition increases their propensity to transmit various diseases associated with high morbidity and mortality (Olayemi *et al*., 2010).Different mosquito species serve as vectors of human pathogens including yellow fever (YFV), chikungunya Virus (CHIKV), Zika Virus (ZIKV), Dengue Virus (DENV), Rift valley Fever Virus (RVFV), West Nile Virus (WNV), and those that cause malaria and lymphatic filariasis mainly in tropical regions (LaBeaud *et al.*, 2011). Diallo *et al.* (2014) reported that among the three subfamilies of Toxorhynchitinae, Anophelinae and Culicinae, only the Anophelines and Culicines have been incriminated in human pathogen transmission. Culicine mosquitoes have been implicated in the transmission of a wide range of arboviruses, with species in the *Culex* and *Aedes* genera playing a key role. Culincine mosquitoes are known to breed in diverse habitats and occur in different environment, some species of which have adapted to colonise urban centres. For instance, *Culexquinquefasciatus*, a vector of filarial worms, WNV and a secondary vector of RVFV, breed in organic polluted water cess pits, drainage canal and sewage systems (Noori *et al.*, 2015). In Africa, particularly Nigeria, *Culex* mosquitoes, especially the species of *Culex quinquefasciatus* have been incriminated in the transmission of diseases such as filariasis and elephantiasis (Omudu *et al*., 2010).

Mosquito-borne infectious diseases (MBIDs) account for high number of reported cases, mortality and disability-adjusted life years (World Health Organization, 2018). Malaria, for example, has an enormous burden globally. In 2016, there were an estimated 216 million cases of Malaria worldwide- a slight increase from the previous year- and an estimated 445,000 deaths (WHO, 2017). Dengue fever also has a large global burden with researchers estimating that there are 96 million disease cases per year with less than 390 million infections annually (WHO, 2017). Although the global burden resulting from Zika, Chikungunya and West Nile respectively are not as high as those for Malaria, and Dengue, their impact are nevertheless important, particularly as these diseases and transmission has expanded to regions previously unaffected (Campos *et al*., 2015). Various vector control measures are applied in order to suppress mosquito populations. Because of that, knowledge on mosquito biting rate (MBR) is necessary so that appropriate vector control strategies could be planned. Mosquito biting rate (MBR) refers to the density of mosquitoes involved in biting. Information on biting behavior of vectors facilitates the selection of personal protection measures that would prevent human-mosquito contact (Korgaonkar *et al*., 2012). Biting behavior is crucial to be examined in order to understand biting cycles of the vector species (Rohani *et al*., 2008). With equal number of catches ranging over the same catch points being performed for an hour, a preliminary interpretation of the mosquito biting patterns collected in the chosen areas could be obtained (Rohani *et al.*, 2008).

The occurrence of adequate population of mosquitoes that contribute biting nuisance or vectors of disease-causing organism is due to the availability and diversities of aquatic habitat (Adebote *et al*., 2008). Mosquitoes show high preference to water with suitable pH, optimum temperature, dissolved oxygen, electrical conductivity, concentration of nitrate and phosphate (Afolabi *et al*., 2013). Strong correlations found between certain physico-chemical parameters and larval abundance elucidates the influence of these parameters on the distribution and abundance of mosquito larvae in their breeding habitat and also indicates the possibility of mosquito larval control through the manipulations of such parameters (Olayemi *et al*., 2010)

1.2 Statement of the Research Problem

Culex mosquitoes constitute a major threat to public health, being ranked with the genera of *Anopheles* and *Aedes* in the transmission of epidemiologically important diseases (Omudu *et al.*, 2010). *Culex* mosquitoes, especially the species of *Culex quinquefasciatus* are responsible for the transmission of diseases such as filariasis, as well as multiple zoonotic agents such as Kamese viruses, St. Louis encephalitis, and Japanese encephalitis in Africa and Nigeria in particular (Obi *et al.*, 2010; Omudu *et al.*, 2010; Braack *et al.*, 2018). According to WHO (2018), more than 1.3 billion people in 83 countries are at risk of infection. The economic burden pose by these diseases is enormous as a result, many countries including Nigeria spend billions of public funds, which could have been channeled into other productive sectors of the economy, on fighting these diseases (WHO, 2018).

The epidemiology of these mosquito-borne diseases in Nigeria is complicated (Obi *et al.*, 2010), owing to various factors that are predominantly related to the vector species involved and these factors include ubiquitous distribution of the disease vector (which increases vector–human contacts), an inherent ability to survive in an assortment of habitats (Olayemi *et al.*, 2014), varying degree of anthropogenic activities which provides varieties of suitable oviposition sites for adults and fitting habitats for the larval development, clemency of the Afrotropical climate (which favors the rapid development of vectors and parasites) and genetic variability (Ukubuiwe *et al.*, 2016). Therefore, this study will examine the distribution, biting behaviour, and productivity of breeding sites of *Culex* mosquitoes.

1.3 Aim and Objectives of the Study

This study aims at evaluating the distribution, biting behaviour, and productivity of breeding sites of *Culex* mosquitoes in Badeggi, Niger state, Nigeria.

The objectives of the study are to determine the:

i. species composition and relative abundance of *Culex* mosquitoes in Badeggi, Niger State.
ii. biting periodicity of the *Culex* mosquitoes of the area.
iii. biting location (indoor versus outdoor) preferences of the *Culex* mosquitoes.

iv. physico-chemical characteristics of larval breeding sites in the area

v. temporal productivity of the larval breeding sites.

1.4 Justification for the Study

In addition to the nuisance caused by culicine mosquito species, some important species that blood feed on humans, such as *Cx. neavei, Cx. univittatus, Cx. quinquefasciatus*, and *Cx. antennatus* are important vectors of filarial worms and West Nile virus in Africa. Also, *Culex* mosquitoes have been incriminated as vectors in the transmission of avian malaria parasites (Zele *et al.*, 2014, Schmid *et al.*, 2017), as well as multiple zoonotic agents such as Rift valley, Kamese viruses, St. Louis encephalitis, and Japanese encephalitis (Braack *et al.,* 2018).

Because of their potential medical and veterinary importance, it is essential to improve our taxonomic understanding and bio-ecology of culicine mosquitoes. An understanding of mosquito bio-ecology, mosquito diversity, and pathogens transmitted by mosquitoes is essential for control strategies and for building predictive models of disease emergence in humans and wildlife in response to environmental changes (Lutomiah *et al.,* 2013, Ribeiro *et al.,* 2012). For any vector control measures to be successful, good knowledge of the breeding ecology of mosquitoes including, the types and preferences for larval habitats, spatial and temporal distribution of breeding sites, as well as, the physical, biological and chemical characteristics of the habitats are required (Olayemi *et al.,* 2010).

The rate of vector-borne disease transmission depends on vector abundance and distribution, the presence of diverse larval habitats and human lifestyle. Mosquito larvae are highly restricted to their habitats with minimal chances of evading control measures as compared to free-flying adult mosquitoes, which makes larviciding an effective control strategy. Integrating larval source management (LSM) with adult control methods significantly reduces mosquito populations (Barrera *et al.*, 2018). Adult and larval surveillance plays an important role in the provision of information on mosquito species and habitat distribution for the design of effective control strategies (Trewin *et al.*, 2017).

Physiochemical compositions of mosquito breeding water bodies are complicated and determine their condition and fauna composition. Physicochemical factors such as salts, dissolved organic and inorganic matter, degree of eutrophication, turbidity, presence of suspended mud, temperature, light, shade, Hydrogen ion concentration and presence of food substances influence oviposition, survival rate and the distribution of mosquito species (Chatterjee *et al.,* 2015). Larval control can be achieved through larval habitat management by altering physiochemical properties of breeding habitats (Chatterjee *et al.,* 2015). Therefore, understanding the impact of these parameters will lead to better decision making in relation to mosquito control activities. Having quantitative data on the influence of these physiochemical parameters on the development and fitness of mosquito vectors is important. The information will update the current literature on biology of the vector, the role the parameters play in biological fitness for disease transmission and provide information on the potential use of such parameters in vector control via environmental manipulation.

More so, feeding behaviour of the mosquitoes are considered to be the important factor which facilitates the man – vector contact and thereby leading to the transmission of vector borne diseases. Mosquitoes exhibit host preference behavior as well as typical rhythmic pattern in their biting behavior. The difference in the feeding pattern contributes significantly in the transmission pattern of diseases among various hosts during different seasons (Paramasivan *et al.*, 2015). This current study will therefore be conducted to examine the distribution, biting behaviour, and productivity of breeding sites of *Culex* mosquitoes so as to provide information that could contribute to the development of cost-effective, successful, integrated and eco-friendly *Culex* mosquitos' vector control protocols.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Distribution of *Culex* Mosquitoes

Culex species are the most widespread mosquito species across the world (Bhattacharyar *et al.,* 2016). They are known to be highly opportunistic feeders on humans and animals, a behavior which increases their potential to transmit zoonotic disease and makes them important threat to public health (Weissenbock *et al.,* 2010). One of the most important groups in the *Culex* genus is the *Culex pipiens* complex which comprises six members: *Culex quinquefasciatus* Say, *Cx. pallens* Coquillet, *Cx. pipiens* Linnaeus**,** *Cx. australicus* Dobrotworsky and Drummond, *Cx.globocoxitus* Dobrotworsky and *Cx. molestus* Forsskal (Farajollahi *et al.*, 2011; Zittra *et al.*, 2016).

Species of the *Cx. pipiens* complex particularly *Cx. quinquefasciatus* are widespread and predominant in the urban environment notably in Africa particularly in Nigeria where suitable environmental conditions created by rapid unplanned urbanization is contributing to their proliferation (Awolola *et al.*, 2007). *Culex quinquefasciatus* can be found in all types of water collection including temporary or permanent stagnant water bodies such as drains, septic tanks, wet pit latrines, organically polluted sites, puddles (Satler *et al.*, 2005) and has emerged as the most common mosquito species in major African cities (Ekloh *et al.,* 2013). In addition to nuisance that *Culex* species could induce, they also transmit diseases such as Japanese and Saint Louis encephalitis, Rift valley fever, West Nile Virus and Lymphatic Filariasis (LF) (Goddard *et al*., 2002). The later caused by the parasite *Wucheria bancrofti* is largely prevalent in Asia and Sub-Saharan Africa and is considered as one of the leading causes of long term disability in the world (Manimegalai *et al.,* 2014).

2.2 Life Cycle of *Culex* Mosquitoes

Culex mosquitoes are holometabolous, going through four distinct life stages: egg, larva, pupa, and adult (figure 2.1). The egg, larval, and pupal stages are aquatic. Adults leave the water by flight to find plants or vertebrates on which to feed. Oviposition can occur in natural reservoirs of salt water or fresh water, or temporary pools, but oviposition sites are generally stagnant. Many species associate closely with humans, using accumulated ground water in developed areas for oviposition (Azari-Hamidian and Harbach, 2009).

2.2.1 Eggs of *Culex* Mosquitoes

Culex eggs are laid in groups by adult females, often numbering over a hundred. Most species lay the eggs on the surface of stagnant water. The female lays the eggs vertically and side by side, held together by a sticky substance excreted to coat the eggs, head end down, creating an egg raft that is convex below and concave above with ends that are typically upturned. Species that use this form of egg-laying typically hatch as first instar larvae within a few hours of laying. Oviposition on the surface of stagnant water is mostly common. Eggs are laid and embryological development occurs, but the eggs do not hatch till flooded. After flooding, the eggs will hatch within two to three days (Becker *et al.*, 2010).

2.2.2 Larvae of *Culex* Mosquitoes

Culex larvae are adapted to almost every aquatic environment worldwide, excepting flowing streams and open areas of large water masses. Larvae have three body regions – head, thorax, and abdomen – as well as having compound eyes and antennae on their heads. The same body regions can be found in *Culex* adults, but the form of each region is very different in the larvae and adults. The larvae have four instars from hatching to pupation that occur over four days to two weeks. *Culex* larvae can be distinguished from larvae of *Anopheles* by the presence of the posterior siphon. The siphon is used for breathing and breaks the water surface, so the larvae can take in air (Azari-Hamidian and Harbach, 2009). Most species hang from the surface of the water, anterior end down, so the siphon stays at the water surface. Larvae eat small aquatic organisms and plant material in the water using brush-style and grinding mouth parts. A few species are predatory and have additional mouth parts for grasping. Larvae use jerks of their bodies for locomotion, combined with propulsion using the mouth bristles. They are sensitive to the conditions of the water in which they live, including light, temperature, and many other factors, and are also subject to predation and depend on aquatic vegetation to hide from predators (Becker *et al.*, 2010).

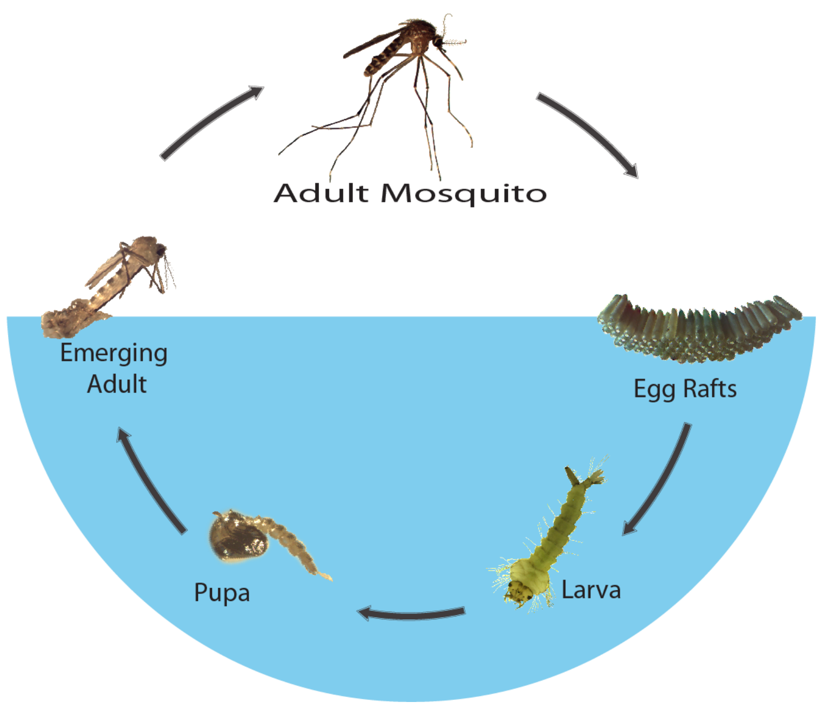

Figure 2.1: Life cycle of *Culex* mosquitoes Source: Becker *et al.* (2010).

2.2.3 Pupae of *Culex* Mosquitoes

Culex pupae are aquatic and do not feed, but they do require air intake. All pupae must come to the water surface for air. Pupae are exarate, allowing movement of the exposed abdomen. Thrashing of the abdomen can move the pupae quickly, sideways or downward, but as soon as movement of the abdomen stops, the pupae return to the surface of the water. The pupa naturally rises to the surface of the water due to an air pocket between the wing cases that make it lighter than water. Pupation lasts as little as one day to as much as several weeks, because some diapause can occur (Becker *et al.*, 2010).

2.2.4 Adults of *Culex* Mosquitoes

Adult mosquitoes are about equal in proportions of males and females, but males emerge from the pupal stage before females. Males stay near the breeding ground and mate soon after the females emerge. Females only need to mate once, and then store sperm to use over their lifetimes. After mating, adults leave the breeding ground and can fly great distances. *Culex* adults inhabit almost every environment, and both males and females feed on plant sugars. Females also feed on animal blood, which most species need before they can lay eggs. After a blood meal, females take two or more days to digest the blood before oviposition (Becker *et al.*, 2010). After egglaying, females begin searching for another host for a blood meal. Different species of mosquitoes have preferences to blood meals from specific species of hosts, but can feed on other species. Adults have three body regions, with narrow membranes joining the segments, and are two to 15 mm in length. The first body region, the head, holds the large compound eyes, proboscis-style mouth parts, and plumose antennae. The antennae of males are more plumose than those of females, to catch pheromones to find a mate. The thorax is covered in scales and setae helpful in species identification. Attached to the thorax are three pairs of long, slender legs, a pair of fore wings used for flight, and hind wings reduced to halteres for balance. The abdomen is slender, but membranous so it can swell when feeding. The abdomen has 10 segments, but only eight are visible. The last two segments are reduced and used for reproduction. The lifespan of adult *Culex* can vary greatly based on environment, predation, and pest control (Azari-Hamidian & Harbach, 2009).

2.3 Abundance and Distribution of *Culex* Mosquitoes

The distribution and abundance of mosquito species is affected by many factors. According to Simon-Oke *et al.* (2012) mosquito distribution and abundance are related to population, land use and human activities. Afolabi *et al.* (2013) also suggested that differences in the abundance and distribution of mosquitoes species may be due to the difference in social and anthropological activities as within the locations as areas with high activities may have high population density of mosquitoes and vice versa.

Culex mosquitoes have being a common occurrence in Nigeria from different studies on these mosquito species. They are epidemiologically significant as *Culex quinquefasciatus* is a potential vector of bancroftian filariasis, yellow fever and other arboviruses (Abdulrasheed *et al.* 2016). In the report of Abdulrasheed *et al.* (2016), *Culex* mosquitoes were the most abundant mosquito species in Azare town, Katagum Local Government of Bauchi State, Nigeria. Out of the six (6) species sampled from the study area, the predominant species, constituting about 91.38 % of the total collection of mosquito species, were *Culex quinquefasciatus* (57.89 %), *Cx. molestus* (25.87 %) and *Cx. pipiens* (7.62 %).

While *Aedes aegypti* and *Aedes vittatus* rarely occurred constituting 5.11 % and 2.69 % of the total collection respectively.

The distribution of mosquito of mosquito activity can be highly variable even in the same geographical area (Martha *et al.,* 2013). This suggests that mosquito distribution is influenced by a number of factors which in turn affect emergence and re-emergence of diseases. A study was conducted to determine the species composition and relative abundance of mosquitoes breeding in discarded automobile tyres within Minna by Haruna and Abdulhamid (2019). Out of the two (2) genera and six species of mosquito identified in the study area, 8 (1.0 %) *Culex pipiens* 7 (0.9 %) *Culex pipiens,* 43 (5.4 %) *Culex quinquefasciatus,* 9 (1.1 %) *Culex simpsoni*, 15 (1.9 %) *Culex tigripes*, and *Aedes aegypti* 8 (1.0 %) were recognized. Olayemi *et al.* (2014) likewise recorded two genera of culicine mosquito; *Culex* and *Aedes* species in Minna metropolis, Nigeria. Four species of *Culex* mosquitoes were identified by Olayemi *et al.* (2014) in Minna metropolis, Nigeria viz; *Culex pipiens pipiens, Cx. salinarius, Cx. restuans* and *Cx. nigripalpus* with *Culex p. pipiens* being the most widely distributed species. According to Olayemi *et al.* (2014), the ecology of *Cx. p. pipiens* mosquitoes may be responsible for its abundance, as the species is the foremost cosmopolitan mosquito thriving particularly in urban slums where anthropogenic environmental degradations result in the proliferation of polluted water receptacles preferred for breeding by the mosquito.

In a recent study by Lapang *et al.* (2019) on the abundance and diversity of mosquito species larvae in Shendam LGA, Plateau State, North-Central Nigeria, out of the four genera (*Anopheles, Culex, Aedes* and *Mansonia*) recorded in the study area, *Culex* (60.11

%) was the most abundant, while *Culex quinquefasciatus* together with and *Anopheles gambiae* were the most abundant species.

Olajire *et al.* (2017) carried out a study on the abundance and spatial distribution of mosquitoes in the ecological zones of the Ondo State. From the results, five species of *Culex (Cx. quinquefasciatus, Cx. andersoni, Cx. duttoni, Cx. pipiens* and *Cx. trigripis)* were identified in the study area with *Cx. quinquefasciatus* and *Cx. andersoni* being the most predominant *Culex* species in the study area. Similarly, Afolabi *et al.* (2019) reported *Culex* species as the most abundant mosquito species in Akure South Local Government Area, Ondo State, Nigeria. They identified 6 species of *Culex* which were *Cx. andersoni, Cx. tigripes, Cx. quinquefasciatus, Cx. striatipes, Cx. horridus* and *Cx. macfei.*

Three genera and five species of culicine mosquitoes were identified, including *Culex pipiens* L., *Cx. tritaeniorhynchus* Giles, *Cx. sinaiticus* Kirkpatrik, *Cx. modestus* Ficalbi, *Ochlerotatus caspius* Pallas and a *Culiseta* species by Navidpour *et al.* (2012) in the Shadegan wetland in southwestern Iran. Out of the four genera identified by Simon –Oke and Ayeni (2015) in Federal University Of Technology Akure Hostels, Ondo State, Nigeria, *Aedes* and *Culex* species were the only culicine mosquitoes with *Aedes* being the most abundant with 275 (38.73 %). Species of *Aedes* and *Culex* encountered in their study were; *Aedes aegypti*, *Ae. furcifer*, *Culex tarsalis, Cx. fatigans*, *Culiseta inornata* and *Cu. incidens*.

According to the research of Aigbodion *et al.* (2013) on the distribution of various mosquito genera and abundance in an increasingly urbanizing town Benin City, Nigeria, *Culex* genera recorded was the highest abundant mosquito species with seven (7) *Culex* species; (*Culex quinquefasciatus, C. nebulosus, C. tigripes* , *C. decens, C.*

pipiens, *C. moucheti* and *C. cinereus*). The most commonly encountered species was *Culex quinquefasciatus.* In a similar report by Dhimal *et al.* (2014), *Culex* mosquitoes (29 %) accounted for the second most abundant mosquitoes after *Anopheles* (55 %) in Nepal. The principal vector of lymphatic filariasis, *C. quinquefasciatus*, and the Japanese encephalitis virus vector *Culex tritaeniorhynchus* accounted for 12 % and 31 % of the total collected *Culex* mosquitoes (n = 742).

Amao *et al*. (2018) recorded six species of *Culex* mosquito species in Lagos, Southwest Nigeria. The species encountered were; *Culex pipiens* (49.35 %), *Cx nebulosus* (20.71 %), *Cx moucheti* (6.89 %), *Cx cinereus* (10.43 %), *Cx decens* (8.75 %) and *Cx tigripes* (3.87 %) with *Cx. quinquefasciatus* being the most common and abundant species in all locations examined. The work of Olorunniyi (2016) however recorded *Anopheles* mosquitoes having the highest mean monthly value, followed by *Aedes* and least in *Culex* at Ilokun and Irasa Communities, Ado-Ekiti, Nigeria.

Also, Manyi *et al*. (2017) found *Culex quinquefasciatus* to be the most abundant mosquito species in Makurdi Area of Benue State, North Central Nigeria. According to Umaru *et al*. (2007) the abundance of *Culex* mosquitoes in a particular area is consequential in the transmission of filariasis all year round. Umaru *et al*. (2007) identified in Jimeta-Yola metropolis, species of *Anopheles* and *Culex* mosquitoes and concluded that both species of mosquitoes abound in Yola with potential health consequences in the transmission of malaria and filariasis all year round. Afolabi *et al.* (2013) recorded *Culex andersoni* as the most abundant mosquito species in in Akure, Ondo State, Nigeria with 23.1 % abundance followed by *Culex fatigans* (21.9 %).Significant variations in mosquito species composition have been attributed to differences in ecotypes, microclimatic conditions and sometimes sampling techniques (Olayemi *et al.,* 2011).

Cx. quinquefasciatus was the most common and abundant species in almost all the studies reviewed above. This is not surprising because *Cx quinquefasciatus* is the most widely distributed mosquito in the tropical and sub-tropical regions of the world usually near human dwelling.

2.4 Breeding Habitat and Productivity of Breeding Sites

Several environmental characteristics affect larval density which may influence the development and survival rate of the mosquito larvae. These characteristics include climate, physical and chemical conditions of the aquatic habitats, vegetation type and biological characteristics. Knowledge of larval vector ecology is a key factor in risk assessment and establishment of effective control measures, because the most effective method for controlling vector populations is to control the larvae in their aquatic habitats before they emerge as adults (Ebuzoeme, 2016).

Anthropogenic activities have seriously encouraged the breeding successes of mosquito species close to human habitation, thereby increasing the rate of disease transmission. Climate change such as temperature extremes, rainfall, relative humidity are major ecological factors which have devastating effect on the environment, thereby influencing the abundance and diversity of mosquito species (Hasnana *et al.,* 2016; Wilke *et al.,* 2019). Mosquito species have shown high preferences and greater affinity to different habitats. Some breed in natural habitats while others prefer artificial breeding sites where they mature to adult mosquitoes which are haematophagous in nature and are vectors of diseases in which some are either anthropomorphic or zoophilic. The breeding sites can be very diverse, including ponds, lakes, swamps, mashes, rice field, small rain pools, hoof prints, tyre-tracks, tree holes, plant axils, edge of streams (Wilke *et al.*, 2019; Zogo *et al*., 2019).

Natural breeding sites such as ponds, swamps, springs and streams sustain vector populations. Artificial breeding sites which include gutters, ditches, tyre-tracks, construction sites and swimming pools provides the most abundant sources of mosquito larvae in urban centres of Africa (Castro *et al.*, 2010; Siri *et al*., 2010). Tyre tracks and swimming pools were reported to contain all life stages of mosquito species, suggesting that they were particularly productive habitats (Matthys *et al.*, 2010) and were found mainly in poorly-drained peri-urban areas.

Culex mosquitoes are known to breed in diverse habitats and occur in different environments, some species of which have adapted to colonise urban centres. For instance, *Cx. quinquefasciatus* (a member of the *Cx. pipiens* complex), a vector of filarial worm, West Nile virus and a secondary vector of Rift Valley fever virus, breeds in organic polluted water in cess pits, drainage canals, and sewerage systems. It has also been reported by several authors that mosquitoes larvae co-habit together in relation to the breeding habitats. This is true as Lapang *et al.* (2019) found out that *Anopheles* and *Culex* mosquito larvae co-existed in different breeding sites in Shendam LGA, Plateau State, and North-Central Nigeria. Wilke *et al.* (2019) who collected mosquitoes larvae and pupae in 76 different types of aquatic habitats scattered throughout 141 neighborhoods located in the urbanized areas of Miami-Dade County of Florida, USA also found out that *Anopheles* and *Culex* mosquito larvae co-existed in different breeding sites.

Similarly, Bashar *et al.* (2016) found that both *Anopheles* and *Culex* mosquito larvae co-existed in different breeding sites in in semi-urban areas of Bangladesh and Emidi *et al.*

(2017) in a rural setting of Muheza, Tanzania. Emidi *et al.* (2017) however showed that the overall association between mean larval and pupa densities of *Anopheles* and *Culex* were highest in breeding sites comprising of roadsides water collections and in road potholes. Mwangangi *et al*. (2009) also reported high larval abundance of *Cx. quinquefasciatus* and *An. gambiae* in tyre tracks in Kibwezi, lower eastern Kenya.

In the report of Lapang *et al.* (2019), *Culex* breed close to houses but rice paddy was the most productive habitat type. Rice paddy accounting for the site with the highest abundance of mosquito larvae may probably be due to the fact that other breeding sites were easily prone to flooding and water run-off since the study was carried out during the wet season whereas rice seedlings served as breaks or reduced the speed of flowing water in rice field thereby providing a suitable breeding ground for mosquitoes since they are known to breed in stagnant water bodies (Lapang *et al.*, 2019).

The research of Nchoutpouen *et al.* (2019) found *Culex* species breeding in different types of breeding sites including polluted and unpolluted sites with *Cx*. *quinquefasciatus* larvae to be highly prevalent in polluted sites. According to Antonio-Nkondjio *et al.* (2012), it is likely that females of *Culex* species are more attracted by oviposition indications released by the microbial fauna in polluted habitats. In addition, these habitats are rich in nutrients and could thus reduce competition for resources between species. This could also be because mosquitoes in polluted sites are also frequently exposed to intensive selective pressure induced by pollutants and xenobiotics (Antonio-Nkondjio *et al.*, 2012; 2014) different strategies were reported to promote *Culex* species adaptation to different ecological constraints. These include the development of resistance or detoxification mechanisms to a large set of insecticides and xenobiotics (Ghorbani *et al.*, 2018) and development of cuticle resistance in larvae (Huang *et al.*, 2018).

Culex quinquefasciatus is normally known to breed in open drains, open or cracked septic tanks, flooded pit latrines and drains, especially when polluted with organic matter (David *et al.,* 2012). However, the breeding habit of *Cx. quinquefasciatus* can be very interesting as it tends to exploit human activities to their advantage. For example, the findings of Emmanuel *et al.* (2013) revealed that *Cx. quinquefasciatus* in the Imo River Basin area breed in pots of fermenting cassava, which is another example of successful exploitation of peoples' habits for self-perpetuation by the vectors. This food processing habit is an all-year-round practice and may therefore ensure an all-year-round breeding of *Cx. quinquefasciatus.* This is in line with the contention that human activity is altering the pattern of disease transmission in the tropics. Other breeding sites for *Cx. quinquefasciatus* as revealed by Emmanuel *et al.* (2013) in the area include natural containers of decaying Mbele fruits and broken suck away. It also breeds in septic tanks in neighbouring Okigwe town (David *et al.,* 2012). Furthermore, *Culex nebulosus*, *Cx. moucheti* and *Cx. cinereus* has been noted to be very common in polluted waters and sites which have foul smell (David *et al.,* 2012).

The increasing abundance of mosquitoes in the breeding sites can be attributed to a combination of factors such as temperature, pH, dissolved oxygen, relative humidity, conductivity and anthropogenic related factors (such as opened drainage system) (Afolabi *et al.*, 2013). According to Ciota *et al.* (2014), temperature influences larval developmental time and survival of adults of *Culex* mosquitoes, Studies have also shown that *Culex* species could easily adapt in clear-cut forests. The research of Mayi *et al.* (2019) revealed that *Culex* were more abundant in the selectively logged forest and less abundant in the young palm plantation. Selectively logged forest was described as a forest slightly fragmented due to selective logging of especially hardwood trees. The presence of these *Culex* species in the young palm plantation can be ecologically significant, given that these species could be associated with degraded environments characterized by the complete absence of woody vegetation except for young palm oil trees. In the young palm plantation, resting places and natural larval sites were rare due to the absence of trees and canopy. Mosquitoes resting on the vegetation were hard to find in the plantation because of too much heat (higher temperature recorded in this habitat as compared to the selectively logged forest), and may have rested in the surrounded remnant forest patches (Mayi *et al*., 2019).

According to the report of Karuitha *et al.* (2019), *Cx. pipiens* was found in several habitats in Kenya. These habitats include abandoned fountains, construction cemented tanks, poorly discarded PVC mats and polythene papers, garbage dumping sites, roadside rainwater collections, and open ornamental pots, poorly discarded scrap metal and trailers in garages, among others. All habitats were found to contain high numbers of late instar larvae and pupae, indicating their ability to attract gravid *Culex* mosquitoes for oviposition and successfully support the development of the immature mosquito to adult stages. Hence, owing to their productivity and stability, these habitats should be the primary target for vector control in the region.

Aggregated distribution of *Culex* immature stages observed within different larval habitats indicates that the dynamic interaction of factors in different aquatic habitats such as nutrients, social interactions and physical features influences the diversity and distribution patterns of immature mosquitoes (Noori *et al.*, 2015). Water turbidity and age of habitats are important environmental variables in determining the abundance and diversity of *Culex*mosquito larvae. According to the findings of Karuitha *et al.* (2019) *Culex* larvae were found to colonize aquatic habitats polluted with sand, mud, sewage and garbage more than *Aedes* species. A similar observation was reported in the study of Noori *et al.* (2015) who found that organically polluted water favoured the breeding of *Cx. pipiens* larvae. This is an indication that the water produces is rich in nutrients for the successful development of the *Culex* mosquito immatures.

Culex species demonstrate the abilities to breed at various habitat types throughout the year and this indicates a high potential for diseases. Olayemi *et al.* (2014) found *Culex* species in stagnant pools, gutters, domestic run-offs, containers, tree holes and leaf axils. Although its population was higher in containers and pools, it showed no distinct preference for a particular habitat as breeding sites.

As documented by Olayemi *et al.* (2014), *Cx. nigripalpus* and *Cx. salinarius* were encountered in three of habitat types (i.e., rice-fields, gutters and septic tanks), while *Cx. restuans* and *Aedes aegypti* were encountered in the gutters and the rain pools. Their study however revealed that the rice-fields and gutters were the most productive larval habitats, in terms of mosquito abundance and diversity. The rice field could be highly productive as a result of its water-logging attributes, high organic decay and inorganic chemical inputs by the farmers.

2.5 Biting Behavior of *Culex* Species

Mosquitoes exhibit host preference behavior as well as typical rhythmic pattern in their biting behavior. The difference in the feeding pattern contributes significantly in the transmission pattern of diseases among various hosts during different seasons. The rapid change in the ecosystem due to several factors such as the increase in global warming, unplanned urbanization, deforestation, changing human behavior, availability of hosts are found affecting the behavior of mosquitoes and thereby enhancing vector borne pathogen's transmission (Chaves *et al.*, 2008).

It is known that abundance, attractiveness, and availability of the human host are influencing vector biting behavior. According to Kweka *et al.* (2016), alterations to the landscape and environment due to human activity can influence disease epidemiology indirectly through changes in vector populations, ecology, biology and host-seeking behaviors of vectors searching for alternative habitats and new blood-feeding sources.

Biting behavior or host-seeking behavior of different mosquito's species has been documented by several researchers. However, these studies conducted in different countries all have different timing of sunrise and sunset. In addition, the timing as mentioned by these researchers may not correspond to the standard regional time. This may affect the timing of local authorities to conduct vector control activities, especially fogging. Light intensity controls biting activity of mosquitoes to a very fine degree. In other words, the host-seeking behavior of mosquitoes would likely depend on the presence of sunlight during sunrise and sunset (Chee *et al.*, 2014).

The study of Paramasivan *et al.* (2015) reveled that *Culex quinquefasciatus* exhibited a nocturnal biting pattern, which biting continued throughout mid-night and showed a declining trend after mid-night peak in south India. In addition, a mild biting activity was also observed in the early morning time. Emmanuel *et al.* (2013) reported that *Culex quinquefasciatus* mosquito exhibited a peak biting density between 1800 and 2000 hours outdoor outdoors in the Lower Imo River Basin, Nigeria. The report of Chee *et al.* (2014) similarly revealed *Culex quinquefasciatus* and *Cx. vishnui* to be nighttime feeders with multiple biting peaks throughout the night in Malaysia.

Paramasivan *et al.* (2015) also reported that *Culex tritaeniorhynchus* showed a typical nocturnal biting pattern and the biting rhythm reached a peak at mid-night. After mid-night peak, the decrease in the density of biting mosquitoes was observed up-to dawn. Similarly, Rohani *et al.* (2013) recorded three peaks of biting activity of *Cx. tritaeniorhynchus*.

Another study conducted in Benin City of Nigeria by Aigbodion and Emiebor (2008) showed that April, May, and June possessed a two-hour biting peak for *Culex quinquefasciatus* from 0000 to 0200, while only a one-hour biting peak from 0100 to 0200 was observed in March, July, August, and September.

Cx. gelidus, a zoophilic mosquito has been reported to exhibit nocturnal biting pattern with a prominent post dusk peak of activity. According to the report of Paramasivan *et al.* (2015), the biting activity of this mosquito was restricted during the early part of the night, i.e., before mid-night. However, Sudeep (2014) observed its biting activity throughout night with a peak biting between 0300 and 0600 hours. Paramasivan *et al*. (2015) further reported a typical nocturnal uniform biting activity exhibited by *Cx. infula* and the biting was restricted uniformly during the dark phase. *Cx. vishnui* and *Cx. pseudovishnui* showed a nocturnal biting rhythm and showed a post dusk biting peak like *Cx. gelidus* (Paramasivan *et al.,* 2015).

2.6 Physicochemical Parameters of Breeding Sites

Mosquito species differ in the type of aquatic habitats they prefer for oviposition based on location, physicochemical conditions of water body, and the presence of potential predators. Physiochemical compositions of the water bodies are complicated and determine their condition and fauna composition. Physicochemical factors that influence oviposition, survival rate and the distribution of mosquito species include salts, dissolved organic and inorganic matter, degree of eutrophication, turbidity, presence of suspended mud, temperature, light, shade, Hydrogen ion concentration and presence of food substances (Chatterjee *et al.,* 2015). Larval control can be achieved through larval habitat management by altering physiochemical properties of breeding habitats (Chatterjee *et al.,* 2015). Understanding the impact of these parameters will lead to better decision making in relation to mosquito control activities.

In addition, the physico-chemical properties of the mosquito larval habitats determine its quality, in terms of attractiveness to gravid female mosquitoes for oviposition, developmental success of immature mosquitoes, species distribution and adult life traits (Eneanya *et al.,* 2018). Both the physical and chemical characteristics of mosquito breeding sites may have some effects on mosquito vectors oviposition, survival and spatial distribution (Garba and Olayemi, 2015). Physicochemical parameters such as temperature, salinity, conductivity, total dissolved solids (tds), hardness and pH have a significant influence on the occurrence and larval abundance among mosquito species (Imam and Deeni, 2015).

Mosquitoes show preference to water with suitable pH, optimum temperature, dissolved oxygen, concentration of ammonia, nitrate. These physico-chemical parameters have been found to affect larval development and survival in breeding water. As observed by Afolabi *et al.* (2019), physico-chemical parameters of mosquito habitat determine mosquito oviposition and abundance.

It has been suggested that the strong correlations found between certain physico-chemical parameters and larval abundance confirm the influence of these parameters on the distribution and abundance of mosquito larvae in their breeding habitats and also indicate the possibility of mosquito larval control through the manipulations of such parameters (Olayemi *et al.*, 2010).

To date, many studies have found that some biological and physicochemical characteristics of larval habitats such as pH, water temperature, dissolved oxygen, turbidity, soluble solids, conductivity, salinity, and resistance were correlated with the presence of mosquito larvae (Liu *et al.,* 2012, Mereta *et al.,* 2013). Olayemi *et al.* (2010) reported significant differences in physico-chemical properties of conventional mosquito breeding habitats in Minna Nigeria with attendant influence on species composition and relative abundance of mosquitoes in such habitats.

It was also reported by Anderson and Harrington (2005) that *Culex* mosquito prefers to lay eggs in polluted or stagnant waters, such that their presence in a water body is an indication of pollution. The report given by Nikookar *et al.* (2017) pointed out that an apparent relationship exists between mosquito breeding and poor water quality. High levels of dissolved organic matter are said to provide nutrients for the bacteria and algae used as food by mosquito larvae. Larval density was also said to depend on factors like type of plant cover, food availability and predator abundance.

Water temperature influences many aspects if mosquito life traits and even vector competence (Ciota *et al.,* 2014). According to the findings of Olajire *et al.* (2017), the temperature range in which culine mosquito breeding was found in the study area is 25.09-27.22 ^oC.

As revealed by the results of Olajire *et al.* (2017), temperature, relative humidity, pH, electrical conductivity and dissolved oxygen are the major factors that could play an important role in breeding and propagation of mosquitoes. Afolabi*et al.* (2013) reported that temperature range of 27.3–29 ^oC is favorable physico-chemical parameters that favor breeding of mosquito species. Likewise, Afolabi and Ndams (2010) stated that female mosquitoes preferred water temperature range of 24.7 to 28.3 ^oC and that temperature below 24.7 ^oC and above 28.3 ^oC are fatal to mosquito species. Similarly, the work of Afolabi *et al.* (2013) established that mosquitoes breed at water temperature of 26.5 to 29.3 ^oC. A recent study conducted by Afolabi and Aladesanmi (2018) also shows that the optimal temperature that favored breeding in Akure North is 28 ^oC while mosquito breeding is not likely to be found in temperature below 25 ^oC.

The report given by Owolabi and Bagbe (2019) revealed that *Culex* mosquitoes prevailed in open waters within the temperature range of 29-30 ^oC for the breeding sites. This is similar to the findings of Nikookar *et al.* (2017) who found *Culex* mosquitoes in the temperature range of 20-25 ^oC. *Cx. quinquefasciatus* has the ability to thrive even in a low dissolved oxygen breeding habitat as reported by Olajire *et al.* (2017) who recorded abundance of *Cx. quinquefasciatus* when the DO of the studied areas was low (1.95 – 2.67). Afolabi *et al.*

(2019) however reported dissolved oxygen range of 2.43–3.84 mg/L in *Culex* mosquito's habitats.

The discharge of agricultural wastes, domestic wastes and organic materials into water body contribute to low dissolved oxygen in mosquito breeding habitat. The survival of larvae when submerged depends on their ability to absorb oxygen through the cuticle. When the level of DO is low the rate of loss of buoyancy is said to be rapid, this suggests that the outward diffusion of gas into the water is significant. This might be the reason why there can be abundance of *Cx. quinquefasciatus* when the DO of the breeding habitat is low, because it has the ability to survive for considerable longer period than any other species (Olajire *et al.,* 2017).

One of the chemical water parameters that can affect the breeding of *A. gambiae* development and survivorship is pH. The pH levels are the degree of acidity used to express acidity or basicity. The pH range ranges from 0 to 14. The pH value of less than 7 indicates an acidic environment, while the above 7 indicates an alkaline environment (Hidayah *et al.,* 2017). The results of Grahaperkasa *et al.* (2016) showed that the average number of larvae that developed into mosquitoes in water with pH 5 was 76.5 %, pH 7 was 98 %, and pH 9 was 86.5 %. This shows the possibility of a correlation between water pH and the proliferation of mosquito vectors.

Many studies have shown that the effect of pH is of unquestionable importance and that its significance lies in the fact that, under natural conditions, it dictates the fevourability of association between chemical and biological factors in breeding places upon which the successful or unsuccessful development of larvae depend (Mereta *et al.,* 2013). The larvae of certain species tend to actually restrict themselves to water exhibiting a pH index within a definite short range, and that the pH indexes is consequently often reliable as to whether the chemical and biological group associations will fevour or preclude the successful development of such larvae. The pH of water is dependent on the concentration of anions and cations derived from salts, fertilizer compound and other synthetic compounds all together accounted for the pH. Therefore, it may directly or indirectly detect the life of any aquatic organisms. The anions and cations may indirectly affect mosquito breeding by fevouring certain aquatic organisms or vegetation on which mosquito larvae feed or affect potential biological control agents of *A. gambiae* (Mattah *et al.*, 2017). If pH falls below the tolerance range, death would ensue as result of disturbance of the acid and base of the hemolymph (Mattah *et al.*, 2017).

For aquatic insects, ambient pH levels influence balance in body fluid ionic composition, which is chief in maintaining homeostasis and development (Mattah *et al.*, 2017). The pH of an aquatic habitat is also a major physical factor that limits survivorship and, hence, distribution of mosquito species, affecting availability of essential mineral and food elements for the development of mosquitoes. Studies have shown that mosquito larvae are capable of adapting to and tolerating fluctuations in ionic levels in these habitats (Mattah *et al.*, 2017).

Several authors reported that almost all the alkaline pH (pH >7) favored the breeding of culine mosquitoes in Nigeria. This is because most mosquito species thrive better in alkaline environment. Olajire *et al.* (2017) recorded slightly alkaline pH (7.07-7.24) in Ondo, Nigeria and this might have resulted in the abundance of mosquitoes in the studied areas. Similarly, Afolabi *et al.* (2013) also reported abundant culicine mosquitoes in alkaline breeding habitats at Ondo, Nigeria, with the pH range of 7.1 to 7.3 supporting breeding in all the habitats sampled. Afolabi *et al.* (2019) also found the favorable pH that favor breeding of *Culex* mosquitoes to be in the range of 7.14–7.30, in Ondo, Nigeria.

The optimal pH recorded in these studies has also been reported by other authors (Afolabi *et al.,* 2010). The authors reported that pH range of 6.8–7.2 and 7.0–7.4 were suitable for the weakening of the mosquito egg shells for the emergence of its first instar larvae and that pH less than 5.0 and higher than 7.4 have fatal effects on survival of mosquito species. The pH range recorded by Owolabi and Bagbe (2019) however showed that *Culex* mosquitoes can thrive well in an environment with a wide range of pH (7.7-8.9).

Mosquitoes are known to show preference to water with suitable pH, optimum temperature, dissolved oxygen, concentration of ammonia, and nitrate (Afolabi *et al.,* 2013). According to the work of Aminuwa *et al.* (2018), water pH has significant effects on the duration of embryonic development and egg hatchability of *Culex quinquefasciatus*. There was a significant reduction in the performance of the mosquito as pH tilted towards acidity and alkalinity from neutrality (pH 7.0). Among the pH values tested, extreme acidic condition (pH 4.0) did not support embryology and eclosion, while, extreme alkaline (pH 10.0) did; though, with a significant increase in duration of embryogeny.

In a more recent study, the results of Ukubuiwe *et al*. (2020) revealed pH values ranging from 4.0 to 10.0 supported the survivorship of *Culex quinquefasciatus* mosquitoes but affect the life stages in various ways. The pH values in their study greatly affected the number of emergent adult mosquito, with significantly higher number of emerging female than male mosquitoes at all pH levels investigated. Significantly lower numbers of emergent were observed at pH values of 4.0 and 10.0. Post-emergence longevity was significantly affected by the pH value of water used for rearing. Those reared at pH 6.0 to

8.0 lived the longest than those from other regimens; the shortest-lived were from pH 4.0 and 10.0.

Some studies also revealed that water pH could have significant effects on the body size of mosquitoes. For example, the report of Aminuwa *et al.* (2018) revealed that *Culex quinquefasciatus* mosquitoes raised on pH 10 were the smallest, while those on pH 7 were the biggest. The information above provides insight into the role played by pH conditions in the control of mosquito proliferation in the wild. Such information could be handy in the distribution of scarce economic resources in vector control interventions; such resources could, perhaps, be channeled to controlling vectors in habitats with most suitable favorable breeding pH values, while allowing 'nature' to control those at deleterious pH conditions.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Study Area

The study was carried out in Badeggi Community, located in Katcha Local Government Area of Niger State. The Community is located 94 Kilometres from Minna, the administrative and economic Capital of the State. Badeggi is home to the National Cereal Research Institute (NCRI). The land in the area is highly arable, with favourable wetland micro-climatic conditions for rice production.

The community, located within Latitude 9^{o} 3' 0" N and Longitude 6^{o} 9' 0" E, has a population of 71,657 people (figure 3.1). The climate of the area is typically tropical with two distinct seasons of rain (May to October) and dry (November to April). The nearest available weather conditions to Badeggi are those of Minna, with mean annual temperature, relative humidity and rainfall of 30.20 ^{o}C, 61.00 % and 1334.00 mm, respectively.

Business ownership and subsistence farming are the major occupations of the residents; and the farmers are famous for fishing, and rice, sugar cane and soy beans production. The soil type of the area is mostly sandy loam and a sizeable proportion of the arable land in the community is swampy and subject to intensive back-to-back rice cultivation, made possible by dry season irrigation practices.

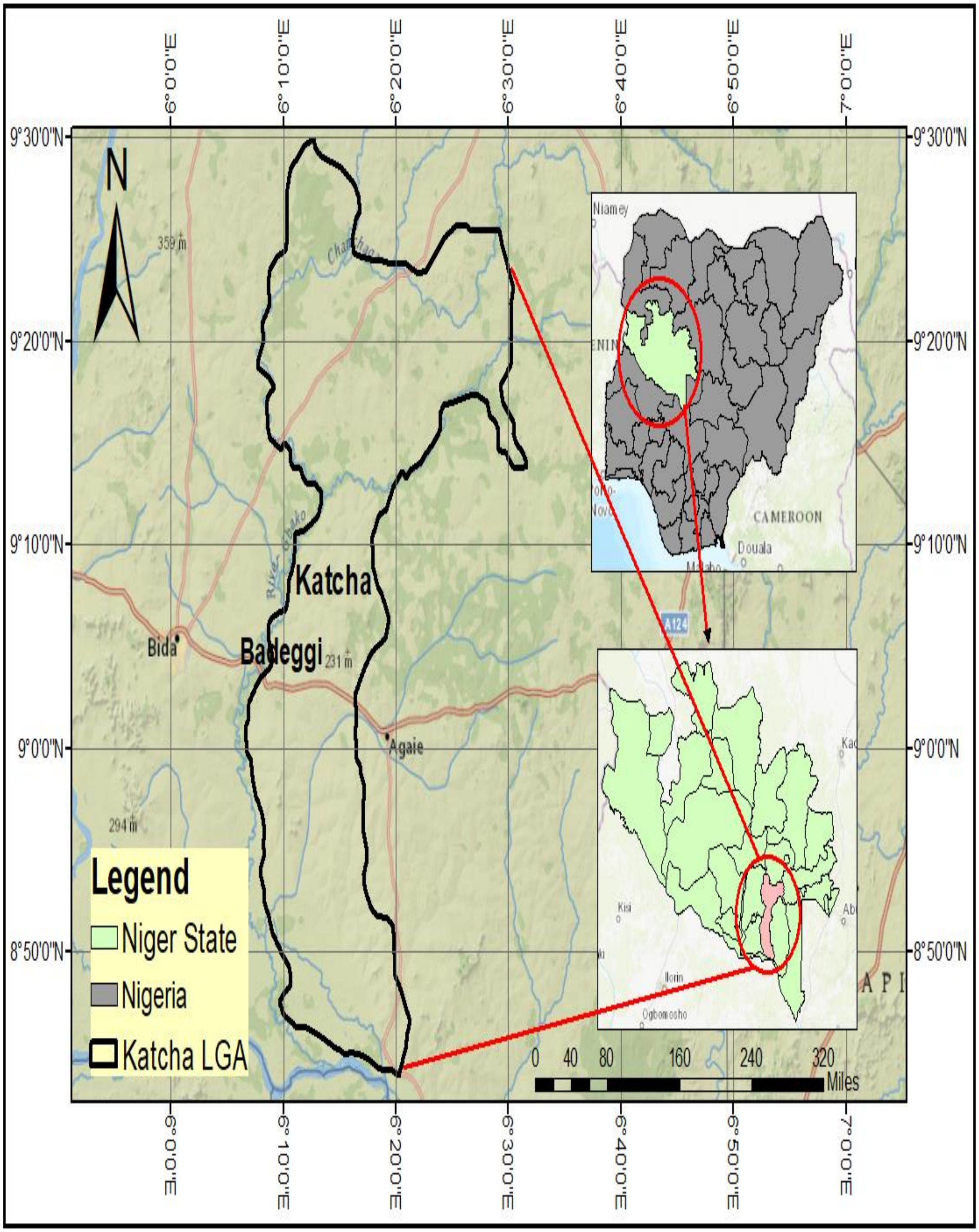

Figure 3.1: Map of the Study Area

3.2 Adult *Culex* Mosquito Collection

3.2.1 Procedure for indoor adult mosquito collection

Centre for Disease Control Light Trap (CDC LT) was used for adult mosquito collection. The CDC LT was assembled 1.5 metres above the floor level using a support, close to the legs of sleeping bait under a non-treated bed-net. The collection cups was labelled (on hourly basis for collections between 1800 to 0600 hours) prior to collection. The CDC LT was connected and switched on at exactly 1800 hours, and collection was made on hourly basis. Collected mosquitoes were extracted using an aspirator and placed in the pre-labelled cup corresponding to the hour of collection. Collected samples were sorted and kept free from destruction by ants by placing them in field boxes (CDC, 2010).

3.2.2 Procedure for outdoor adult mosquito collection

Sleeping bait was made to sleep outside the house in an open/ uncovered space under bed-net. The CDC LT was assembled 1.5 metres above the floor level using a support, close to the legs of sleeping bait under a non-treated bed-net. The collection cups was labelled (on hourly basis for collections between 1800 to 0600 hours) prior to collection. The CDC LT was connected and switched on at exactly 1800 hours, and collection made on hourly basis. Collected mosquitoes were extracted using an aspirator and placed in the pre-labelled cup corresponding to the hour of collection. Collected samples were sorted and kept free from destruction by ants by placing them in field boxes (CDC, 2010).

3.3 Procedure for Adult Mosquitoes' Preservation and Transportation to the Laboratory:

For preservation of adult mosquitoes, 1.5 ml Eppendorf tubes were half-filled with self-indicating blue silica gel and covered with white paper. Each collected mosquito was put in a tube, using forceps and the lid of the tube covered. The tubes were labelled legibly with marker to include time and date of collection. Based on time of collection, the well-labelled Eppendorf tubes (containing mosquito samples) were packaged in Zip-lock bag (containing silica gel). Preserved specimens were then transported to the laboratory for identification and further analyses.

3.4 Morphological Identification of *Culex* Mosquitoes

3.5 Determination of the Productivity of Larval Habitats

The productivity of the larval habitats was determined by sampling larvae from two types of mosquito breeding habitats (Rice field and Pond). Sampling was done between the hours of 16:00-18:00, for three days, using a standard 350 ml capacity Dipper. Twenty dipper samples were taken randomly from each sampling site and then the mosquito larvae recovered were preserved immediately in specimen bottles, using 70 % alcohol following the method in Soumendranath *et al.* (2015). The preserved larvae of mosquito were transported to the laboratory of the Department of Animal Biology, Federal University of Technology, Minna for Identification.

3.6 Water Sample Collection and Physico-chemical Analysis

3.6.1 Water sample collection

Surface water from mosquito larval breeding sites in the stations was collected from the habitats from 16:00-18:00 hours using 350 ml bottles (for Biological Oxygen Demand, BOD and Dissolved Oxygen, DO analysis) and 750 ml bottles (for other physico-chemical analysis). They were carefully labeled and transported to the Laboratory of Department of Fisheries, Federal University of Technology, Minna for analyses. The water samples collected for analyses of Dissolved Oxygen (DO) were fixed at site using the Winkler's Method, by adding Manganese Sulphate and Alkaline Iodide Solution. However, water Samples for other analyses were not preserved.

3.6.2 Physico-chemical analysis

i. **Temperature (ºC):** Temperature of the breeding habitats was determined *in situ* using a Hanna multiparameter.

ii. **pH:** It was determined according to the method of Manivaskam (2005), using a pH meter (Jenway 3305). Briefly, the meter probe was standardized with buffer solutions of pH 4.0, 7.0 and 10.0 before insertion into water sample from habitats and left for about 5 minutes until it stabilized before readings were taken.

iii. **Electrical Conductivity (µS/cm):** The conductivity of the habitats was determined by using digital conductivity meter (Manivaskam, 2005). A hand electrical conductivity meter (CD 4303 Lutron) probe was inserted into sampled water from habitats for 5 minutes until reading stabilized; readings were taken and expressed in microsiemens/cm.

iv. **Total Hardness (mg/L):** Fifty milliliters of water sample collected from the breeding habitats was filtered through ordinary filter paper and water collected in the evaporating dish of known weight. Further it was heated until water totally evaporated. The amount of dissolved solid matter present accumulated at the bottom of evaporating dish. The evaporating dish was cooled and weighed. By weight difference method, the total dissolved solids were determined (APHA, 2005).

v. **Dissolved Oxygen (mg/L):** Winkler's method was followed for the analyses of DO. The water samples from habitats were fixed right on site with 1ml of Manganese Sulphate and 1ml of Alkaline Iodide Solution formed by equal volumes of KOH AND KI. About 2ml of concentrated sulphuric acid was added to each sample and 10 ml of the sampled titrated against 0.025 M Sodium thiosulphate, using starch as indicator until it turns colourless.

vi. **Alkalinity (mg/L):** The alkalinity of water sample was determined by titrating it against standard acid solution using indicators like phenolphthalein and methyl orange (APHA, 2005).

vii. **Nitrate, Calcium, Chlorine and Phosphate Contents (mg/L):** These were also determined according to the method described by APHA (2005).

viii. **Biological Oxygen Demand (BOD):** The BOD was determined using Winkler's method. Water samples were incubated in the dark for 5 days before titrating for Oxygen as in the case of DO.

3.7 Identification of Mosquito Larvae

3.8 Data Analysis

Data collected from the field study and those generated in laboratory studies were processed into means and standard deviation using Microsoft Office Excel 2010.The species composition and relative abundance of the mosquitoes was represented in percentages and Pie chart. Physico-chemical properties of breeding sites and productivity of larval habitats was compared between sites using student t-test and correlated with adult mosquito ecological parameters using linear correlation coefficient. All decisions on statistical comparison of means were taken at $p<0.05$ level of significance.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Species Composition and Relative Abundance of Adult *Culex* Mosquitoes in Baddeggi, Niger State, Nigeria

A total of 2848 *Culex* adult mosquitoes were collected using a baited CDC light trap method during the research period, from January to December 2020 with the exception of the months of April, May and June due to the restriction of movement during the Corona Virus Pandemic.

The species composition and relative abundance of the *Culex* mosquitoes is shown in Figure 4.1. Five (5) species were encountered during the work which include; *Culex nigripalpus, Culex quinquefasciatus, Culex restuans, Culex salinarius and Culex tritaeniorhynchus. Cx. quinquefasciatus* recorded the highest percentage (52 %), followed by *Cx. salinarius* (24 %), *Cx. tritaeniorhynchus* (17 %), *Cx. restuans* (5 %) and *Cx. nigripalpus* (2 %) which was the least. The principal *Culex* mosquito in Badeggi is *Cx. quinquefasciatus*.

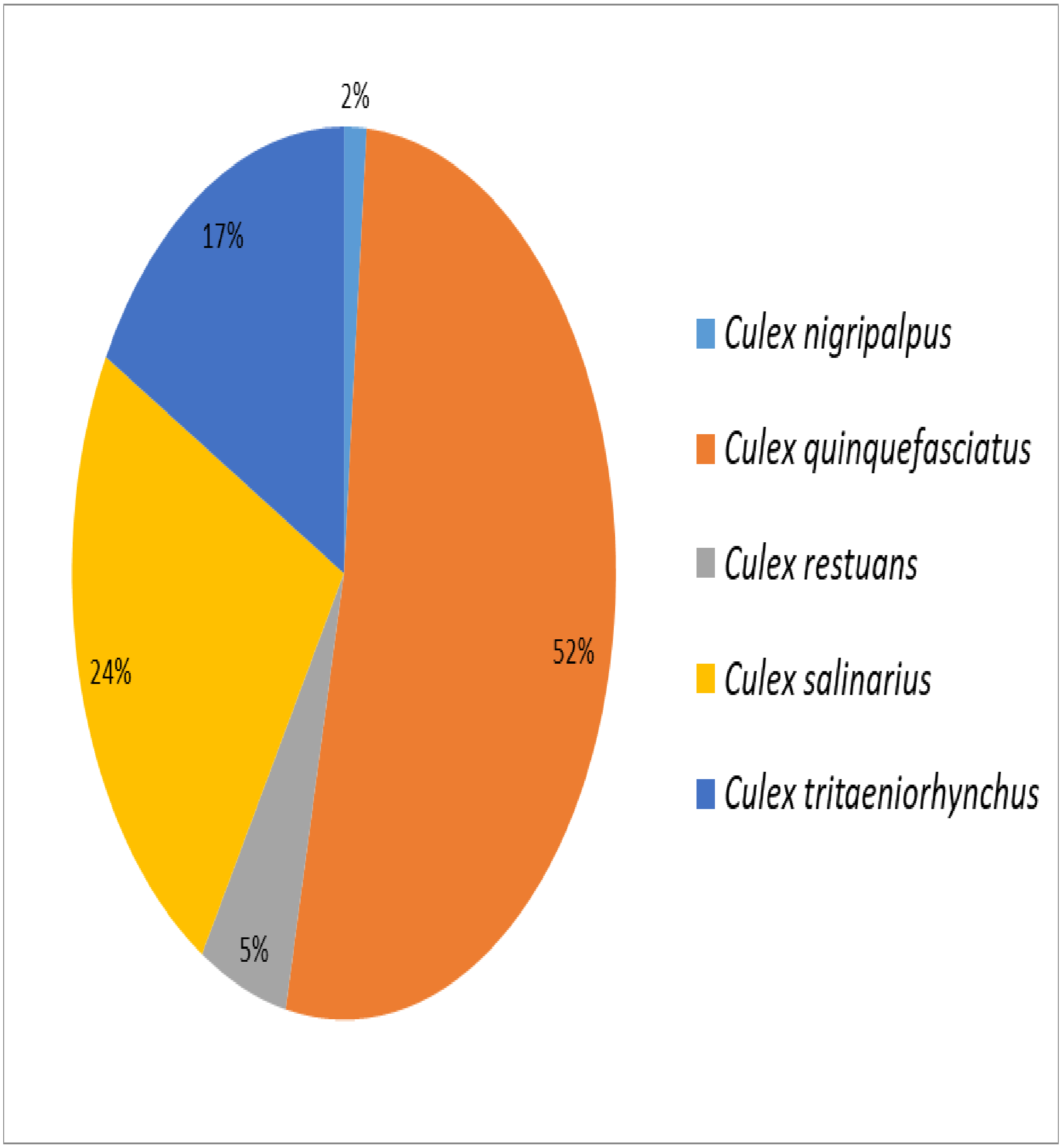

Figure 4.1: Composition and Relative Abundance of *Culex* Mosquito Species in Badeggi, Niger State, Nigeria

4.1.2 Biting Periodicity of *Culex* Mosquitoes in Badeggi, Niger State, Nigeria

The biting periods of *Culex* mosquitoes in Badeggi, in the Months of January- March, July-September and October- December are shown in Figure 4.2a, 4.2b and 4.2c respectively.

In the Months of January-March, biting activities were low at the hours of 6-7 pm and 5-6 am. Biting activities increased between the hours of 7-9 pm at its peak, drops a bit between the hour of 9-10 pm and further increased between the hours of 10-1 am, drops again between the hour of 1-2am and further increased again until its plummet at the hour of 5-6 am. The number of mosquitoes recorded was more in the month of February, followed by the month of January and the month of March which recorded the least.

In July-September, there was low biting activites between 6-7 pm, a higher increase of biting activities between 7-9 pm, drops a bit between the hours of 9-11 pm, further increased between the hours of 11-2 am until it drops again at the hour of 5-6 am. A high number of *Culex* mosquitoes were recorded in August then followed by July; September recorded the least number of mosquitoes.

In the months of October- December, low biting activities was also recorded between the hour of 6-7 pm, increased at its peak between the hour of 7-8 pm, drops a bit at the hours of 8-10pm, further increase at the hour of 10-11 pm, drops again at the hour of 12-1 am then further increase again until it plummet at the hour of 5-6 am.

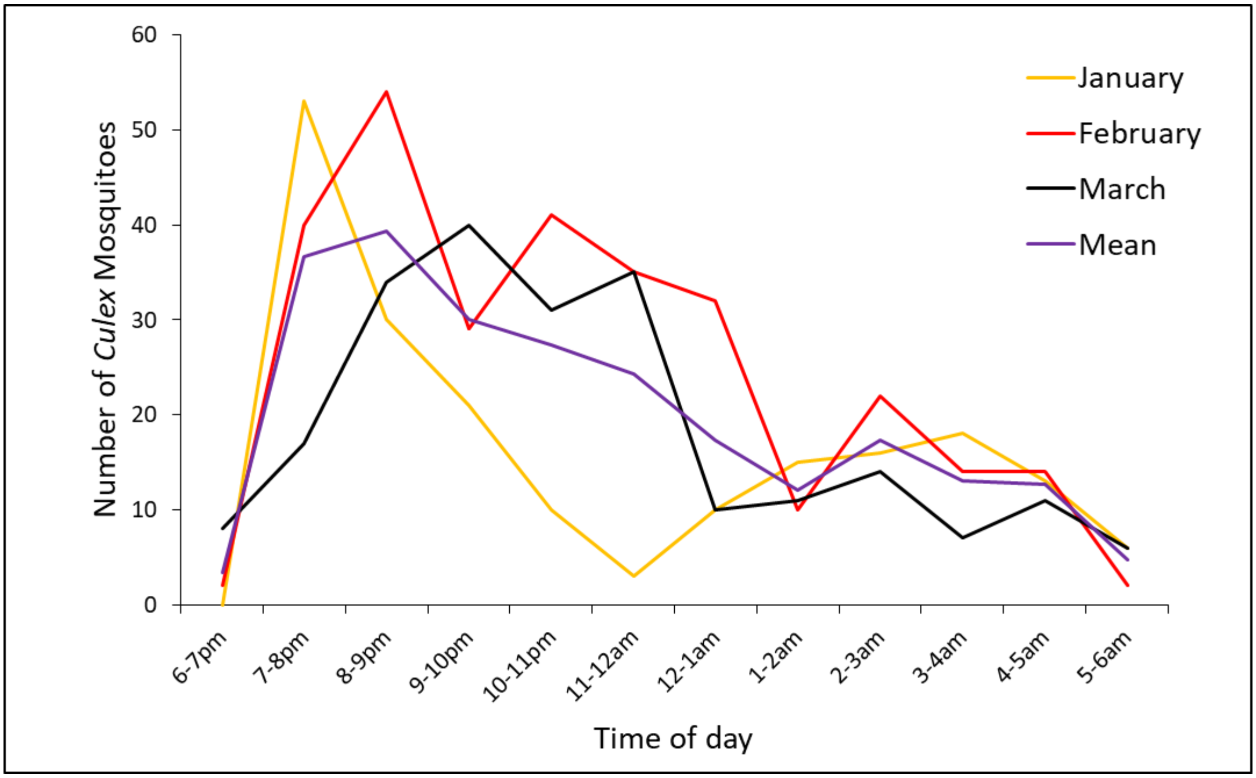

Figure 4.2a: **Biting Periodicity of *Culex* Mosquitoes in Badeggi Nigeria, January-March, 2020**

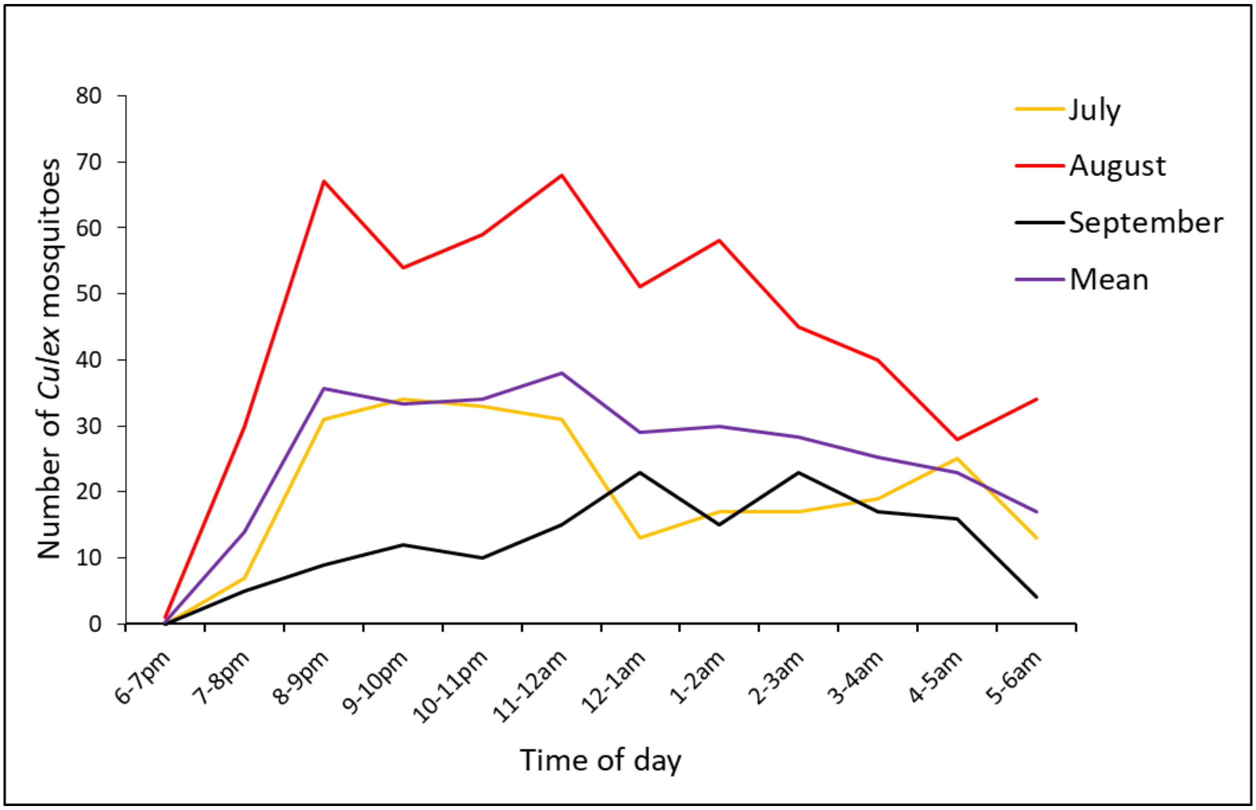

Figure 4.2b: Biting Periodicity of *Culex* Mosquitoes in Badeggi Nigeria, July - September 2020

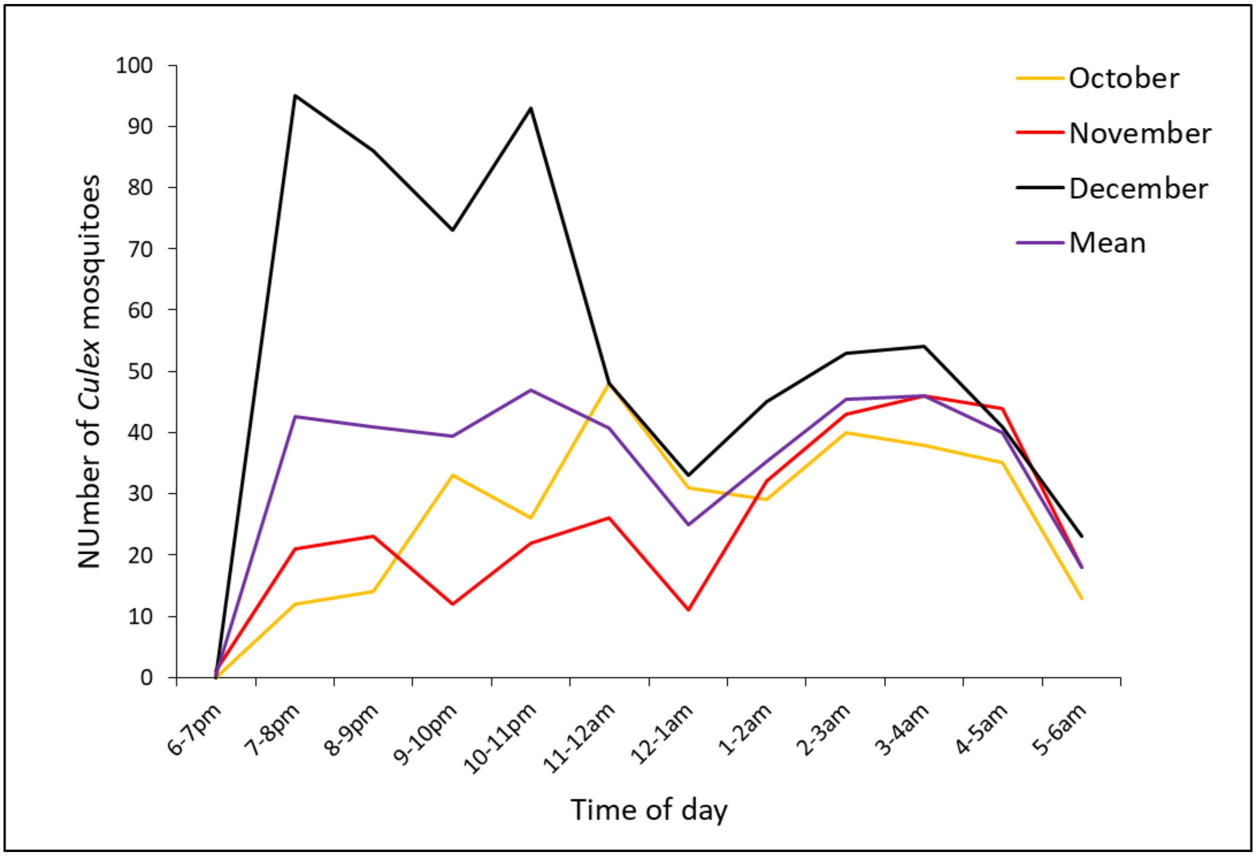

Figure 4.2c: Biting Periodicity of *Culex* Mosquitoes in Badeggi Nigeria, October - December, 2020

4.1.3 Biting Location Preferences of *Culex* mosquitoes in Badeggi, Niger State, Nigeria

Figure 4.3 shows the preferred biting location of *Culex* mosquitoes in Badeggi, Niger State, Nigeria. In the months of January-March, and August, mosquitoes bit more outdoors compared to indoors, also, in the months of July, September and October, mosquitoes bit more outdoors even though a considerable number also bit indoors. While in the months of November and December, mosquitoes were encountered biting more indoors compared to outdoors.

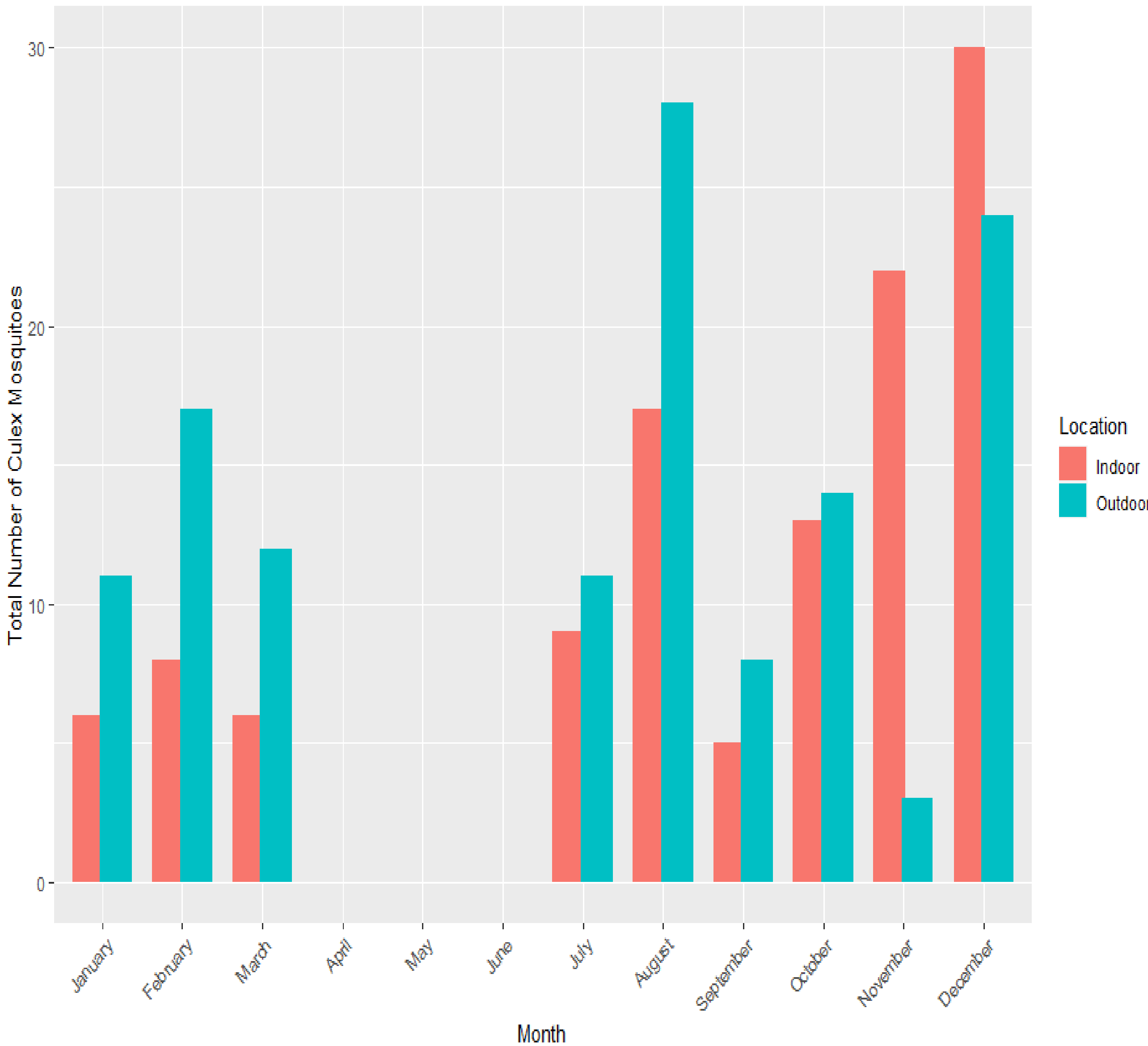

Figure 4.3: Biting Location Preferences of *Culex* mosquitoes in Badeggi, Niger State, Nigeria

4.1.4 Physico-chemical characteristics of larval breeding sites in Badeggi, Niger State

The physico-chemical parameters analyzed from the water samples collected from rice field and pond during the months of March, July, August and October, 2020 in Badeggi, Niger State Nigeria include the following: Temperature (Temp), pH, Electrical Conductivity (EC), Total Alkalinity (TA), Total Hardness (TH), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Nitrate (NO_3), Phosphate (PO_4), Total Dissolved Solid (TDS), Calcium (Ca) and Chlorine (Cl).

4.1.4.1 Variation of the physico-chemical parameters in rice field

Variation of the physico-chemical parameters in rice field is shown in Table 4.1a. The water temperature was lower in the months of July and August (22.25 ^{o}C and 25.45 ^{o}C) and slightly higher in the months of March and October (28.55 ^{o}C and 26.50 ^{o}C). Likewise PO_4, it was lower in the months of July and August (0.62 mg/L and 0.75 mg/L) and slightly higher in the months of March and October (1.15 mg/L each). 6.2 0mg/L and 6.80 mg/L of DO were recorded in the months of March and July while 8.50 mg/L and 8.00 mg/L were recorded in the months of August and October. 21.79 mg/L, 18.23 mg/L, 22.30 mg/L and 17.64 mg/L of Cl were recorded in the months of March, July, August and October respectively. pH was slightly acidic in the months of March, July and October (6.69, 6.81 and 6.41) while it was neutral at the month of August (7.04). 238.50 us/cm and 252.00 us/cm of EC was recorded in the months of August and October while 253.50 us/cm and 291.50 us/cm was recorded in July and March respectively. 89.00 mg/L and 102.00 mg/L of TA was recorded in the months of October and July while in August and March it was

111.00 mg/L and 112.50 mg/L. 69.00 mg/L, 70.00 mg/L, 83.00 mg/L and 91.00 mg/L of TH were recorded in the month of August, October, July and March respectively.

BOD was 3.20 mg/L and 3.65 mg/L in the months of October and July while in the months of March and August, it was 4.00 mg/L and 4.15 mg/L respectively. 2.24 mg/ of NO_3 was recorded in the month of July, 3.23 mg/L and 3.57 mg/L was recorded in the months of March and August respectively, while in the month of October, it was 5.27 mg/L. 78.59 mg/L, 82.86 mg/L, 95.41 mg/L and 146.03 mg/L of TDS were recorded in the months of August, October, March and July respectively. 14.92 mg/L, 18.08 mg/L, 20.55 mg/L and 21.86 mg/L of Ca were recorded in the months of August, October, July and March respectively.

The mean±standard deviation values of these physico-chemical parameters are shown in the table.

Table 4.1a: Variation of Physico-Chemical Parameters in Rice field

Month / Parameter	March	July	August	October	Mean±sd
Temp (ºC)	28.55	22.25	25.45	26.50	25.69±2.63
Ph	6.69	6.81	7.04	6.41	6.74±0.26
EC (µs/cm)	291.50	253.50	238.50	252.00	258.88±22.77
TA (mg/L)	112.50	102.00	111.00	89.00	103.63±10.79
TH (mg/L)	91.00	83.00	69.00	70.00	78.25±10.62
DO (mg/L)	6.20	6.80	8.50	8.00	7.38±1.06
BOD (mg/L)	4.00	3.65	4.15	3.20	3.75±0.42
NO_3 (mg/L)	3.23	2.24	3.57	5.27	3.58±1.28
PO_4 (mg/L)	1.15	0.62	0.75	1.15	0.92±0.28
TDS (mg/L)	95.41	146.03	78.59	82.86	100.72±31.04
Ca (mg/L)	21.86	20.55	14.92	18.08	18.85±3.05
Cl (mg/L)	21.79	18.23	22.30	17.64	19.99±2.39

Temp= Temperature; EC= electrical conductivity; TA= Total Alkalinity; TH= Total Hardness; DO= Disolved Oxygen; BOD= Biological Oxygen Demand; NO_3= Nitrate; PO_4= Phosphate; TDS= Total Dissolved Solid; Ca= Calcium; Cl = Chlorine

4.1.4.2 Variation in physico-chemical parameters in pond

Table 4.1b shows the variation in Physico-chemical parameters in Pond. Water temperature was lower in the months of July and August (23.55 ^{o}C and 25.85 ^{o}C) and higher in the months of March and October (29.40 ^{o}C and 27.50 ^{o}C). pH was slightly acidic in the months of March and October (6.89 and 6.77) while it was neutral in the months of July and August (7.1 and 7.20). 249.5 us/cm, 345.00 us/cm, 473.00 us/cm and 595.50 µs/cm of EC was recorded in the Months of August, July, March and October respectively. 101.00 mg/L, 115.00 mg/L, 132.00 mg/L and 148.50 mg/L of TA was recorded in the months of July, August, October and March respectively.

TH was less in the Months of July and August (86.00 mg/L and 99.00 mg/L) and more in the months of March and October (130.00 mg/L and 131.00 mg/L). DO was less in the months of March and October (6.15 mg/L and 6.25 mg/L) and more in the months of July and August (7.30 mg/L and 6.70 mg/L) 4.65 mg/L, 4.85 mg/L, 5.00 mg/L and 5.15 mg/L of BOD was recorded in the months of August, March, October and July respectively. NO_3 was lower in the month of July (3.62 mg/L), higher in the month of October (9.39 mg/L) and moderate in the months of March and August (5.04 mg/L and 5.57 mg/L). PO_4 was lower in the month of July (0.96 mg/L), higher in the month October (3.18 mg/L) and moderate in the months of August and March (1.60 mg/L and 1.63 mg/L). 82.45 mg/L, 143.24 mg/L, 154.74 mg/L and 194.45 mg/L of TDS was recorded in the months of August, July, March and October respectively. Calcium was less in the months of July and August (18.69 mg/L and 20.60 mg/L) and more in the months of March and October (42.18 mg/L and 36.58 mg/L). Chlorine also was less in the months of July and August (14.56 mg/L and 17.91 mg/L) and more in the months of March and October (24.13 mg/L and

20.91 mg/L). The mean±standard deviation values of these physico-chemical parameters are shown in the table.

Table 4.1b: Variation in the Physico-Chemical Parameters in Pond

Month / Parameter	March	July	August	October	Mean±sd
Temp (^oC)	29.40	23.55	25.85	27.50	26.58±2.48
Ph	6.89	7.10	7.20	6.77	6.99±0.19
EC (us/cm)	473.00	345.00	249.50	595.50	415.75±150.81
TA (mg/L)	148.50	101.00	115.00	132.00	124.13±20.61
TH (mg/L)	130.00	86.00	99.00	131.00	111.50±22.58
DO (mg/L)	6.15	7.30	6.70	6.25	6.60±0.52
BOD (mg/L)	4.85	5.15	4.65	5.00	4.91±0.21
NO_3 (mg/L)	5.04	3.62	5.57	9.39	5.90±2.46
PO_4 (mg/L)	1.63	0.96	1.60	3.18	1.84±0.94
TDS (mg/L)	154.74	143.24	82.45	194.45	143.72±46.37
Ca (mg/L)	42.18	18.69	20.60	36.58	29.51±11.65
Cl (mg/L)	24.13	14.56	17.91	20.91	19.38±4.09

Temp= Temperature; EC= electrical conductivity; TA= Total Alkalinity; TH= Total Hardness; DO= Disolved Oxygen; BOD= Biological Oxygen Demand; NO_3= Nitrate; PO_4= Phosphate; TDS= Total Dissolved Solid; Ca= Calcium; Cl = Chlorine

4.1.4.3 Comparison between physico-chemical parameters of the breeding sites

Comparison between physico-chemical parameters of the breeding sites is shown in table

Physico-chemical	**Site**		**P-value**
parameters	**Rice field**	**Pond**	

4.1c. Analyses revealed a significant ($p < 0.05$) variation in some of the physico-chemical parameters of the breeding sites studied (rice field and pond).

There was significant difference between the pH, Electrical Conductivity (EC), Total Alkalinity (TA), Total Hardness (TH), Biological Oxygen Demand (BOD), Nitrate (NO_3), Phosphate (PO_4), Total Dissolved Solid (TDS) and Calcium (Ca) of Rice field and Pond. While between the Temperature (T), Dissolved Oxygen (DO) and Chlorine (Cl) of Rice field and Pond, there was no significant difference.

T(◦C)	25.69±2.63	26.58±2.48	0.4689
PH	6.74±0.26	6.99±0.19	0.0452*
EC (μs/cm)	258.88±22.77	415.75±150.81	0.0281*
TA (mg/L)	103.63±10.79	124.13±20.61	0.0344*
TH (mg/L)	78.25±10.62	111.50±22.58	0.0029*
DO (mg/L)	7.38±1.06	6.60±0.52	0.0880
BOD (mg/L)	3.75±0.42	4.91±0.21	0.0000*
NO3 (mg/L)	3.58±1.28	5.90±2.46	0.0280*
PO4 (mg/L)	0.92±0.28	1.84±0.94	0.0212*
TDS (mg/L)	100.72±31.04	143.72±46.37	0.0448*
Ca (mg/L)	18.85±3.05	29.51±11.65	0.0498*
Cl(mg/L)	19.99±2.39	19.38±4.09	0.7664

Table 4.1c: Comparison Between Physico-chemical Parameters of the Breeding Sites

NB: ***** P -values with asterix are statistically significant ($p < 0.05$)

T= Temperature; EC= Electrical Conductivity; TA=Total Alkalinity; TH=Total Hardness; DO=Disolved Oxygen; BOD=Biological Oxygen Demand; NO_3= Nitrate; PO_4= Phosphate; TDS= Total Dissolved solid; Ca= Calcium; Cl = Chlorine

4.1.5 Temporal productivity of larval breeding sites of *Culex* mosquitoes (no. of mosquitoes/no. of dips)

Temporal productivity of larval breeding sites of *Culex* mosquitoes is shown on Table 4.2. A total of 8.67±5.68 mosquitoes/no. of dips was collected during the period of study and four (4*) Culex* mosquito species were encountered. These species are *Cx. nigripalpus, Cx. quinquefasciatus, Cx. restuans* and *Cx. salinarius*. Rice field and Pond were the habitats investigated. There was no significant difference (p>0.05) in the productivity of rice field (3.19±1.96) and pond (5.48±3.72).

Culex nigripalpus (0.40±0.20) and *Cx. restuans* (0.23±0.05) were found more in rice field than *Culex nigripalpus* (0.38±0.25) and *Cx. restuans* (0.03±0.04) in pond, while *Cx. quinquefasciatus* (2.61±0.92) and *Cx. salinarius* (2.46±2.51) were found more in pond than *Cx. quinquefasciatus* (1.90±1.07) and *Cx. salinarius* (0.66±0.6) in rice field.

Table 4.2: Temporal Productivity of Larval Breeding Sites of *Culex* mosquitoes (Larvae/Dip) in Badeggi, Niger State, Nigeria

Month	March		July		August		September		October		Aggregate		P valu
Species	**Rice field**	**Pond**	**Rice field**	**Pond**	**Rice field**	**Pond**	**Rice field**	**Pond**	**Rice field**	**Pond**	**Rice field**	**Pond**	
Cx. nigripalpus	0.40±0.20	0.15±0.14	0.00±0.00	0.03±0.04	0.00±0.00	0.20±0.07	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.40±0.20	0.38±0.25	0.966
Cx.quinquefasciatus	1.85±1.00	2.13±0.53	0.05±0.07	0.18±0.04	0.00±0.00	0.20±0.21	0.00±0.00	0.10±0.14	0.00±0.00	0.00±0.00	1.90±1.07	2.61±0.92	0.802
Cx. Restuans	0.23±0.05	0.03±0.04	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.23±0.05	0.03±0.04	0.436
Cx.salinarius	0.53±0.60	0.25±0.28	0.00±0.00	0.15±0.21	0.13±0.04	1.98±1.98	0.00±0.00	0.08±0.04	0.00±0.00	0.00±0.00	0.66±0.64	2.46±2.51	0.207
Total	3.01±1.85	2.56±0.99	0.05±0.07	0.36±0.29	0.13±0.04	2.38±2.26	0.00±0.00	0.18±0.18	0.00±0.00	0.00±0.00	**3.19±1.96**	**5.48±3.72**	**0.265**

Values are in Mean±Standard Deviation

4.1.6 Relationship between abundance of larvae of *Culex* mosquitoes and physico-chemical parameters

Analyses showed various strength of relationship between larvae of *Culex* species and physico-chemical parameters of breeding sites (Table 4.3). Significant ($p<0.05$) relationship between temperature and *Cx. nigripalpus, Cx. quinquefasciatus,* and *Cx. restuans* were positive and very strong. Dissolved Oxygen (DO) exhibited a moderately strong but negative relationship with *Cx. quinquefasciatus* and *Cx. salinarius*, while pH exhibited a positive and slightly strong relationship with *Cx. salinarius* species.

Though there were various strength of relationship between the larvae of *Culex* mosquito species and other physic-chemical parameters, the relationship was not significant.

Table 4. 3: Relationship Between Abundance of Larvae of *Culex* Mosquito and Physico-Chemical Parameters

***Culex* species**	**physico-chemical parameters**											
	T(◦C)	**pH**	**EC(us/cm)**	**TA(mg/L)**	**TH(mg/L)**	**DO(mg/L)**	**BOD(mg/L)**	**NO3(mg/L)**	**PO4(mg/L)**	**TDS(mg/L)**	**Ca(mg/L)**	**Cl(mg/L)**
C. *nigripalpus*	**0.6706**	-0.1471	-0.2853	0.0471	-0.0971	-0.3941	-0.3118	-0.3618	-0.3147	-0.3676	-0.0941	-0.1412
C. *quinquefasciatus*	**0.8559**	-0.3853	0.0529	0.3412	0.1676	**-0.6500**	-0.2794	-0.2147	-0.1294	-0.0441	0.2176	0.1853
C. *restuans*	**0.8559**	-0.4265	0.0529	0.3176	0.1618	**-0.6382**	-0.3353	-0.1882	-0.0971	-0.0647	0.2176	0.1912
C. *salinarius*	-0.0853	**0.5735**	-0.3735	-0.1500	-0.1441	0.1206	0.3000	-0.0441	-0.1118	-0.3794	-0.2882	-0.3118

NB: Values bolded have strong correlation at $p<0.05$

T= Temperature; EC= Electrical Conductivity; TA= Total Alkalinity; TH=Total Hardness; DO= Disolved Oxygen; BOD=Biological Oxygen Demand; NO_3= Nitrate; PO_4= Phosphate; TDS= Total Dissolved Solid; Ca= Calcium; Cl = Chlorine

4.1.7 Relationship between abundance of Adult *Culex* mosquito species and physico-chemical parameters

Various strength of relationship between adult *Culex* species and physico-chemical parameters of breeding sites is shown in table 4.4. Electrical conductivity (EC) and Calcium (Ca) had a significant ($p<0.05$) relationship with all the five (5) species of the *Culex* mosquito. EC and Ca exhibited a positive and strong relationship with *Cx. nigripalpus*, negative and strong relationship with *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus*, positive and strong relationship with *Cx. restuans* and negative and strong relationship with *Cx. salinarius*.

Total Alkalinity (TA), Total Hardness (TH), Dissolved Oxygen (DO), Total Dissolved Solid (TDS) and Chlorine (Cl) had a significant ($p<0.05$) relationship with four (4) species of the *Culex* mosquito. TA, TH and Cl exhibited a positive and strong relationship with *Cx. nigripalpus* and *Cx. restuans,* while it exhibited a negative and a strong relationship with *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus*. DO exhibit a negative and strong relationship with *Cx. nigripalpus* and *Cx. restuans* while it exhibited a positive and strong relationship with *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus*. TDS exhibited a positive and strong relationship with *Cx. nigripalpus*, while it exhibited a negative and strong relationship with *Cx. quinquefasciatus*, *Cx. salinarius* and *Cx. tritaeniorhynchus*.

Biological Oxygen Demand (BOD) and Nitrate (NO_3) had a significant ($p<0.05$) relationship with three (3) species of the *Culex* mosquito. BOD exhibited a positive and strong relationship with *Cx. nigripalpus* and *Cx. restuans*, while it exhibited a negative and strong relationship with *Cx. tritaeniorhynchus*. NO_3 exhibited a negative and strong relationship with *Cx. nigripalpus*, while it exhibited a positive and strong relationship with *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus.*

pH had a significant ($p<0.05$) with two (2) species of the *Culex* mosquito. It exhibited a positive and strong correlation with *Cx. restuans* and *Cx. salinarius*. Temperature also had a significant ($p<0.05$) relationship but with only one of the species. It exhibited a negative and strong relationship with *Cx. tritaeniorhynchus*.

Table 4.4: Relationship Between Abundance of Adult *Culex* Mosquito Species and Physico-chemical Parameters

***Culex* species**	**physico-chemical parameters**											
	T(◦C)	**Ph**	**EC(us/cm)**	**TA(mg/L)**	**TH(mg/L)**	**DO(mg/L)**	**BOD(mg/L)**	**NO3(mg/L)**	**PO4(mg/L)**	**TDS(mg/L)**	**Ca(mg/L)**	**Cl(mg/L)**
Cx. nigripalpus	0.4521	0.3749	**0.9463**	**0.9786**	**0.9963**	**-0.9827**	**0.8111**	**-0.6683**	0.3518	**0.8059**	**0.9309**	**0.9054**
Cx. quinquefasciatus	-0.2496	0.0276	**-0.8914**	**-0.5927**	**-0.7603**	**0.8521**	-0.4829	**0.6982**	-0.0361	**-0.9108**	**-0.8091**	**-0.6891**
Cx. restuans	0.3995	**0.6065**	**0.6020**	**0.9091**	**0.7904**	**-0.6963**	**0.7901**	-0.4043	0.4373	0.4066	**0.6422**	**0.7028**
Cx. salinarius	-0.2220	**0.5048**	**-0.5728**	-0.1145	-0.3372	0.4530	0.0609	0.3124	0.0012	**-0.5799**	**-0.5094**	-0.3873
Cx. tritaeniorhynchus	**-0.6071**	0.1075	**-0.9766**	**-0.7901**	**-0.8980**	**0.9306**	**-0.5075**	**0.5590**	-0.4357	**-0.8345**	**-0.9564**	**-0.9012**

NB: Values bolded have strong correlation at $p<0.05$

T= Temperature; EC= Electrical Conductivity; TA=Total Alkalinity; TH= Total Hardness; DO=Disolved Oxygen; BOD=Biological Oxygen Demand; NO_3= Nitrate; PO_4= Phosphate; TDS= Total Dissolved Solid; Ca= Calcium; Cl = Chlorine

4.1.8 Relationship between larval and adult population densities of *Culex* mosquito species in Badeggi, Niger state, Nigeria

Table 4.5 shows the relationship between larval and adult densities of *Culex* mosquito species. There was a positive and strong relationship between the larval and adult densities of *Cx.nigripalpus* and *Cx. salinarius*. A positive but weak relationship occurred between the larval and adult population densities of *Cx. restuans*, while for *Cx. quinquefasciatus*, it was a negative and slightly weak relationship.

Although various strength of relationships was exhibited between the larval and adult densities of *Culex* species, there was a significant difference ($p < 0.05$) between the larval and adult densities of *Cx. salinarius*.

Table 4.5: Relationship between larval and adult population densities of *Culex* mosquito species in Badeggi, Nigeria

Species	Correlation coefficient (r)	Correlation coefficient^2 (r^2)	t-value	Df	P-value
Cx. nigripalpus	0.9334	0.8712	3.6812	2	0.067
Cx. quinquefasciatus	-0.4583	0.2100	-0.7292	2	0.542
Cx. restuans	0.3840	0.1475	0.5882	2	0.616
Cx. salinarius	0.9935	0.9870	12.3530	2	0.006*

***** P -values with asterix are statistically significant ($p < 0.05$)

4.2 Discussion

4.2.1 Species composition and relative abundance of *Culex* mosquitoes in Badeggi, Niger state, Nigeria

Culex mosquitoes have being a common occurrence in Nigeria from different studies on this mosquito species. They are epidemiologically significant as *Culex quinquefasciatus* is a potential vector of bancroftian filariasis and other arboviruses (Manyi *et al.,* 2017). In this study, the species composition and relative abundance of adult *Culex* mosquitoes in Baddeggi, Niger State, Nigeria was investigated. Five (5) species were encountered during the work which include; *Culex nigripalpus, Culex quinquefasciatus, Culex restuans, Culex salinarius and Culex tritaeniorhynchus.* These species of *Culex* were similar to the ones previously reported by Olayemi *et al.* (2010) who identified *Culex pipiens pipiens, Cx. salinarius, Cx. restuans* and *Cx. nigripalpus* in Minna metropolis, Nigeria. Haruna and Abdulhamid (2019) likewise recorded *Culex pipiens*, *Culex quinquefasciatus, Culex simpsoni* and *Culex tigripes* as species of *Culex* within Minna metropolis.

The abundance and distribution of *Culex* mosquitoes in these regions could be explained by the versatile behaviors of mosquitoes of this genus that adapt in a variety of aquatic habitats, both permanent and transient (Olayemi *et al.,* 2011). In addition, these species are found in all types of water collection including temporary or permanent stagnant water bodies such as drains, septic tanks, wet pit latrines, organically polluted sites and puddles which is suitable environmental conditions for their proliferation (Ekloh *et al.,* 2013).

This result is however dissimilar from the findings of Olajire *et al.* (2017) who reported *Cx. quinquefasciatus, Cx. andersoni, Cx. duttoni, Cx. pipiens* and *Cx. Trigripis* as the species of *Culex* mosquitoes in the ecological zones of the Ondo State, Nigeria. Also, Afolabi *et al.* (2019) reported *Cx. andersoni, Cx. tigripes, Cx. quinquefasciatus, Cx. striatipes, Cx.*

horridus and *Cx. macfei* as species of *Culex* mosquito species in Akure South Local Government Area, Ondo State, Nigeria. More also, this present result disagrees with the findings of who recorded *Culex quinquefasciatus, C. nebulosus, C. tigripes* , *C. decens, C. pipiens*, *C. moucheti* and *C. cinereus* as species of *Culex* mosquito species in Benin City, Nigeria. Similarly, Amao *et al.* (2018) recorded *Culex pipiens*, *Cx nebulosus*, *Cx moucheti*, *Cx cinereus*, *Cx decens* and *Cx tigripes* as *Culex* mosquito species in Lagos, Southwest Nigeria.

Significant variations in mosquito species composition have been attributed to differences in ecotypes, microclimatic conditions and sometimes sampling techniques (Olayemi *et al.*, 2011). Therefore, the differences in the abundance and distribution of mosquitoes species may be due to the difference in social and anthropological activities as within the locations as areas with high activities may have high population density of mosquitoes and vice versa (Afolabi *et al.*, 2013). According to Simon-Oke *et al.* (2012), mosquito distribution and abundance are related to population, land use and human activities.

This study also revealed that *Culex* mosquito abundance in the study area is dominated by *Cx. quinquefasciatus* where it accounted for about 52 % of the total *Culex* mosquito collected. This is in accordance to the findings of Haruna and Abdulhamid (2019) who reported *Cx. Quinquefasciatus* (5.4 %) as the most abundant *Culex* mosquito in Minna, Abdulrasheed *et al.* (2016),*Culex quinquefasciatus* (57.89 %) in Azare town, Katagum Local Government of Bauchi State, Nigeriaand Amao *et al.* (2018) *Culex quinquefasciatus* (49.35 %) in Lagos, Southwest Nigeria. Similarly, Lapang *et al.* (2019) in Shendam LGA, Plateau State, North-Central Nigeria, Olajire *et al.* (2017) in the ecological zones of the Ondo State, Aigbodion *et al.* (2013) Benin City, Nigeria and Manyi *et al.* (2017) in

Makurdi Area of Benue State, North Central Nigeria found *Culex quinquefasciatus* to be the most abundant mosquito species.

Cx. quinquefasciatus as the most common and abundant species in these studies is not surprising because *Cx quinquefasciatus* is the most widely distributed mosquito in the tropical and sub-tropical regions of the world usually near human dwelling. Conferring to Awolola *et al.* (2007), species of the *Cx. pipiens* complex particularly *Cx. quinquefasciatus* are widespread and predominant in the urban environment notably in Africa particularly in Nigeria where suitable environmental conditions created by rapid unplanned urbanization is contributing to their proliferation.

4.2.2 Biting behavior of *Culex* mosquitoes in Badeggi, Niger state, Nigeria

There was variation in the biting periods and location of *Culex* mosquitoes in the study area during the period of study. Low biting activities was recorded between the hours of 6-7 pm and 5-6 am but reach its peak at 7-9 pm. This result is consistent with the findings of Emmanuel *et al.* (2013) who reported that *Culex quinquefasciatus* mosquito exhibited a peak biting density between 6pm and 8pm hours outdoors in the Lower Imo River Basin, Nigeria.Similarly, Paramasivan *et al.* (2015) reported a typical nocturnal uniform biting activity exhibited by *Cx. infula* and the biting was restricted uniformly during the dark phase. Also, Paramasivan *et al.* (2015) reported *Cx. vishnui* and *Cx. pseudovishnui* to show a nocturnal biting rhythm and showed a post dusk biting peak like *Cx. gelidus*.

This result was however contrary to some previous studies which showed peak biting at midnight and some after midnight. Paramasivan *et al.* (2015) and Aigbodion and Emiebor (2008) reported peak biting of *Culex quinquefasciatus* at mid-night. Rohani *et al.* (2013)

however recorded three peaks of biting activity of *Cx. tritaeniorhynchus* while Chee *et al.* (2014) similarly revealed *Culex quinquefasciatus* and *Cx. vishnui* to be nighttime feeders with multiple biting peaks throughout the night in Malaysia. The differences in the biting behavior as observed in these studies might be attributed to differences in timing of sunrise and sunset. In addition, the timing as mentioned by these researchers may not correspond to the standard regional time. This may affect the timing of local authorities to conduct vector control activities, especially fogging. Light intensity controls biting activity of mosquitoes to a very fine degree. In other words, the host-seeking behavior of mosquitoes would likely depend on the presence of sunlight during sunrise and sunset (Chee *et al.*, 2014).

In the months of January-March, August, July, September and October, mosquitoes bit more outdoors compared to indoors even though a considerable number also bit indoors. While in the months of November and December, mosquitoes were encountered biting more indoors compared to outdoors.It is known that abundance, attractiveness, and availability of the human host are influencing vector biting behavior. According to Kweka *et al.* (2016), alterations to the landscape and environment due to human activity can influence disease epidemiology indirectly through changes in vector populations, ecology, biology and host-seeking behaviors of vectors searching for alternative habitats and new blood-feeding sources.

4.2.3 Productivity of breeding sites of *Culex* species in Badeggi, Niger state, Nigeria

Both the physical and chemical characteristics of mosquito breeding sites may have some effects on mosquito vectors oviposition, survival and spatial distribution (Garba and Olayemi, 2015).The results of this present study indicate that presence of various physicochemical parameters in mosquito breeding sites at various levels has some influence on mosquito vector oviposition, survival and spatial distribution. Some physicochemical parameters appeared to significantly influence the larval density of individual mosquito species. This result concurs with the findings of Emidi *et al.* (2017) whose study demonstrated that various levels of physicochemical parameters have effects on *Anopheles* and *Culex* larvae and pupae densities. Also, Olayemi *et al.* (2010) reported significant differences in physico-chemical properties of conventional mosquito breeding habitats in Minna Nigeria with attendant influence on species composition and relative abundance of mosquitoes in such habitats.This study also support the report given by Nikookar *et al.* (2017) who pointed out that an apparent relationship exists between mosquito larvae breeding and poor water quality. High levels of dissolved organic matter are said to provide nutrients for the bacteria and algae used as food by mosquito larvae. Larval density was also said to depend on factors like type of plant cover, food availability and predator abundance.

According to Imam and Deeni (2015), physicochemical parameters such as temperature, salinity, conductivity, total dissolved solids (TDS), hardness and pH have a significant influence on the occurrence and larval abundance among mosquito species. It has also been suggested that the strong correlations found between certain physico-chemical parameters and larval abundance confirm the influence of these parameters on the distribution and abundance of mosquito larvae in their breeding habitats and also indicate the possibility of mosquito larval control through the manipulations of such parameters (Olayemi *et al.*, 2010).

The physicochemical parameters survey in various mosquito breeding sites has revealed that the quality of water ranges from fresh to highly pollute both with the presence of various densities *Culex* mosquitoes. The water temperature as observed in this study ranged from 22.25 ^{o}C to 28.55 ^{o}C with a mean of 25.69 ^{o}C in the rice field and 2355-29.40 ^{o}C with the mean value of 26.58 ^{o}C in pond. This is consistent with the findings of Olajire *et al.* (2017), who recorded the temperature range in culine mosquito breeding site to be 25.09-27.22 ^{o}C. Similarly, the work of Afolabi *et al.* (2013) established that *Culex* mosquitoes breed at water temperature of 26.5 to 29.3 °C. Nikookar *et al.* (2017) recorded temperature values ranging from 20-25 °C in *Culex* mosquito breeding habitat, while Owolabi and Bagbe (2019) reported that *Culex* mosquitoes prevailed in open waters within the temperature range of 29-30 ^{o}C for the breeding sites.

The temperature range obtained in this study is within the favorable temperature that favors the breeding of *Culex* mosquito species. Water temperature is important physico-chemical parameters that influences many aspects of mosquito life traits and even vector competence (Ciota *et al.*, 2014). As revealed by Olajire *et al.* (2017), water temperature and some other physico-chemical parameters are the major factors that could play an important role in breeding and propagation of mosquitoes. It influences oviposition, survival rate and the distribution of mosquito species (Chatterjee *et al.,* 2015).

The range of the DO observed in this study was between 6.20 mg/L–8.00 mg/L with a mean value of 7.38 mg/L in the rice field and 6.15 mg/L –7.30 mg/L in the pond. This is different from the findings of Olajire *et al.* (2017) who recorded DO of the studied areas of *Cx. quinquefasciatus* to be 1.95–2.67 mg/L. Afolabi *et al.* (2019) however reported dissolved oxygen range of 2.43–3.84 mg/L in *Culex* mosquito's habitats. The DOobtained in this present study is higher than that obtained by Olajire *et al.* (2017) and Afolabi *et al.* (2019). This shows that *Culex* mosquitoes have the ability to thrive even in a low dissolved oxygen breeding habitat. The survival of larvae when submerged depends on their ability to absorb oxygen through the cuticle. When the level of DO is low the rate of loss of buoyancy is said to be rapid, this suggests that the outward diffusion of gas into the water is significant. This might be the reason why there can be abundance of *Cx. quinquefasciatus* when the DO of the breeding habitat is low, because it has the ability to survive for considerable longer period than any other species (Olajire *et al.*, 2017).

There was variation in the pH of the field and pond habitat of *Culex* mosquitoes. The pH as observed in this study ranged from 6.41 to 7.04 with a mean of 6.74 in the rice field and 6.77-7.20 with the mean value of 6.99. This result is similar with the findings of Olajire *et al.* (2017) who recorded slightly alkaline pH (7.07-7.24) in culicine mosquitoes habitats in Ondo, Nigeria, Afolabi *et al.* (2013) 7.1 to 7.3 also in in culicine mosquitoes habitats in Ondo, Nigeria. Also similar to this result is the report of Afolabi *et al.* (2019) who found the pH that favored breeding of *Culex* mosquitoes to be in the range of 7.14–7.30, in Ondo, Nigeria.The authors reported that pH range of 6.8–7.2 and 7.0–7.4 were suitable for the weakening of the mosquito egg shells for the emergence of its first instar larvae and that pH less than 5.0 and higher than 7.4 have fatal effects on survival of mosquito species. The pH range recorded by Owolabi and Bagbe (2019) however showed that *Culex* mosquitoes can thrive well in an environment with a wide range of pH (7.7-8.9). In a more recent study, the results of Ukubuiwe *et al*. (2020) revealed pH values ranging from 4.0 to 10.0 supported the survivorship of *Culex quinquefasciatus* mosquitoes but affect the life it stages in various ways. These findings show that *Culex* mosquitoes can thrive and survive in varying level of pH. Mosquito larvae are capable of adapting to and tolerating fluctuations in ionic levels in these habitats. The pH of water is dependent on the concentration of anions and cations derived from salts, fertilizer compound and other synthetic compounds all together accounted for the pH. Therefore, it may directly or indirectly detect the life of any aquatic organisms. The anions and cations may indirectly affect mosquito breeding by favoring certain aquatic organisms or vegetation on which mosquito larvae feed or affect potential biological control agents of *A. gambiae* (Mattah *et al.*, 2017). If pH falls below the tolerance range, death would ensue as result of disturbance of the acid and base of the hemolymph (Mattah *et al.*, 2017).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, the species composition and relative abundance of adult *Culex* mosquitoes in Baddeggi, Niger State, Nigeria was investigated. Five (5) species were encountered during the work which include; *Culex nigripalpus, Culex quinquefasciatus, Culex restuans, Culex salinarius and Culex tritaeniorhynchus.*This study also revealed that *Culex* mosquito abundance in the study area is dominated by *Cx. quinquefasciatus* where it accounted for about 52 % of the total *Culex* mosquito collected.

There was variation in the biting periods and location of *Culex* mosquitoes in the study area during the period of study. Low biting activities was recorded between the hours of 6-7 pm and 5-6 am but reach its peak at 7-9 pm. In the months of January-March, August, July, September and October, mosquitoes bit more outdoors compared to indoors even though a considerable number also bit indoors. While in the months of November and December, mosquitoes were encountered biting more indoors compared to outdoors.

The results of this present study indicate that presence of various physicochemical parameters in mosquito breeding sites at various levels has some influence on mosquito vector oviposition, survival and spatial distribution. Some physicochemical parameters appeared to significantly influence the larval density of individual mosquito species.

The water temperature as observed in this study ranged from 22.25 ^{o}C to 28.55 ^{o}C with a mean of 25.69 ^{o}C in the rice field and 23.55-29.40 ^{o}C with the mean value of 26.58 ^{o}C in pond. The range of the DO observed in this study was between 6.20 mg/L – 8.00 mg/L with a mean value of 7.38 mg/L in the rice field and 6.15 mg/L – 7.30 mg/L in the pond. There was variation in the pH of the field and pond habitat of *Culex* mosquitoes. The pH as observed in this study ranged from 6.41 to 7.04 with a mean of 6.74 in the rice field and 6.77-7.20 with the mean value of 6.99.

5.2 Recommendations

Based on the findings of this research, the following are recommended

i. Other breeding sites in Badeggi, for example, drainages and domestic containers should be sampled and investigated for productivity of larvae.
ii. Selected measures including larviciding of breeding sites are among recommended measures to be implemented annually particularly monthly before the onset of the wet season in the area to reduce the menace of mosquito vector borne diseases.
iii. This study has provided information on temporal distribution and larval habitats of mosquitoes in Badeggi, Niger State, Nigeria. Since most of the species encountered are potential vectors of mosquito-borne diseases, it is therefore recommended that the residents of Badeggi be enlightened on the environmental factors that contribute to mosquito breeding.
iv. In order to maintain historical records of relative vector population densities and seasonal population trends, continuous monitoring of various mosquito species is highly recommended.

5.3 Contribution to Knowledge

Information on species composition and relative abundance, biting behavior and productivity of larval breeding sites in Badeggi, Niger State, Nigeria have been added to scientific knowledge. This scientific knowledge will complement effort and guide cost effective deployment of scarce resources for optimum vector control impact.

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