MOSQUITO SPECIES AND THEIR BREEDING HABITATS IN KADUNA METROPOLIS, KADUNA STATE.

BY

YAYOCK, HOSEA .C. B.Sc. (ABU 2000)
MSc/Sci/33682/02-03 (old)
MSc/Scien/17615/07-08 (new)

A thesis submitted to the Postgraduate school, Ahmadu Bello University in partial fulfillment of the requirements for the award of a Master of Science degree in Zoology, to the Department of Biological Sciences, Faculty of Science, Ahmadu Bello University, Zaria.

DECEMBER, 2008.

Declaration

I declare that the work in the thesis entitled: MOSQUITO SPECIES AND THEIR BREEDING HABITATS IN KADUNA METROPOLIS, has been performed by me in the Department of Biological Sciences under the supervision of Prof. C.G. Vajime, Dr. I .S. Ndams and Dr. E. Kogi. The information derived from the literature has been duly acknowledged in the text and list of references provided. No part of this thesis was previously presented for any Degree or Diploma at any University.

_____	_____	_____
Yayock, Hosea .C.	**Signature**	**Date.**

Certification

This thesis entitled: MOSQUITO SPECIES AND THEIR BREEDING HABITATS IN KADUNA METROPOLIS, KADUNA STATE, by YAYOCK, HOSEA .C., meets the regulations governing the award of the Degree of Master of Science in Zoology, of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

_____ _____

Prof. C.G. Vajime **Date.**
Chairman, supervisory committee,
Department Of Biological Sciences,
Ahmadu Bello University, Zaria.

_____ _____

Dr. I.S. Ndams **Date.**
Member, supervisory committee,
Department Of Biological Sciences,
Ahmadu Bello University, Zaria.

_____ _____

Dr. E. Kogi **Date.**
Member, supervisory committee
Department Of Biological Sciences,
Ahmadu Bello University, Zaria.

_____ _____

Dr. Jehu Auta **Date.**
Head of Department, Biological Sciences,
Department Of Biological Sciences,
Ahmadu Bello University, Zaria.

_____ _____

Prof. S. A. Nkom **Date.**
Dean, Postgraduate School,
Ahmadu Bello University, Zaria.

Dedication

This thesis is dedicated to GOD, the father of our Lord and Savior JESUS CHRIST who gave me the opportunity and also saw me through to the successful completion of this work.

Acknowledgement

I thank God for seeing me throughout all the rigors of the work involved in this project. I also thank my supervisors; Prof. C.G Vajime, Dr. I.S Ndams and Dr. E. Kogi-immensely for their contributions, effort and time given to me. I wish to also say thank you to Mr.D.A Adebote, who helped in the identification of mosquito species; and other lecturers of the department, may God bless you all.

My parents, Mr. and Mrs. S.A Yayock, your efforts are so wonderful; I lack words to express my appreciation to you. Also, to my darling, sweet lovely wife, Happy (Sweet Angel); you have been a source of joy, strength and encouragement to me each time I seem to lag behind. Ezekiel and Zipporah, as my siblings each time you look up to me, I am encouraged to face the challenge and move forward.

I wish to also thank the laboratory technicians, Mr. Babalola, Oga Cletus, Sunday and others for the help you rendered. I wish to also recognize the sacrifices of my friends; Jeremiah, Debaeh, Salau, Sam, Tim.B, Jummai, Philip-you have been more than friends to me, may God bless you abundantly.Yohanna, Femi and Philemon thank you for helping me during the final stage; Sis. Bose my typist, God bless you. My colleagues, Odeji, Hassan, Slyvester, Victor, Onimisi, Kehinde, Mary, Mrs. Maigari, Mrs. Sangowawa, Mrs. Bankwot, Maha, Sunday and others, thanks for the warm fellowship we had together.

Finally, I express my immeasurable gratitude to Prof. and Mrs. J.Y. Yayock, Mr. and Mrs. S.N Duniya, Mr. and Mrs. J. Kagai, the ESM family, Mrs. E. Nchok, Mrs. R Adon and several other people whose names I may not mention here for their diverse support and prayers in my quest for higher education.

Abstract

An update of the mosquito fauna of 15 settlement areas in Kaduna metropolis within the Northern Guinea Savannah zone of Nigeria was made from November 2004 - November 2005. Larval samples were obtained and 15 species of mosquitoes identified comprising of the following; *Aedes aegypti* L, 138 (1.97%), *Ae. vittatus* Bigot,103 (1.47%), *Ae. simpsoni* Theobald, 12 (0.17%), *Anopheles species*, 4 (0.06%); *Culex pipiens molestus* Forskal, 3307 (47.30%), *Cx. pipiens quinquefasciatus* Say, 1836 (26.26%), *Cx. pipiens pipiens*, 456(6.52%), *Cx. decens* Theobald, 868 (12.42%), *Cx. tigripes* Grandpre,31 (0.44%), *Cx. univittatus* Theobald, 34 (0.49%), *Cx. horridus* Edwards, 115 (1.64%), *Cx. musarum* Edwards, 40 (0.57%), *Cx. nebulosus* Theobald, 4(0.06%), *Cx. macfei* Edwards,41(0.59%), *Cx. duttoni*, 2 (0.03%). The most abundant species encountered in all the 15 settlements sampled were *Culex. p. molestus* and *Cx. p. quinquefasciatus*. Mosquito species bred in eight different sites identified as major breeding habitats in Kaduna metropolis; the proportion of total catch from these habitats is indicated: Concrete gutters (38.23%), Stagnant pool/pond (29.92%), Peridomestic runoffs (PDRF) (22.3.4%), Clay pot (0.86%), Metal containers (0.59%), Abandoned tyres (2.73%), Plastic containers (1.22%) and Roadside potholes (3.61%). Significant difference in breeding populations was noticed among habitats (P=0.024). Concrete gutters, Stagnant pool/ponds and PDRF were encountered in all settlement areas. There was no significant difference in the total mosquito species sampled among the 15 settlements (P=0.436). The old settlement areas had more mosquito species;(13) in comparism to 11 species in the new settlement areas. Diversity in the mosquito species breeding observed during the wet months was significantly higher than those of the dry months (P=0.004); with the highest species diversity of 11 species in August. There was a preponderance of *Culex*

pipiens complex (*Cx. p molestus* and *Cx. p quinquefasciatus*) over other mosquito species and this suggests that environmental degradation by human activities associated with rapid urbanization, has provided numerous insanitary breeding habitats for Culicine mosquitoes, particularly *Culex. p. molestus* and *Cx. p. quinquefasciatus.*

Table of Content

Contents **Page**

Title page ---------- i
Declaration---------- ii
Certification---------- iii
Dedication---------- iv
Acknowledgement---------- v
Abstract---------- vi
Contents---------- viii
List of tables---------- xi
List of figures---------- xii
List of plates---------- xiii
Abbreviations---------- xiv

Chapter 1

1.1 Introduction----------1
1.2 Justification----------3
1.3 Aim and Objective----------5
1.4 Hypothesis----------5

Chapter 2 Literature Review ----------6

2.1 Classification----------6
2.1.1 Subfamily Toxorhynchitinae----------6
2.1.2 Subfamily Anophelinae----------7
2.1.3 Subfamily Culicinae----------7
2.2 Distribution----------7
2.3 Culicidae External Morphology----------10
2.3.1 Adults----------10
2.3.2 Larvae----------11
2.3.3 Pupae----------11

Content **Page**

2.4 Mosquito Biology----------12
2.4.1 Egg----------12
2.4.2 Larvae----------13
2.4.3 Pupae----------13
2.4.4 Adult Mosquito----------13
2.5 Mosquito Control----------14
2.5.1 Biological Control Method Directed at Aquatic Stage----------14
2.5.2 Chemical Control Method Directed at Adult Mosquito----------15
2.5.3 Environmental Management (control)----------17
2.6 Insecticide Resistance----------18
2.7 Climate and Mosquito Abundance----------19
2.7.1 Climate Changes and Impact----------20

Chapter 3 Materials and Methods----------21
3.1 Study Area----------21
3.2 Sampling Area----------21
3.3 Sampling Procedures----------24
3.4 Identification of Mosquito Larvae----------25
3.4.1 *Culex* species----------25
3.4.2 *Aedes* species----------25
3.4.3 *Anopheles* species----------26
3.5 Data Analysis----------26

Chapter 4

Results ----------27
4.1 Mosquito Species Composition ----------27
4.2 Seasonality of Species ----------27
4.3 Mosquito Distribution in Kaduna Metropolis----------30
4.4 Breeding Habitats in Kaduna Metropolis----------37
4.5 Association of *Culex, Aedes* and *Anopheles* mosquito with breeding Habitats---37

Content **Page**

Chapter 5
Discussions----------42
Conclusion----------46
Recommendation ----------48
References----------49
Appendices----------60

List of Tables

Table **Page**

Table 3.1: Settlements Sampled in Kaduna Metropolis ----------23

Table 4.1: Abundance of Mosquito Species From Kaduna Metropolis ----------28

Table 4.2: Monthly Mosquito Species Composition and Abundance----------29

Table 4.3: Mean Number of Mosquito Species Collected In all Settlements--- -------35

Table 4.4: Number and Percentage of Various Mosquito Habitats Encountered At all Settlements ----------38

Table 4.5: Breeding Habitats and Number (%) of Mosquito Species----------40.

List of Figures

Figure **Page**

Figure 3.1: Map of Kaduna Metropolis ----------22

Figure 4.1: Pooled Monthly Mosquito Species Population (%)---------- ----------31

Figure 4.2: Map Showing Species of Mosquitoes Sampled in Various Settlements------32

Figure 4.3: Mosquito Breeding Habitat Composition.----------38b

List of Plates

Plate **Page**

Plate1: Road side Aquatic Habitat at G.R.A. ----------60

Plate 2: Abandoned Tyres Habitat at Barnawa ----------61

Plate 3: Pool/Pond Habitat at Malali ----------62

Plate 4: Out-let of PDRF behind a House at Kawo ----------63

Lists of Mosquito species. **Abbreviation**.

1. *Culex pipiens quinquefasciatus* =*C.p.q* *Culex = Cx.*
2. *Culex pipiens molestus* = *C.p.m* *Aedes = Ae.*
3. *Culex pipiens pipiens* = *C.p.p* *Anopheles = An.*
4. *Culex decens* = *C.de*
5. *Aedes aegypti* = *A.ae*
6. *Aedes vittatus* = *A.vi*
7. *Aedes simpsoni* = *A.si*
8. *Culex tigripes* = *C.tg*
9. *Culex univittatus* = *C.un*
10. *Culex musarum* = *C.mu*
11. *Culex horridus* = *C.ho*
12. *Culex nebulosus* = *C.ne*
13. *Culex duttoni* = *C.du*
14. *Culex macfei* = *C.ma*
15. *Anopheles species* = *Ansp*

Settlements and Habitats.

Ung. = Ungwan

G.R.A = Government Reserved Area

PDRF = Peridomestic Run offs, i.e domestic waste effluent or used water from houses.

CHAPTER 1

1.1 Introduction.

Mosquitoes are slender and relatively small, flying insects measuring about 3mm – 6mm in length; although some species can be as small as 2mm – 3mm, while others may be as long as 10mm. The body is distinctly divided into head, winged thorax and abdomen (Service, 1980). There are about 3,100 species of mosquitoes belonging to 34 genera, arranged in 3 subfamilies: *Toxorhynchitinae, Anophelinae* and *Culicinae*. The most important human biting species belong to the genera *Anopheles, Culex, Aedes, Mansonia, Haemagogus, Sabethes* and *Psorophora* (Service, 1980). Mosquitoes have a world wide distribution, they occur through out the tropical and temperate regions and extend their range northwards into the Artic circle; the only area from which they are absent is Antartica (Smith, 1978).

Various species from the genera *Anopheles, Culex, Aedes, Mansonia, Haemagous* and *Sabethes* are vectors of human diseases, including; malaria, yellow fever, arboviruses, dengue fever and bancroftian filariasis (Johnson, 1979). Mosquitoes are also in themselves a nuisance to humans because of their biting habits and the sound they produce (Gillet, 1971).

Malaria, transmitted by several *Anopheles* species is probably the most prevalent and devastating disease of mankind in the tropics. The incidence of malaria worldwide is estimated to be between 300 – 500 million clinical cases each year, with about 90% of these occurring in Africa, south of the Sahara – Mostly caused by *Plasmodium falciparum.* Malaria (either alone or in

combination with other diseases) is thought to kill between 1.1 and 2.7 million people worldwide each year; (WHO, 1997; WHO, 2000). Most of these deaths occur in pregnant women, infants or very young children (Lindsay and Marten, 1998; Joana *et al*., 2001).

Filariasis, although somewhat limited in distribution than malaria, is a common disease in tropical areas. Lymphatic filariasis (elephantiasis) infects about 120 million people in tropical Africa, India, Southeast Asia, the Pacific Island, South and Central America (WHO, 1997). In recent years, this disease has increased because of urbanization, which has created breeding areas for *Culex* species of mosquitoes that transmit the nematode, *Wuchereria bancrofti,* that causes lymphatic filariasis, (Rao *et al*., 1981).

Aedes aegypti, the vector of Yellow fever in urban areas in Africa is wide spread. It was involved in the 1987 yellow fever epidemic, which occurred in Oyo state, Nigeria, causing hundreds of deaths (WHO, 1988)

Dengue fever is the world is most abundant mosquito borne viral disease, transmitted by *Aedes aegypti*. Over 250 million people worldwide are at risk of infection, coupled with 20 million annual cases in more than 100 countries (WHO, 1997). Mosquito problems and disease transmission in contemporary Africa still presents an unclear picture, especially in sub Saharan African region, where the vector is regarded a major public health factor.

In Nigeria, about 50 million people suffer from malaria annually and the annual death from the disease is estimated to be about 300,000 individuals,

(Anony, 2000; NNN, 2005). The Roll Back Malaria (RBM) programme launched on April 25th, 2000 in Abuja Nigeria has as part of its mandate; to develop new tools for the control and eradication of malaria.

Studies have shown that, in villages, towns and cities, the availability of suitable breeding sites for mosquitoes is related to the geographical location, size of human settlement, standard of living, level of education of the inhabitants and other socio-economic factors (WHO, 1980). Despite the past and current control measures, these disease vectors have continued to be a threat to health and socio-economic development, (Bang *et al*., 1975). In certain developed countries, eradication programme have been achieved, whereas Nigeria and many Africa countries, some level of mosquito control has been achieved by spraying Organochlorines (Dieldrin or BHC) as contact insecticides. (Malaria unit, 1976). However, short-term larval controls with the insecticide-based control programme ended with reports of the development of resistance to insecticides that was reported (Brown and Pal, 1971; Chandre *et al*., 1999).

1.2 Justification

Nigeria is undergoing rapid urbanization of settlements in areas where only a scattered rural population existed formerly. This has resulted in some areas being densely populated. In such settings, organised sanitary facilities are usually poor; also sewage disposal depends largely upon the initiative of the individual resident. Where water supply is available, there may be drains, soakage pits, peri-domestic run offs and pools of standing water. Domestic conditions like these are

ideal as breeding sites of some common mosquitoes; such as *Culex p. quinquefasciatus* (Say) (Subra, 1980). The construction of the surface run-off (gutters/culverts), the provision of open or partially covered soakage pits for houses, the excavation pits made and abandoned by the construction companies at construction sites and cement water reservoirs are also likely to create good and active breeding sites for mosquitoes in urban settlements. This is not only an engineering problem but also has major public heath implication.

Some researchers had studied aspects of mosquito ecology; Hanney (1960) did a general survey of the species of mosquitoes in Zaria province, Northern Nigeria, (Kangimi and Kakuri in Kaduna State) between June 1957 to December 1958. The studies revealed *Anopheles gambiae* (Giles), *Anopheles funestus, An. nili* (Theo) and *An. wellcomei* (Theo) were very much present; they constitute the major potential malaria vectors. While the commonest Culicine vectors were *Mansonia africana* (Theo), and *M. uniformis* (Theo).

An intensive study on the ecology of *Anopheles gambiae* s.l by White and Rosen, (1973) in six villages around Kaduna (Kangimi, Rido, Angwan Mua'azu, Sobawa, Nassarawa and Katabu) revealed *An. gambiae* (83%) and *An. arabiensis* (17%). Data obtained form a survey (Gadzama, 1977) on the Main campus A.B.U, Samaru, Zaria revealed Anopheline and Culicine mosquito species, with about 96% being Culicines only. Anyanwu *et al*. (1999) identified 15 species of mosquito from another survey conducted in some parts of Zaira.

In the proposed study area of Kaduna metropolis, the last of these studies done at the proposed study area was by Rishikesh *et al.* (1985) who studied seasonal variation of *Anopheles gambiae* and *An. arabiensis* in Kaduna, some 20

years ago. Therefore the mosquitoes population structure may have changed during the twenty years period; Thus there is still need for the continuous updating of information on the mosquitos and their breeding habitats in Kaduna metropolis in order to contribute to the pool of information necessary for mosquito and malaria control in the fast growing Kaduna town.

1.3 Aim :

This research aimed at identifying the mosquito species and their habitats in Kaduna Metropolis.

Objectives:

1. To determine the species composition in Kaduna metropolis.
2. To determine the mosquito abundance in Kaduna metropolis.
3. To determine the distribution of mosquito species within the settlements.
4. To determine mosquito breeding habitats in Kaduna metropolis.

1.4 Hypothesis:

1. There is no significant difference in the species of mosquito in Kaduna metropolis,
2. There is no significant difference in the abundance of mosquito species in Kaduna metropolis,
3. The distribution of mosquito species is not different between settlements.
4. The breeding habitats of mosquito species in Kaduna metropolis are similar.

CHAPTER 2

Literature Review

Mosquito is a Spanish word meaning, “Little fly” but spelt “musketas”. The English called mosquitoes “gnats” (Tom, 2004). Information exists on the various aspects of the biology of mosquitoes.

2.1 Classification

Kingdom – Animalia; Sub kingdom – Metazoa;Phylum- Arthropoda; class – Insecta; Suborder – Nematocera; Infraorder – Culicomorpha; Super family – Culicoidea; Family – Culicidae. All mosquitoes belong to the family – Culicidae; the family Culicidae is divided into three Sub Families, Namely; *Toxorhynchitinae, Anophelinae* and *Culicinae,* (Service, 1993). There are 34 genera in these 3 Sub families altogether.

2.1.1 Sub family *Toxorhynchitinae*

This sub family contains only one genus; *Toxorhynchites*. They are mainly Cosmo tropical, being found in Africa, Asia, Central and South America and also costal areas of Japan and Russia. There are about 65 known species. The commonest in Nigeria is *Toxorhynchites brevipalpis* (Theo) (Service, 1980). *Toxorhynchites* adult mosquitoes do not “bite” due to the possession of a proboscis, which is recurved, thus incapable of piercing the skin to take blood meals. They are therefore of no medical importance, but the larvae are cannibals / predators of other mosquito species when breeding in the same habitat, (Service, 1993).

2.1.2 Sub family *Anophelinae*

This Sub Family *Anophelinae* contains three genera; these are *Anopheles,* which are cosmopolitan, *Bironella, which* occurs only in Australia, New Guniea, Melanesia and Moluccas; and *Chagasia* species that are found only in Central and South America. Only *Anopheles* species is of medical importance, the last two are not, (Service, 1980). There are approximately 380 species of *Anopheles* but only 60 are confirmed vectors of malaria (Kristina, 2002).

2.1.3 Sub family *Culicinae*

The sub family has two tribes, which are *Sabethini* and *Culicini.* There are altogether 30 genera of mosquitoes in these 2 tribes. The medically important species belong to the following genera: *Culex, Aedes, Mansonia, Sabethes, Haemagogus and Psorophora* (Service, 1993).

2.2 Distribution

Mosquitoes have a worldwide distribution, occurring throughout the tropical and temperate regions and are only absent in Antartica (Smith, 1978). However, some genera have a restricted distribution and may be confined to certain areas; for instance, the genus *Haemagogus* is only found in central and South America (Service, 1980). Certain mosquito species are said to be ubiquitous but are more wide spread in the tropical and sub tropical regions and are also found in temperate climates and even in Artic during summer (Bates, 1949). Species that are of medical importance (examples, *Anopheles gambiae* complex, *An. funestus* and *An. arabiensis*) co-exist widely over much of the African and Asian continents. Some species may appear to have a disjunct distribution, although doubtless other localized populations in the several zones

remain to be discovered. *Anopheles gambiae s.s* is evidently absent from all areas of the North-East Africa, whereas in West Africa its range extends well into the sahel region of Mauritanian zone (Giles and Coetezee, 1987).

Culex pipiens complex includes, the anautogenous subspecies –*Culex pipiens pipiens* L, the autogenous *Culex pipiens molestus* Forskal and *Culex pipiens quinquefasciatus*. They occur in Europe, extra tropical parts of Asia, Africa, middle part of North America, part of South America and Australia (Vinogradova, 1997). *Cx. p pipiens* has also been registered mainly in the Southern and Northern part of Africa. It is wide spread in Egypt, where both autogenous and anautogenous forms (*Cx. p. molestus* & *Cx. p. pipiens* respectively) coexist. Also, these species coexist together with *Cx. p. quinquefasciatus* in South Africa. *Cx. p. pipiens* is the most common subspecies even in some places of the Afro tropical realm, totaling 92% of the collection from a marsh and in the Kenya highlands, (Logan *et al*., 1991).

In Nigeria, mosquitoes are widely distributed throughout the country; the most common species belong to the genera *Anopheles, Culex* and *Aedes,* (Surtees, 1959; Hanney, 1960 and Service, 1963). The most notorious mosquito species which have been incriminated in the transmission of such disease like malaria (*Anopheles gambiae, An. arabiensis*) yellow fever (*Aedes aegypti*) L and Filariasis (*Anopheles gambiae* s.l and *Culex .p. quinquefasciatus*), have also been identified in Nigeria (Bruce-Chwatt, 1949; Hanney, 1960; Service 1963 & 1966; White and Rosen, 1973; Richards *et al*., 2005). The major malaria vector in the rain forest parts of Nigeria is *Anopheles gambiae*, while *Anopheles funestus* is the major malaria vector in the southern parts, (Service, 1963). Recently in an interesting research, resting *Anopheles*

gambiae s.l, *An .funestus* and *Culex* species were collected in some house holds from a survey in four sentinel villages in Nasarawa and Plateau states. Only the Anopheline mosquitoes were found to harbour *Wuchereria bancrofti* larvae (Richards *et al*., 2005).

The range and relative abundance of *An. gambiae* and *An. funestus* appear to be strongly influenced by climatological factors, especially total annual precipitation, (Lindsay *et al*., 1998). *An. gambiae* and *An. arabiensis* tend to occur in sympatry and changes in the composition often occur, with *An. arabiensis* predominating during the dry season and *An. gambiae* being more abundant during the rainy season; or sometimes vice versa (Service, 1970). Based on collections in various zones in Nigeria, *An. gambiae* is prevalent in forest and savannah zones; while *An. arabiensis* is predominant in sudan, sahel and northern guinea savannah zones. It is absent in southern guinea savannah, but it is present further down south (Coluzzi *et al*., 1979). However, in contrast, the distribution and abundance of *An. arabiensis* has been encountered in some localities of southern guinea savannah (Abuja, Lokoja and Makurdi) by Onyabe & Conn, (2001). This observation suggests that *An.arabiensis* has extended its range. To confirm the above suggestion, morphological and molecular characterization of *Anopheles* species (Ndams, 2004) revealed *An.arabiensis* and *An.gambiae s.s* both the M & S forms in some parts of Kaduna and Benue states. More recently, (Sow *et al*., 2008) reported on the distribution and susceptibility of *Anopheles* mosquitoes to permethrin insecticide in some selected localities within southern guinea savannah zone of Kaduna state.

The ecology of the adult mosquitoes of the Northern Guinea Savannah in two Hausa villages at Kaduna (Angwan Rimi, which is now urbanised and Kangimi)

was studied (Service, 1963). The research showed that *Anopheles gambiae s.l, An. nili, An. funestus, Culex pipiens fatigans* now, *Cx. p. quinquefasciatus* and *Mansonia uniformis*, were the most common mosquito species during the period of study.

The occurrence and distribution of other mosquito species could be based on habitats availability, climate, environment and human activities. Larval surveys have shown that *Cx. p. quinquefasciatus* is the commonest mosquito breeding in the numerous polluted streams, open drains etc of townships like Lagos (mangrove forest and coastal vegetation), Ibadan (low land rain forest), Bauchi-Jos-plateau (Guinea Savannah), Kano (Sudan Savannah), and Sokoto-Birin kebbi (Sahel Savannah). (Service, 1963) Okogun *et al.*, (2003) in Esan and Etsako region of Edo state, (formerly Midwestern Nigeria) suggested that mosquito abundance is related to population and human activities; example, the university town of Ekpoma occupied predominantly by students and farmers had a higher relative abundance (35.70%) of mosquito larval species. Also, Amusan *et al*., (2004) studied the various habitats in a rice field within a populated village in Abeokuta (rain forest zone) Ogun state; *Aedes aegypti* was most abundant species.

2.3 Culicidae External Morphology

2.3.1 Adults Adult mosquitoes measure about 4 – 6mm in length; they posses a distinct head, winged thorax and abdomen. The head is more or less globular in shape and has a conspicuous pair of kidney shaped compound eyes. Between the eyes arises a pair of filamentous and segmented antennae. All species of mosquitoes can be conveniently sexed by examination of the antennae. Individuals with feathery antennae are males; while those with only short and rather inconspicuous antennal hairs are females. Just below the antenna is a pair

of palps, which may be long or short, dilated or pointed at the tip depending whether a female or male; Anophelines or Culicines. Arising between the palps is a single elongated proboscis that contains the piercing mouthparts of the mosquito, (Service, 1980).

The thorax is slightly humped and is covered dorsally and laterally with scales, which may be dull or shiny and metallic, black white or almost any colour; small bristles are also present. The numbers, pattern of distribution and colour of the scale are important characters used in the morpho-taxonomic identification of different mosquito species (Service, 1980). The wings on the thorax are long and relatively narrow. The number and arrangement of the wing veins is virtually the same for all mosquito species, the veins are covered with scales that are usually brown, black white or creamy yellow. Scales also project as a fringe along the posterior border of the wings. The legs of mosquitoes are long and slender, consisting of a short coxa, trochanter, a long femur and tibia with five-segmented tarsi, which terminates in usually a pair of tooth or simple claws. The legs are also covered with scales that are usually brown, black or white and may be arranged in patterns, often in the form of ring, (Service, 1980).

2.3.2 Larvae. Mosquito larvae are legless aquatic insects with a bulbous thorax that is wider than both head and abdomen. There are four active instar larval stages. All mosquito larvae have a well-developed head, which has a pair of antennae and a pair of compound eyes. Most larval species have prominent mouth brushes that sweep water containing minute food particle into their mouth. The thorax is roundish in outline and has various simple and branched hairs, which are usually long and conspicuous. The abdomen is distinctly segmented and has nine

visible segments most of which have simple or branched hairs. The last segment has two paired groups of long hairs forming the caudal setae; it also has a sclerotised plate, called the saddle that may completely encircle the segment and two pairs of transparent sausage–shaped gills, which are mainly for osmoregulation not respiration

2.3.3 Pupae. Mosquito Pupae are aquatic and comma–shaped. The head and thorax are combined to form the cephalo-thorax, which has dorsally, a pair of respiratory trumpets. The abdomen consists of ten segments, but only eight are visible. Each segment has numerous short hairs and the last segment terminates in a pair of oval and flattened structures termed "the paddles". In between the paddles is a small pouch-like projection containing the developing external genital processes of the adults. Mosquito pupae can thus be readily sexed by examining the end of the abdomen, (Service, 1980).

2.4 Mosquito Biology

Mosquitoes go through four separate and distinct stages of its life cycle; Egg, Larvae, Pupae and Adult.

2.4.1 Egg. Eggs are laid singly in the case of *Anopheles* species; attached together to form rafts as in Culicines or rafts attached to vegetations as in *Mansonia* and *Haemagogus* species. Depending on the species of mosquito, the female lays about 30 – 300 eggs at any oviposition. Eggs are brown or blackish or boat-shaped as in Anophelinae. Some eggs example, *Aedes* species can withstand desiccation. Most eggs hatch into larvae with 48 hours in the tropics, but in cooler regions, it is between 7 - 14 days, (Service, 1980).

2.4.2 Larvae. The characteristic features of the mosquito larva are the head with mouth brushes, eight segments, siphon and gills. Most Culicine larvae have siphon tube for breathing and hang upside down from water surface. Larvae of *Anophelinae* do not have a siphon thus lie parallel to the water surface to get supply of oxygen. Some (*Mansonia* species) posses a specialized siphon that can cut/pierce through roots and stems of aquatic plants; thus they obtain oxygen supply form these plants, (Service, 1980). Mosquito larvae feed on micro-organisms like yeast, bacteria, protozoa and numerous other plants. Mosquito larvae live in water from 4 – 14 days depending on water temperature. Example, larval period of *Anopheles species* in tropical countries is seven days. After the four instar stages, feeding ceases and pupa stage soon follows.

2.4.3 Pupae. The pupae are comma-shaped with a pair of respiratory trumpets dorsally positioned on the head. The Pupa stage is a resting, non-feeding stage of development. They swim up and down the habitat in a jerky fashion when disturbed. Some of the developing structures of the adult mosquito can be seen through the integument of the cephalo-thorax; the most conspicuous features are the pair of dark compound eyes, folded wings, legs and proboscis. In tropical countries, the *Anopheles* pupae lives in water from 1 – 4 days developing, depending upon species. But in cooler temperature regions, pupal development may be extended over 6 – 12 days or longer. At the end of the pupal life, the skin on the dorsal surface of the cephalo-thorax splits and the adult mosquito struggles out, (Service, 1980).

2.4.4 Adult mosquito. After the adults have emerged from their pupal cases, they rest either on the water surface or near by vegetation for about one hour to

allow their wings to unfold and harden sufficiently for them to fly. Soon after emergence mating occur with females entering a swarm of males to be inseminated in some species. The emergence and mating occur early evening commonly around dusk.

Females of most mosquito species require a blood meal either before or usually after mating for the eggs to develop; thus the female mosquito of some species obtain their blood meal from man, animals or birds. After having bitten the vertebrate host, the mosquito goes and rests so that digestion of the blood meal that is essential for the development and maturation of the eggs in the ovaries can take place. The speed of digestion of the blood meal depends on temperature. In most tropical species it takes 2 – 3 days, but in cooler regions 7 – 14 days. After the maturation of the eggs, the female mosquitoes at suitable habitats lay them.

In tropical countries adults mosquitoes probably live on the average for only about 2 –3 weeks but in temperate climates, the average life may be 4 – 6 weeks or longer in the case of some hibernating over wintering species, (Service, 1980).

2.5 Mosquito Control

Mosquito control can be directed at either the immature aquatic stages or the adults, or at both stages simultaneously.

2.5.1 Biological control method directed at the aquatic stage:

2.5.1.1 ***Use of predators*****:** Mosquito larvae and pupae have been reduced in aquatic environments by the use of predators. The commonly used predators are

fish, example *Gambusia* species. Also other predators are tadpoles of frogs and toads, and various aquatic insect larvae, but these have rarely proved effective control agents. A few mosquitoes have predacious larvae, for example *Toxorhynchites brevipalpis* Theo that are used to control larvae of other container-breeding mosquitoes, (Collins & Blackwell, 2000).

2.5.1.2 *Pathogens:* There are numerous pathogens such as viruses (for example, iridescent and cytoplasmic polyhedrosis viruses), bacteria (for example, *Bacillus thurningiensis and B. Sphaericus*), Protozoa (for example, *Nosema* and *Thelomania*) and fungi (for example, *Coelomomyces, Lagenidium* and *Culicinomyces*) that cause larval mortality. Some of these pathogens appear harmless to man, (Service, 1980).

2.5.2 Chemical Control Directed At Adult Mosquito:

A principal strategy for controlling malaria is to use insecticides to eradicate the vectors. The most widely practiced method of chemical control targeted at the adult mosquito is the application (spraying) of residual insecticides to the interior surface of walls, ceilings, and roofs of houses; for endophagic or endophilic mosquito species. Also behind houses, windows, open shades / rafts, outside the house and the surroundings of human or animal habitations; for exophagic or exophilic mosquito species. The use of insecticide-treated mosquito nets and other materials are being used currently as vector control measures against mosquitoes. The new class of insecticide; Pyrethroids (Deltamethrin Permethrin) are used to treat bednets and insect window nets (WHO, 1993).

Insecticides, examples Dichloro, diphenyl, tirchloroethane (DDT) is used. Before the advent of resistance to insecticides by mosquito, DDT was the best

insecticide. Organochlorine insecticides like Dieldrin (cyclodiene) and HCH, which are toxic to man than DDT are also used for indoor residual spraying under strict safety measures. If mosquitoes are resistant to DDT then organophosphate insecticide such as Malathion, Fenthion (Baytex), Fenitrothion (Sumithion) or Carbamates; such as Carbaryl (Sevin) and Propoxur (Arprocarb) are used. But they are less persistent and spraying may have to be repeated severally (4-6 times) in a year. Furthermore, they are more expensive than DDT that are toxic to man, thus greater safety measures may have to be taken during control campaigns, (Service, 1980).

In some countries, where local malaria vector is still susceptible, DDT is used for indoor residual spraying. However, in almost all countries, DDT has been banned due to its adverse toxic effects on man, animal, agriculture, earth's resources and biodiversity, (WHO, 2000).

The use of DDT was addressed at the 1995 meeting of the WHO study group on Vector Control for Malaria and Other Mosquito-Borne Diseases, (WHO1995). The study group stated that DDT might be used for vector control provided that it is (a) only used for indoor spraying, (b) effectively used, (c) the WHO product specifications are met and (d) the necessary safety precautions are applied for its use and disposal. Control strategies that do not rely heavily on insecticides are therefore required. However, spraying too many insecticides has triggered the development of Insecticide Resistance in mosquitoes resulting in a failure of the disease control, (Brodgon & McAllister, 1998; WHO, 2000)

2.5.3 Environmental Management (Control)

Environmental management for vector control aims to induce changes in the ecosystems that help reduce their receptivity to the propagation of disease vectors. It is not intended to replace other control strategies; rather, it provides a basis for other methods, such as chemical control to build on in a complementary fashion, while reducing the environmental cost and resistance risks incurred by excessive use of insecticides, (WHO, 1982). Unfortunately environmental management fell off the Malaria Control agenda when DDT became the main tool for the World Health Organisation's (WHO) Malaria eradication program from 1957-1967. Thus, the effectiveness of environmental management has remained tragically under exploited, (WHO, 1993)

Environmental management for malaria vector control consists of options for reducing the number of mosquito habitats or reducing biting by adult mosquitoes. A simple form of control consists of filling in of all available mosquito larval habitats with soil and gravels. Examples of larval habitat range from water-filled tree holes, ponds to small marshes. Abandoned cans, metal drums, pots and tyres also other containers or receptacles of water can constitutes a good habitat for mosquitoes breeding. The water in such containers is to be thrown away. In areas where containers are to be used to collect and maintain drinking waters, such as water storage jars, village pots etc, they could be minimized or covered properly. Larval breeding places such as large ponds burrow pits fresh or salt water marshes can be drained. The advantage of filling-in is that, it can lead to permanent control of larvae or pupae.

Ecological changes can also prevent mosquito breeding; for example, cutting down over hanging vegetation to increase sunlight on the water may prevent breeding by species that like shaded habitats; whereas planting vegetation near water may stop breeding by sun-loving species.

Another method of controlling mosquito larvae is by the application of mineral oils to the water. Larval habitats have to be treated with chemicals such as paris green or oils and organophosphate chemicals. But most chemicals are toxic to other aquatic life and are consequently not so widely used, due to its health implication to aquatic life and to man, (Service, 1980).

2.6 Insecticide Resistance.

There are already reported cases of insecticide resistance by some mosquito species; as of 1992, the list of insecticide-resistant vectors included 56 Anopheline and 39 Culicine mosquitoes, (WHO, 1992). In many countries, *Aedes aegypti* has developed insecticide resistance to DDT, dieldrin and HCH and sometimes also to organophosphate insecticides such as malathion (WHO, 1967). Wide spread dieldrin resistance developed in the 1960s and it's still present in many Anopheline populations. Unlike dieldrin resistance, DDT resistance in malaria vectors took longer to develop and was not so wide spread. It was generally induced by a DDT-specific resistance mechanism (glutathione-s-transferases) in mosquitoes. However, in West Africa, another resistance mechanism in mosquitoes called, kdr (knock down resistance) has been recently found which confers cross-resistance to DDT and a wide range of pyrethroids. It

results from the point mutation in sodium channels, which is the target site for DDT and pyrethroids, (Martinez-Torres *et al.*, 1998).

Pyrethroid resistance has already been found in some important malaria vectors such as *Anopheles gambiae s.s* in West Africa, *An.albimanus* in Central America, *and An.sacharovi in* Turkey and *An.stephensi* in India, Pakistan and parts of the Arabian Peninsula. Also, the *kdr* gene is been reported recently in field population of *Anopheles gambiae s.s* in southern Nigeria,(Awolola *et al*., 2002). Its presence has also been strongly suspected in *Anopheles stephensi*, *An. albimanus* and *An. sacharovi*, (WHO, 2000). Also, it is established that the urban mosquito which causes nuisance, *Cx. p. quinquefasciatus*, has developed resistance to six pyrethroids, namely; Alpha-cypermethrin, Cyfluthrin, Deltamethrin, Etofenprox, Lambdacyhalothrin and Permethrin which are used for Bednet impregnation as control against malaria vectors, (Chandre *et al*., 1998; WHO, 2003).

2.7 Climate and Mosquito Abundance.

Many mosquito species depend on the availability of water. The first three stages of mosquito life cycle (egg, larvae and pupae) are aquatic. Thus, mosquito abundance can be affected by hydrologic variability, in particular, fluctuations in the water cycle / rainfall that alters the availability of suitable habitats, (Shaman and Day, 2005).

Rainfall has two principal influences on the mosquito life cycle.

(i) The increased near – surface humidity associated with rainfall enhances mosquito flight activity and host seeking behaviours.

(ii) Rainfall can alter the abundance and type of aquatic habitats available to the mosquito for oviposition .

These climate changes may or may not favour an increase in mosquito species composition, abundance and age structure that may lead to either an increase or a decrease in disease transmission (shanks et al., 2002).

However, the availability of suitable mosquito habitats is not a linear function of rainfall. Surface wetness depends on a number of environmental conditions other than precipitation, including antecedent wetness, soil type and rates of combined evaporation and transpiration. Furthermore, excessive rainfall can decimate some mosquito populations by flushing larval habitats. Other mosquito species can benefit from drought conditions such as when the environment dries up or when standing waters become eutrophic with increased organic content, which provides additional food for mosquito larvae, (Shaman and Day, 2005).

2.7.1 Climate Change and Impact

Studies, which give vector-specific information regarding climate and mosquito distribution, were revised and applied to world climate scenarios. They reveal a global increase of 260-320 million people at risk by the year 2080 living in malaria zones. The distribution of *Anopheles gambiae* complex is projected to undergo a net increase in distribution in Southern Africa under three (Rainfall, Relative humidity and temperature) climate change scenarios. (Climate change, 2001)

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area:

The research was conducted between November 2004 and November 2005 in Kaduna metropolis, which is the administrative capital of Kaduna State, Nigeria. It is located between 10^0 33' North of the Equator and 07^0 27' East of the greenwich Meridian, (Gazetta, 1965). Kaduna is located within the Northern Guinea Savannah Zone of Nigeria on a gentle undulating plain with land ranging from 500m to 650m above sea level, (Atere, 1991).

The estimated population figures as at March 2006 National Population Census (NPC), Kaduna North and Kaduna South which makes up major part of Kaduna metropolis has 760, 084 individuals, (Anon, 2007).

3.2 Sampling Areas.

Largely, two local Government areas; Kaduna North and Kaduna South form Kaduna metropolis. There are altogether 24 settlements within these two L.G.A. that make up Kaduna metropolis. A total of 15 settlement areas were randomly chosen to constitute the Sampling Areas. Each settlement area was numbered as shown in (Fig. 3.1). Sampling collections were conducted in the 15 settlement areas that were divided into two and classified as New and Old settlement areas in Kaduna metropolis.(Table 3.1) . Kaduna metropolis was sectioned into old and new settlement areas based on the known years of human settlement existence.

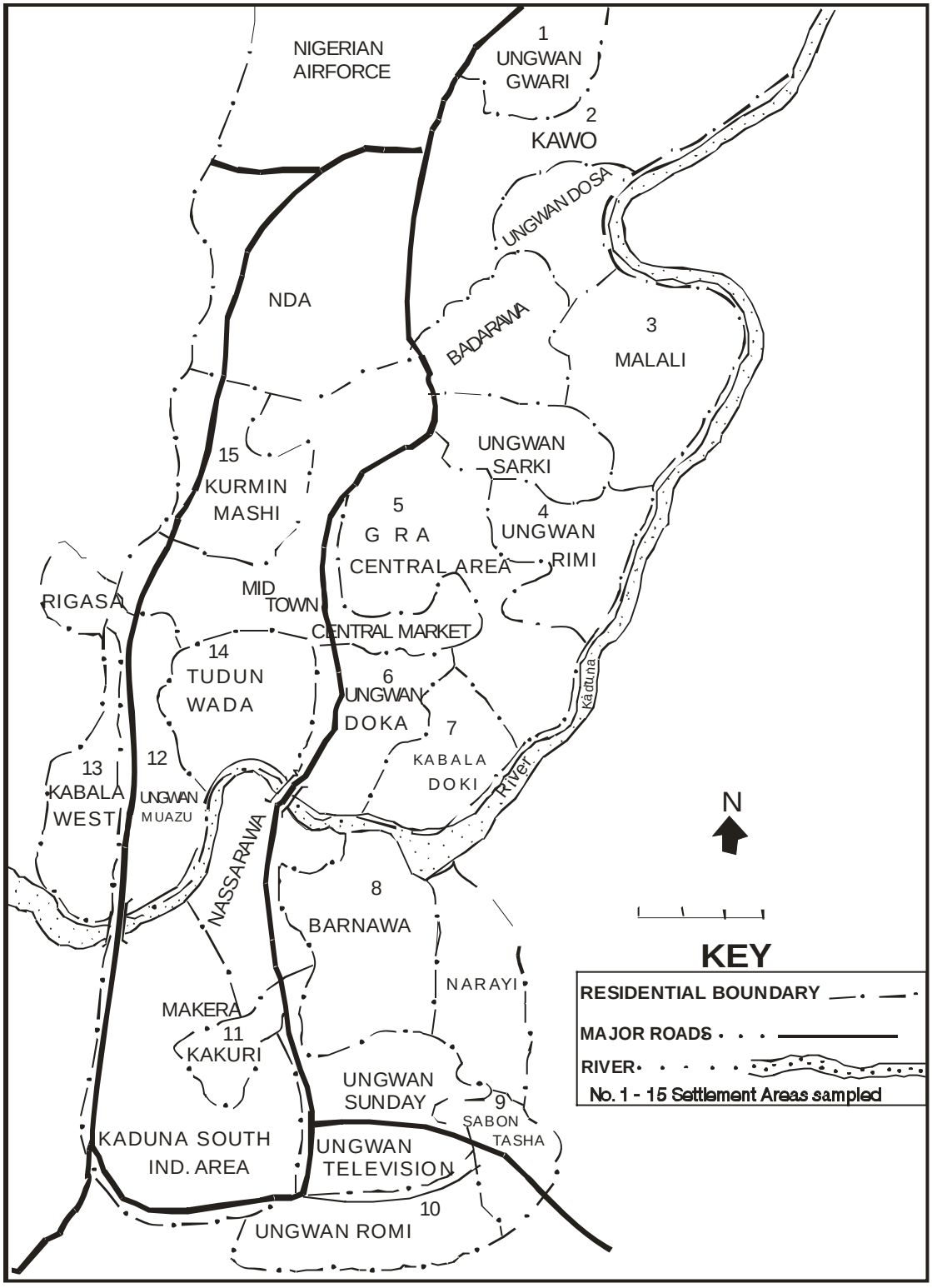


Fig. 3.1 MAP OF KADUNA METROPOLIS

TABLE 3.1 SETTLEMENT AREAS SAMPLED IN KADUNA METROPOLIS.

*S/no	SAMPLING AREAS	TYPE	LATTITUDE (N) in degrees	LONGITUDE (E) in degrees
1*.	UNGWAN GWARI	O.S+	10^0 35.71’	07^0 27.17’
2.	KAWO	O.S	10^0 32.35’	07^0 24.24’
3.	MALALI	N.S	10^0 33.95’	07^0 28.19’
4.	UNGWAN RIMI	O.S	10^0 33.54’	07^0 28.13’
5.	G .R .A	O.S	10^0 31.75’	07^0 26.24’
6.	UNGWAN DOKA	O.S	10^0 30.94’	07^0 27.74’
7.	KABALA DOKI	N.S	10^0 30.10’	07^0 26.59’
8.	BARNAWA	N.S	10^0 28.25’	07^0 26.80’
9.	SABON TASHA	N.S	10^0 27.01’	07^0 27.54’
10.	UNGWAN ROMI	N.S	10^0 25.19’	07^0 25.20’
11.	KAKURI	O.S	10^0 26.11’	07^0 25.20’
12.	UNG. MU’AZU	O.S	10^0 29.76’	07^0 23.77’
13.	KABALA WEST	N.S	10^0 30.14’	07^0 23.26’
14.	TUDUN WADA	O.S	10^0 31.23’	07^0 25.13’
15.	KURMIN MASHI	N.S	10^0 32.73’	07^0 24.97’

*S/no = Settlement’s designated serial numbers. (Settlements will henceforth be referred thus).

+ O.S, N.S = settlement is classified as O.S= old settlement, N.S= new settlement.

The old settlements are areas known since 1960-1965 to date; while the new settlements are areas known to be established by 1985-1990 to date.

Randomization Technique.

The names of the 24 settlement areas were each written on small pieces of paper, squeezed and put into a bag. The bag was shaken thoroughly, and then one was picked. The name written down and the piece of paper were returned into the bag. Each time a settlement's name occurred again it was not recorded. This process was continued until 15 settlement areas were selected.

3.3 Sampling Procedures

Preliminary visits were undertaken to prospect for mosquito breeding in these 15 randomly chosen settlement areas. From 12th November 2004 to 26th November 2005, samples of mosquito immature stages (Larvae and Pupae) were collected once for two weeks each month. The sampling habitats (sites) in the 15 settlement areas were; Gutters (concrete or otherwise), Stagnant pools/ponds, Abandoned construction pits, Soakaway pits, Peri-domestic run offs (PDRF), discarded Clay, Metal and Plastic containers, Abandoned tyres, Roadside potholes and Tree-holes (phytotelms). Some of these objects / habitats which make up good breeding habitats for mosquitoes are shown in the appendix. (Plate 1-4).

From these, only habitats that were positive for mosquito breeding were sampled. Mosquito immature stages were collected from the various positive breeding habitats using a plastic dipper (7cm in diameter and a depth of 5cm, with a 30cm long handle). Habitats such as containers, tyres and clay pots where the dipper could not be used, the water it contains were emptied into the bowl and the

specimens collected, (Service, 1976). Ten dips were collected at each sampling habitat for standardization. The immature stages collected were poured through a fine sieve in an enamel Bowl to concentrate them. All collected specimens were preserved in 70% Ethanol, in covered and labeled specimen tubes, (Service, 1976). All samples were there after transported to the laboratory for identification. Each settlement area was sampled twice per month.

3.4 Identification of Mosquito Larvae.

All mosquito larvae were identified in the laboratory using the Olympus dissecting microscope with objective lens of x10 and x20 with the guide of the pictorial keys by Hopkins (1952); Gillies and Coetzee (1987). All larvae were viewed and identified with simple taxonomic characters such as; the presence or absence of siphon, pectin comb, sub ventral tuffs, gills, meta-pleural spines and tergal plates (Service, 1980). During identification all pupae were discarded because Hopkins (1952) pictorial keys cannot be used to identify the pupae stage of *Culex* species.

3.4.1 Culex Species.

The genus was easily distinguished in the larval state by the invariable presence of more than one pair of sub ventral tuff of hairs on the siphon. The siphon maybe long, narrow or short and fat depending on the species, (Hopkins, 1952; Service, 1980 and Vinogradova, 1997).

3.4.2 Aedes Species

The larvae of mosquitoes belonging to this group have a short barrel shaped siphon and only one pair of sub ventral tuff, which never arises

less than a quarter distance from base of siphon. Some members of this genus are distinguished by the possession of very large meta-pleural spines at the thorax, which have very much the shape of a Rose thorn. The gills also vary at shapes and sizes within the genus (Hopkins, 1952).

3.4.2 Anopheles Species

Larvae of mosquitoes belonging to this group are distinguished by the total lack of siphon (Service, 1980). Larvae have long meso-pleural hairs which are simple, the main abdominal plate on segment five are not more than two thirds distance between bases of palmate hairs. Also, the inner clypeal hairs are either widely or closely separated with the outer clypeal hairs. Some clypeal hairs have eight or fewer branches, (Gillies and Coetzee, 1987).

3.5 DATA ANALYSIS:

The statistical tools for the data analysis are:-

1. ANOVA; to compare species composition between the old and new settlements and also to compare between habitats and species composition.
2. Percentages to be expressed as bar charts and line graphs to show mosquito species abundance in months and habitats.
3. “t” test to compare mosquito species diversity between dry and wet months.

Chapter 4

Results

A total of 6,991 mosquito larval specimens comprising 15 species were collected from 15 settlement areas of Kaduna metropolis, during the 13 months sampling period (November 2004 –November 2005)

4.1 Mosquito Species Composition.

As seen in Table 4.1, the most predominant species encountered that made approximately 80% of the total number of mosquito were the *Culex pipiens* complex (*Culex pipiens quinquefasciatus* [26.26%], *Cx. p. molestus* [47.30%], *Cx. p. pipiens* [6.25%]). *Anopheles specimens* and *Aedes aegypti* represented 0.06% and 1.97% respectively of the total catch; other species were *Aedes simpsoni* (0.17%), *Aedes vittatus* (1.47%), *Culex decens* (12.42%), *Cx. tigripes* (0.44%), *Cx. univttatus* (0.49%), *Cx. musarum* (0.57%), *Cx. horridus* (1.64%), *Cx. duttoni* (0.03%), *Cx. nebulosus* (0.06%) and *Cx. macfei* (0.59%).

4.2 Seasonality of Species

Culex pipiens molestus and *Cx. p. quinquefasciatus* were encountered throughout the year. Specimens of *Anopheles, Culex nebulosus* and *Cx. macfei* were only encountered once in the months of May, June and August respectively throughout the whole period of sampling (Table 4.2). *Aedes aegypti*, which is considered to be of medical importance, was encountered during the months of June – October. Also, from monthly totals, October had the highest percentage of 22.67% abundance during the wet season; next was the month of March (15.00%)

TABLE 4.1 POPULATION OF MOSQUITO SPECIES SAMPLED IN KADUNA METROPOLIS.

S/No	Mosquito species	Total	Percentage composition(%)
1.	*Culex pipiens molestus*	3307	47.30
2.	*Culex pipiens quinquefasciatus*	1836	26.6
3.	*Culex pipiens pipiens*	456	6.52
4.	*Culex decens*	868	12.42
5.	*Aedes aegypti*	138	1.97
6.	*Aedes vittatus*	103	1.47
7.	*Aedes simpsoni*	12	0.17
8.	*Culex tigripes*	31	0.44
9.	*Culex univittatus*	34	0.49
10.	*Culex musarum*	40	0.57
11.	*Culex horridus*	115	1.64
12.	*Culex nebulosus*	4	0.06
13.	*Culex duttoni*	2	0.03
14.	*Culex macfei*	41	0.59
15.	*Anopheles species*	4	0.06
		6,991	100%

TABLE 4.2 MONTHLY MOSQUITO SPECIES COMPOSITION AND ABUNDANCE.

MONTHS	C.p.m	C.p.q	C.p.p	A.ae	A.vi	A.si	C.tg	C.de
NOV. -04	29 (0.87)	127(6.92)	1 (0.22)	-	-	-	-	-
DEC. -04	45 (1.36)	71 (3.87)	-		-	-	-	14 (1.61)
JAN. -05	18 (0.54)	84 (4.58)	-	-	-	-	-	15 (1.73)
FEB. -05	118 (3.57)	131 (7.41)	-	-	-	-	-	35 (4.03)
MAR.-05	601 (18.17)	244 (13.29)	154 (33.77)	-	-	-	-	49 (5.65)
APR.-05	504(15.24)	19 (1.03)	-	-	-	-	1 (3.23)	-
MAY.-05	347 (10.49)	194 (10.57)	129 (28.28)	-	-	-	-	69 (7.95)
JUN. -05	82 (2.48)	138 (7.52)	9 (1.97)	6 (4.35)	-	-	13 (41.94)	42 (4.84)
JUL.-05	66 (2.00)	133 (7.24)	17 (3.73)	14 (10.14)	-	-	-	98 (8.18)
AUG.-05	291 (8.80)	113 (6.15)	11 (2.41)	41 (29.71)	11 (66.67)	8 (66.67)	4 (12.90)	37 (4.26)
SEP. -05	384 (11.61)	186 (10.13)	15 (3.29)	54 (39.13)	92 (89.32)	4 (33.33)	11(35.48)	106 (12.21)
OCT.-05	668 (20.20)	234 (12.75)	120 (26.32)	23 (16.67)	-		1 (3.23)	430 (49.54)
NOV.-05	154(4.66)	162(8.82)	-					
TOTAL	**3307**	**1836**	**456**	**138**	**103**	**12**	**31**	**868**

TABLE 4.2 Cont'd

MONTHS	C.du	C.mu	C.ho	Ansp	C.ma	C.ne	C.un	T.no.spp	Totals (%)
NOV. -04	-	-	-	-	-	-	-	3	158(2.26)
DEC. -04	-	-	-	-	--	-	-	3	130(1.86)
JAN. -05	-	-	-	-	-	-	-	3	117(1.67)
FEB. -05	-	-	-	-	-	-	-	3	284(4.08)
MAR.-05	-	-	-	-	-	-	-	4	1048(15.00)
APR.05	-	-	-	-	-	-	-	3	524(7.50)
MAY.05	-	-	-	4(100)	-	-	3(8.82)	6	746(10.67)
JUN. 05	-	39(97.50)	6(5.22)	-	-	4(100)	-	9	296(4.23)
JUL.05	-	1 (2.50)	-	-	-	-	22(64.71)	7	366(5.24)
AUG.05	2(100)	-	-	-	41(100)	-	6(17.65)	11	566(8.10)
SEP. 05	-	-	-	-	-	-	3(8.82)	9	855(12.23)
OCT.-05	-	-.	109(94.78)	-	-	-	-	7	1585(22.67)
NOV.-05	-	-	-	-	-	-	-	2	316(4.42)
TOTAL	**2**	**40**	**115**	**4**	**41**	**4**	**34**	**15**	**6,991**

(P value = 0.04., P<0.05., tcal= -4.2599., ∝=0.05) **All numbers in parenthesis = percentages (%)**

in the dry season (Table 4.2 and Fig.4.1). The percentage composition of mosquito species was noticed to increase during the rainy season, though in the dry season, during the month of March, an abnormally high percentage (15.00%) was noticed; December and January had the least percentage composition of 1.86% and 1.67% respectively (fig. 4.1).

The month of August had the highest diversity of 11 mosquito species while June and September had nine each; July and October, seven each while other months had only three or four species diversity. It was observed that during the wet season, more diversity of species was encountered than in the dry season. Also, it was during the wet season that rare or uncommon species like; *Culex duttoni*, *Culex macfei* and *Cx. nebulosus* emerged.

4.3 Mosquito distribution in Kaduna metropolis.

The distribution of species in Kaduna metropolis is summarized in fig. 4.2 and shows that 13 species were found in the old settlement areas, while 11 were found in the new settlement areas. There was therefore considerable overlap in species distribution in the two settlement areas. No major difference was observed in the kinds of species that occurred either in the old or new settlement areas. In summary, four species were found exclusively in the old settlements areas while two were found exclusively in the new settlement areas. A breakdown of these findings is presented below. The four mosquito species that were encountered exclusively in the old settlement areas are; *Culex duttoni*, *Culex musarum*, *Anopheles* species and *Cx.nebulosus.*

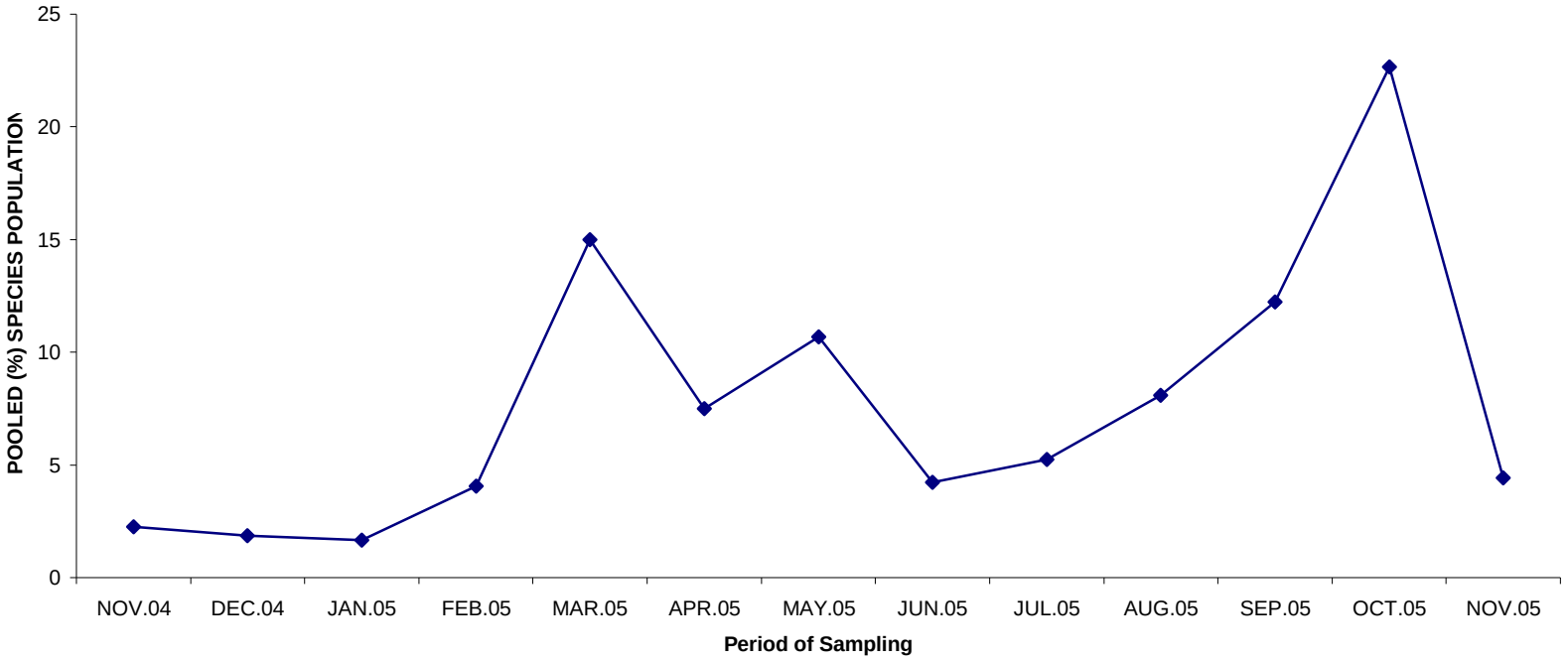


Figure: 4.1 Pooled Monthly Mosquito Species Population.

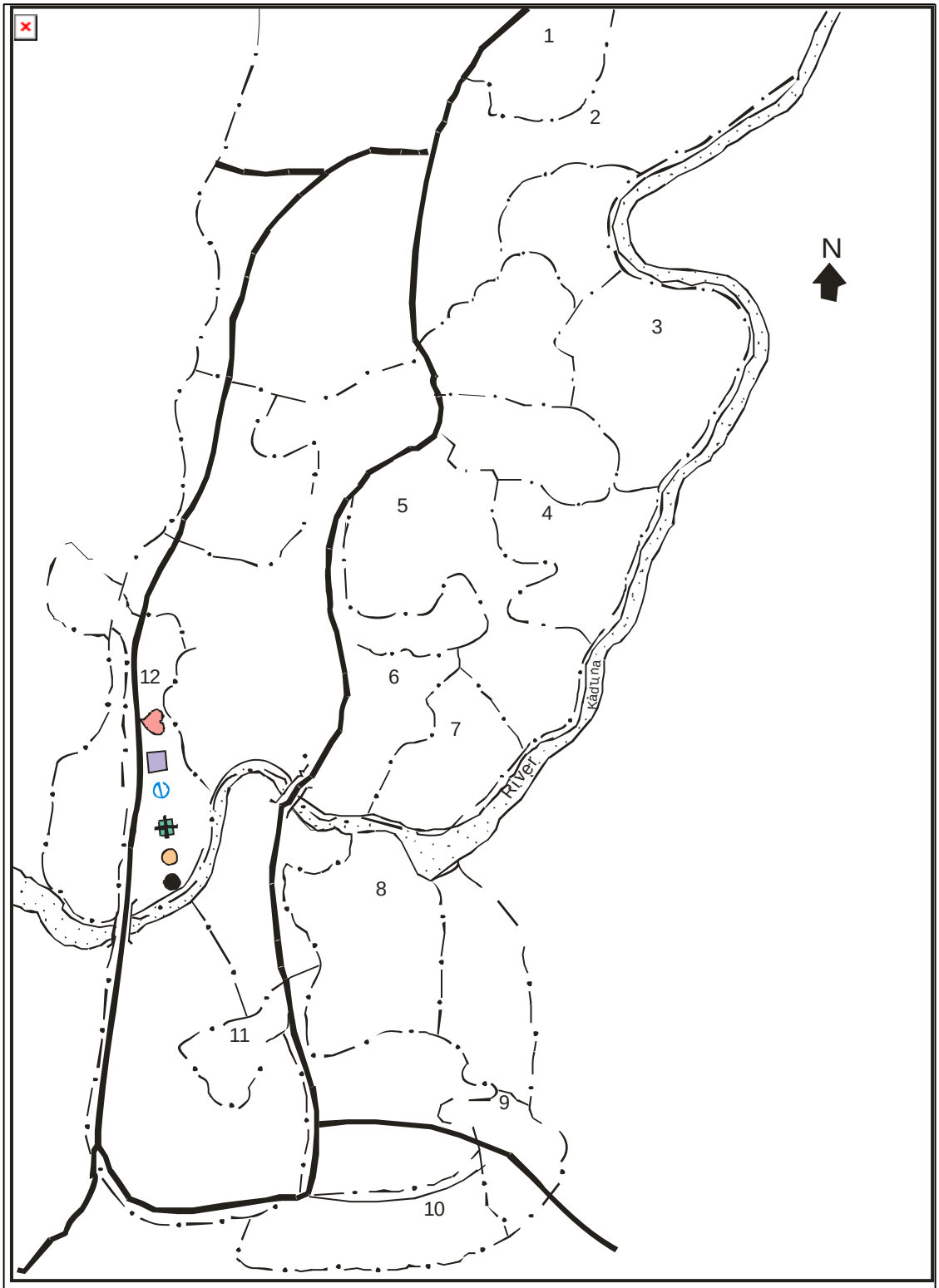


Fig. 4.2 MAP SHOWING DISTRIBUTION OF MOSQUITO SPECIES IN KADUNA METROPOLIS.

Name	Abbreviation	Symbols
Culex pipiens molestus	*C.p.m*	
Culex pipiens quinquefasciatus	*C.p.q*	
Culex pipiens pipiens	*C.p.p*	
Culex decens	*C.de*	
Aedes aegypti	*A.ae*	
Aedes vittatus	*A.vi*	
Aedes simpsoni	*A.si*	
Culex tigripes	*C.tg*	
Culex univittatus	*C.un*	
Culex musarum	*C.mu*	
Culex horridus	*C.ho*	
Culex nebulosus	*C.ne*	
Culex duttoni	*C.du*	
Culex macfei	*C.ma*	
Anopheles species	*Ansp*	

These were found at Ung. Rimi, Ung. Gwari, kakuri and Ung. Mu'azu respectively. Conversely *Culex horridus* and *Culex macfei* were the only two species encountered exclusively in the new settlement area, (Table 4.3).

Considering both old and new settlement areas, the highest diversity of species encountered was at G.R.A (old settlement) where eight species were recorded, while Malali, Barnawa and Kurmin Mashi (new settlements) had seven species each. Ung. Romi and Tudun wada had the least diversity of mosquito species, (Table 4.3). *Culex pipiens quinquefasciatus* and *Cx. p. molestus* were the only two species encountered in all settlements areas; while *Culex pipiens pipiens* and *Cx. decens* were encountered in all settlements except 12 and 14.

Culex pipiens molestus species was dominant in these settlements; (Sabon Tasha 42.08 ± 13.86 and Kawo 42.00 ± 14.12., LSD=24.06429). All the mosquito species collected exclusively belonged to particular settlements except *Cx .p .molestus, Cx .p .quinquefasciatus, Cx. p .pipiens* and *Cx. decens* which were virtually encountered in all settlement areas.(Table 4.3).

Analysis of variance (ANOVA) Test was conducted between the 15 settlement areas and the 15 different species encountered. It revealed that there was no significant difference in the total mosquito species sampled ($p=0.436$ or $P>0.05$); while there was a significant difference in the composition among the species of mosquito in the metropolis ($p=2.56 \times 10^{-36}$ .or $P<0.05$)

TABLE 4.3 MEAN NUMBER OF MOSQUITO SPECIES COLLECTED IN ALL SETTLEMENTS.

SETTLEMENTS	C.pm	C.pq	C.pp	A.ae	A.vi	A.si	C.tg	C.de	C.du	C.mu	C.ho	Ansp	C.ma	C.ne	C.un	T.no Spp
Malali	4.62 (2.99)	12.62 (6.46)	1.85 (1.32)	0.31 (0.31)	2.23 (2.33)	0.00 (0.00)	0.00 (0.00)	12.62 (6.34)	0.00 (0.00)	0.00 (0.00)	8.38 (8.38)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	7
K/doki	14.38 (5.50)	10.77 (4.91)	0.38 (0.38)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.08 (0.08)	11.69 (11.28)	0.00 (0.00)	0.00 (0.00)	0.46 (0.46)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6
Barnawa	19.69 (9.08)	8.77 (5.89)	2.31 (1.58)	2.38 (2.38)	0.00 (0.00)	0.00 (0.00)	0.31 (0.31)	5.15 (3.11)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	3.15 (3.15)	0.00 (0.00)	0.00 (0.00)	7
Sabon tasha	42.08[a] (13.86)	13.54 (4.65)	0.69 (0.61)	1.31 (1.31)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.38 (0.88)	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)	5
Ungwan romi	7.31 (5.62)	7.69 (3.69)	0.31 (0.31)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.15 (0.93)	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)	4
Kabala west	7.31 (5.06)	11.54 (6.90)	1.00 (1.00)	0.00 (0.00)	0.85 (0.85)	0.00 (0.00)	0.00 (0.00)	3.77 (3.77)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.15 (0.15)	6
Kurmin mashi	18.54[a] (9.41)	13.69 (5.16)	13.08[a] (7.37)	1.62 (1.62)	0.00 (0.00)	0.31 (0.31)	0.08 (0.08)	3.77 (3.30)	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)	7
Kawo	42.00 (14.12)	17.15 (5.77)	6.62 (5.02)	0.15 (0.15)	0.00 (0.00)	0.00 (0.00)	1.08 (1.00)	0.38 (0.31)	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)	6
Ungwan gwari	3.62 (2.16)	4.92 (3.10)	0.31 (0.24)	0.31 (0.31)	0.00 (0.00)	0.00 (0.00)	0.23 (0.23)	1.85 (1.39)	0.00 (0.00)	3.08 (2.99)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	7
G.R.A	16.62 (8.40)	9.92 (6.73)	2.46 (1.91)	0.92 (0.92)	4.85 (4.85)	0.00 (0.00)	0.54 (0.54)	1.08 (0.92)	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 (0.23)	8
Ungwan doka	8.31 (6.44)	2.00 (1.84)	1.31 (1.31)	0.54 (0.54)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	11.69 (9.80)	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)	5
Ungwan mu'azu	22.15 (10.98)	8.08 (4.24)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.08 (0.08)	4.23 (4.23)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.31 (0.31)	0.23 (0.23)	6
Kakuri	3.62 (1.73)	8.08 (4.23)	0.31 (0.24)	1.77 (1.77)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	7.69 (6.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.31 (0.31)	0.00 (0.00)	0.00 (0.00)	2.00 (1.69)	7
Tudun wada	24.08 (13.74)	6.31 (3.20)	7.15 (4.27)	0.00 (0.00)	0.00 (0.00)	0.62 (0.62)	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)	0.00 (0.00)	4
Ungwan rimi	17.31 (6.55)	5.23 (2.79)	1.39 (0.79)	023 (0.23)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.31 (0.24)	0.15 (0.15)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6

All numbers in parenthesis = ± standard error (± S.e). $P = 0.436$. ($P > 0.05$). .Figures with superscript [a] = Means are significantly different.
T.no. spp = Total number of species encountered in the settlement area.

4.4 Breeding habitats in Kaduna metropolis.

Only eight active breeding habitats were encountered. Productive habitats were: Concrete gutters, Pools/ponds, Road side potholes, Clay pots, Peri-domestic runoffs (PDRF), Metal containers Plastic containers and abandoned tyres, (Table 4.4). Tree holes were non-productive throughout the study period. The most important breeding habitats in both old and new settlement areas in Kaduna metropolis which harbored the total samples collected amounting to 90% of all the total catch were, concrete gutters (38.23%), pools/ponds (29.92%) and Peri-domestic runoffs (PDRF) (22.84%) respectively, (Fig.4.3).

Breeding activity in Concrete gutters, Pools/pond and Peridomestic run-offs (PDRF) was observed in all settlements of Kaduna metropolis sampled. The only exception was at Malali and Ung./Doka where breeding activity were not observed in Concrete gutters and Peridomestic run-offs(PDRF) respectively. An overview of Table (4.4) shows that there was much breeding activities in the eight various habitats in the old settlement areas than the new settlement areas of the metropolis. Breeding activity was not observed in Clay pots, Metal containers and Plastic container habitats at the new settlement areas. While in the old settlement this was not the case. Breeding in Metal containers was only positive at Kakuri (old settlement area) and had the least total percentage breeding of 0.59% (Fig.4.3).

Also, breeding in abandoned tyres were encountered in all settlements except Kabala Doki (n.s), Ung./Romi (n.s), Kakuri (o.s) and Ung./Doka (o.s).(Table 4.4). It was observed that breeding was positive in seven of the eight identified breeding habitats in all the Old settlement areas; these were G.R.A and Kakuri.

4.5 Association of *Culex, Aedes* and *Anopheles* mosquito with breeding habitats.

Breeding habitats and mosquito species observed in them are summarized in Table 4.5.

TABLE 4.4 NUMBER AND PERCENTAGE (%) OF MOSQUITO HABITATS ENCOUNTERED IN ALL SETTLEMENTS.

	New Settlements						
Habitats	**MAL.03***	**K/D.07**	**BAR.08**	**S/TA.09**	**U/ROM.10**	**K/W.13**	**K/MAS.15**
CONCRETE GUTTER	-	62(12.63)	298(49.11)	369(48.11)	86(40.17)	236(73.75)	216(32.53)
POOL/POND	375(67.69)+	332(67.62)	249(41.71)	122(15.91)	83(38.79)	2(0.63)	76(11.45)
PDRF	133(24.00)	97(19.76)	19(3.18)	259(33.77)	45(21.03)	71(22.190	347(52.25)
CLAY POT	-						
METAL CONTAINER	-						
ABANDONED TYRES	17(3.07)	-	31(5.19)	17(2.22)		5(1.56)	25(3.77)
PLASTIC CONTAINER	-						
ROADSIDE POTHOLE	29(5.23)	-	-	-	-	6(1.88)	
Mean no.	**46.17**	**61.38**	**59.79**	**54.79**	**35.67**	**64.00**	**55.33**

TABLE 4.4. Cont'd

	Old Settlements								
Habitats	**KAW.02**	**U/GW.01**	**G.R.A05**	**U/DO.06**	**U/MU'.12**	**KAK.11**	**T/WA.14**	**U/RI.04**	**TOTAL**
CONCRETE GUTTER	416(51.55)	35(19.20)	136(28.63)	142(45.81)	164(35.96)	57(18.21)	282(55.19)	174(53.05)	**2673**
POOL/POND	363(44.96)	62(33.70)	127(26.74)	127(40.97)	44(9.65)	39(12.46)	18(3.52)	73(22.26)	**2092**
PDRF	11(1.36)	31(16.85)	49(10.32)	-	188(41.23)	74(23.64)	203(39.73)	70(21.34)	**1597**
CLAY POT	2(0.25)		8(1.68)	41(13.23)		1(0.32)	-	8(2.44)	**60**
METAL CONTAINER	-	-	-	-	-	41(13.10)	-		**41**
ABANDONED TYRES	13(2.11)	56(30.43)	12(2.53)	-	4(0.88)	-	8.(1.57)	3(0.92)	**191**
PLASTIC CONTAINER	-	-	80(16.84)	-	1(0.22)	4(1.28)	-	-	**85**
ROADSIDE POTHOLE	2(0.25)		63(13.26)	-	55(12.06)	97(31.00)			**252**
Mean no.	**50.44**	**30.67**	**59.38**	**77.5**	**50.67**	**28.45**	**56.78**	**36.66**	**6,991**

+All figures in parenthesis = percentages (%) *All figures attached to names of settlements= designated serial numbers for the settlement.

Culex

Among the eight habitats presented above, Pool/pond and Abandoned tyres supported the highest number of nine sympatric species; Metal containers supported only three species namely; *Culex pipiens molestus* (07.32%), *Cx. decens* (36.56%) and *Aedes aegypti* (56.10%); (Table 4.5): *Cx. p. molestus* (47.30%) is the only mosquito species that was encountered in all eight breeding habitats. *Cx. decens* (12.42%) a swampy breeding species was encountered in all habitats except Plastic containers and Roadside potholes. (Table 4.5) *Cx. p. quinquefasciatus* (26.26%) that is an urban mosquito was encountered in all habitats except Clay pots, Metal containers and Roadside potholes.

Aedes

The three *Aedine* mosquitos encountered (*Aedes aegypti* [1.97%], *Ae. vittatus* [1.47%] and *Ae. simpsoni* [0.17%]) were observed breeding in only four habitats; these are Clay pots, Metal containers, Abandoned tyres and Roadside pothole. (Table 4.5)

Anopheles

The only record of *Anopheles specimens* (0.06%) observed was at Kakuri (11,old settlement) were larvae of the species bred in a plastic container.

Other mosquito species encountered that bred only in one habitat were*; Aedes simpsoni* (0.17%) and *Culex nebulosus* (0.06%) in tyres; *Cx. horridus* (1.64%) and *Cx. macfei* (0.03%) in PDRF. Three species were observed breeding in only two habitats each; *Ae. vittatus* in Abandoned tyre and Plastic container, while *Cx. univittatus* (0.49%) in Concrete gutter and Pool/pond and *Cx. musarum* (0.57%) in Abandoned tyres and Pond / pool.

TABLE 4.5 BREEDING SITES AND NUMBER (%) OF MOSQUUITO SPECIES

Habitat	C.pq	C.pm	C.pp	C.de	A.ae	A.vi	A.si	C.tg	C.un
Concrete Gutter	733(27.42)	1604(60.00)	250(9.35)	78(2.92)	-	-	-	5(0.19)	3(0.11)
Pool/Pond	546(26.10)	770(36.81)	73(3.49)	604(28.87)	-	-	-	1(0.05)	31(1.48)
PDRF	605(37.88)	825(51.66)	130(8.14)	34(2.13)				1(0.06)	-
Clay pot	-	10(16.67)	-	26(43.33)	17(28.33)	-	-	7(11.67)	-
Metal container	-	3(7.32)	-	15(36.56)	23(56.10)	-	-	-	-
Abandoned Tyre	6(3.14)	13(10.81)	-	4(2.09)	92(48.17)	5(2.62)	12(6.28)	16(8.38)	
Plastic container	9(10.59)	68(80.00)	3(3.53)	-	-	-	-	1(1.18)	-
Roadside pot holes	-	14(5.56)	-	134(53.17)	6(2.38)	98(38.89)	-	-	-
Total & (%)	**1836(26.26)**	**3307(47.30)**	**456(6.52)**	**868(12.42)**	**138(1.97)**	**103(1.47)**	**12(0.17)**	**31(0.44)**	**34(0.49)**

TABLE 4.5 CONT'D

Habitat	C.mu	C.ho	C.ne	C.du	C.ma	An sp	Total	T.no.Spp
Concrete Gutter	-	-	-	-	-	-	**2673**	6
Pool/Pond	1(0.05)	115(5.50)	-	-	41(1.96)	-	**2092**	9
PDFR	-	-	-	2(0.13)	-	-	**1597**	6
Clay pot	-	-	-		-	-	**60**	4
Metal container	-	-	-		-	-	**41**	3
Abandoned Tyres	39(20.45)	-	4(2.09)	-	-	-	**191**	9
Plastic container	-	-	-	-	-	4(4.71)	**85**	5
Roadside pot Holes	-	-	-	-	-	-	**252**	4
Total & (%)	**40(0.57)**	**115(1.64)**	**4(0.06)**	**2(0.03)**	**41(0.59)**	**4(0.06)**	**6,991**	**15**

All numbers in parenthesis = percentages (%)

T.no. spp. = Total number of species

Sympatric species.

Generally, *Culex pipiens molestus, Cx. p. quinquefasciatus* and *Cx. p. pipiens* were found breeding together in the ratio of approximately 2:4:0.5 in Concrete gutters, Pond/pool and PDRF. In some habitats, especially Clay pot, Metal containers, Roadside potholes and Abandoned tyres, only *Culex .p. molestus* was found breeding. Sympatry was encountered in Clay pot at old settlement area 6 (Ung. Doka) between *Cx. decens* and *Ae. aegypti* ; *Ae. aegypti, Ae. vittatus* and *Ae. simpsoni* were found breeding together in an abandoned tyre habitat at settlement areas Ung. Gwari (o.s), Barnawa (n.s) and Kurmin Mashi (n.s). There was another sympatric association among *Cx. p. molestus, Cx. p. quinquefasciatus and Ae. aegypti* in an abandoned tyre habitat located at old settlement area 1 (Ung. Gwari). The only breeding in metal container was noted when *Cx. p. molestus, Cx. decens* and *Ae. aegypti* were found together at Kakuri (11 old settlement).

Culex tigripes, a well-known predator of several species of larvae was observed breeding with either *Culex pipiens* complex in concrete gutters pools/ponds, PDRF and Clay pot, or with *Aedes aegypti* in abandoned tyre habitat. In a Plastic container, a sole specimen of *Culex tigripes* was observed to be breeding amidst numerous mosquito larvae carcasses at settlement 12 (Ungwan Mu'azu).

CHAPTER 5

Discussion

This study has revealed 15 mosquito species in Kaduna Metropolis, with large populations of *Culex species*; relatively small populations of *Aedes species* and a few Anopheline specimens. Members of the genus *Culex* therefore feature quite prominently in this discussion. For this reason, it is important to restate that *Culex pipiens* complex (*Culex .p. molestus, Cx. p. quinquefasciatus* and *Cx. p. pipiens*) and *Cx. decens* were the dominant species in the metropolis and made up 95% of the total collection.

Of these species, *Cx. p. molestus*, *Cx. p. pipiens* and *Cx. musarum* are documented for the first time from Kaduna metropolis. With the exception of the sudden emergence of *Cx. p. molestus* as the dominant species in the metropolis, the present result agrees generally with what is known from earlier studies in the vicinity of Kaduna metropolis or else where. For example Gadzama (1977) reported *Cx. p. fatigans* (Synonymous *Cx. p. quinquefasciatus*) as the abundant species in the main campus area of Ahmadu Bello University while Anyanwu *et al.*, (1999) published similar findings (55.20%) *Cx .p. quinquefasciatus* for the Zaria area. In Edo state, Okogun *et al.,* (2005) reported that the place where these two species breed are generally man made; example, concrete gutters that are usually polluted. It has been reported by many workers that the association of *Cx .p. quinquefasciaus* with pollution dates back to the 1950s when organochlorine insecticides were used in the tropics in the control of insects of medical importance. *Cx. p. quinquefasciatus* showed tolerance to these insecticides and this led to the rapid establishment and spread of this species to polluted breeding places in urban cities (Service, 1966 and Subra, 1980).

In Kaduna metropolis therefore, urbanization (in both new & old settlements areas) and the water contamination associated with it are principal factors responsible for the large year-round populations of *Cx .p. quinquefasciatus* and *Cx. p. molestus* in the city. What remains to

be explained is the dominance in the density of *Cx. p. molestus* over *Cx. p quinquefasciatus* in the town during the present investigation. The phenomenon where a mosquito species replaces another has been reported for several localities in Nigeria: In the 1950s, in Kaduna state Service, (1966) reported the replacement of *Cx. nebulosus* by *Cx. p quinquefasciatus*; However, it is more likely that since both *Cx. p. molestus* and *Cx. p. quinquefasciatus* are closely related, each is endowed with the genetic constitution to exist in the polluted waters of Kaduna metropolis. When mosquito species abundance was considered between the old and new settlement areas, there was no significant difference ($P>0.05$), because virtually all mosquito species were represented in both the old and new settlement areas; though the former had four mosquito species that were not represented in the latter, while the latter had two species that were not encountered in the former settlement areas.

The remaining *Culex species* found in this investigation, *Culex horridus* and *Cx. macfei* are of interest because they were found exclusively in the new settlement areas of Kaduna metropolis. Hanney, (1960) reported that these species were found breeding in tree holes in outskirts of Kaduna area. In the present investigation, the same species were collected from concrete gutter and pool/pond. Sampling of all likely tree hole habitats (phytotelmata) in all the settlements (both old & new) was conducted and none was positive for mosquito species breeding. The present findings therefore add weight to the generalization that some mosquito species are ecologically plastic. It is in this connection that *Cx. decens*, a swampy breeding mosquito species (Hopkins, 1952) was found within Savannah Zone of Kaduna metropolis can be explained. Man-made swamps where observed in almost all the settlements in Kaduna metropolis due to the network of small streams or rivulets provided by River Kaduna; farmers make use of such water bodies for dry season farming consequently, patches of swamps are sustained in which *Cx. decens* breeds. Though analysis shows that there was significant difference noticed among habitats ($P<0.05$) in all the settlements

Aedes aegypti was more regularly encountered compared to the two other Aedine species (Table 4.2) that feature in this investigation. The common habitats for all three Aedine mosquitos were man-made as already presented in the results. Similar observations have been reported by Service, (1980). The months of August and September revealed the three Aedine mosquito species encountered during this study. It is normal for these species to breed even in dry months (Service, 1980). The biology of *Aedes species* shows that breeding occurs in man-made containers including tree holes, which are susceptible to drying out. *Aedes* eggs are capable of withstanding desiccation. It must be added that because of the ability of Aedine eggs to withstand desiccation, other workers have reported breeding of *Aedes species* in the driest months of the year as reported by Ideozu, (1987) for some of the *Aedes* mosquito of Zaria. It is also important to note that *Ae. aegypti* is a confirmed vector of yellow fever; WHO, (1997) and its presence in Kaduna metropolis is therefore of socio-medical importance.

From specimens of *Anopheles* encountered in Kaduna metropolis, members of the genus were confined to four specimens at Kakuri; (old settlement). Species identity of these specimens could not be ascertained. The scarcity of *Anopheles* can be attributed to lack of appropriate breeding grounds. Whereas *Anopheles species* are known to breed mostly in clean waters devoid of pollutants, (Service, 1980); the breeding grounds observed during the present investigation were foul, stagnant, dirty bodies of water presumably unsuitable for supporting larvae of the species. In the present investigation, the record of *Anopheles* at Kakuri merely presents a clue to established situations regarding the presence of malaria vectors in Kaduna metropolis. The most up to date information on records of vectors of malaria such as *Anopheles gambiae* and *An. arabiensis* have been known for more than four decades ago; (Service, 1970; White and Rosen 1973; Rishikesh *et al.,* 1985) for both the city and some villages on its outskirts. So there are grounds that the mosquito fauna of the city includes vectors of malaria.

Considering the socio-economic importance of Kaduna metropolis, it is noted that the roles of *Anopheles* in malaria transmission and that of *Aedes aegypti* in yellow fever transmission are well known (as highlighted above); what is yet to be fully established is the role of *Anopheles species* and *Cx. p. quinquefasciatus* or *Cx. p. molestus* in the transmission of filariasis (*Wuchereria bancrofti*) in the study area. It is already known that *Cx. p. quinquefasciatus* transmits filariasis in many countries of the tropics such as in India; Roa *et al.*, (1981) and more recently, *Anopheles gambiae* s.l in central Nigeria; Richards *et al.*, (2005)*;* Lenhart *et al.*, (2007) for example. In Nigeria, research at university of Jos by Anosike & Onwurili, (1992) with laboratory derived females of *Cx .p. quinquefasciatus* and *Ae. aegypti* revealed that when 120 of each were infected experimentally with *W. bancrofti* parasite, 50 (41.67%) of *Cx. p. quinquefasciatus* harbored and developed *Wuchereria* larvae to the L3 infection stage; while on the other hand *Ae. aegypti* 34 (28.33%) harbored *Wuchereria* larvae L1 pre-infection stage but could not develop to L3 infection stage. The results suggest that *Cx. p. quinquefasciatus* could be actively involved in the transmission of urban bancroftian filariasis in Nigeria, particularly in centers like Kaduna metropolis with large populations of the species throughout the year. In this connection, the role of *Cx .p. molestus*, a close relative of *Cx .p. quinquefasciatus* has not been explored but it is quite possible that this species too might be involved in filarial transmission.

Conclusion

This study has documented 15 mosquito larval species that were encountered (November 2004 – November 2005) within 15 out of about 24 settlements areas in Kaduna metropolis; *Culex pipiens quinquefasciatus*[26.26%], *Cx .p .molestus*[47.30%], *Cx. p. pipiens*[6.52%] and *Cx. decens*[12.42%] were the most abundant mosquito species in Kaduna metropolis due to rapid urbanization and human activities, thus creating conducive habitats. The present findings agree with reports by (Service, 1966; Anyanwu *et al*., 1999; Omale 2005) in and around the study area concurred with the findings that *Culicines* were the most abundant mosquito species, constituting 92.50%. It can be deduced that no species was lost, rather environmental condition that guaranteed habitats or unconducive habitats for some species have been enhanced. Studies by Hanney (1960) and Service (1963) in Zaria province documented all 15 mosquito species encountered except *Cx. p. pipiens, Cx . p. molestus* and *Cx. musarum*. Studies by Omale, (2005); Okogun *et al*., (2005) and Ehindero, (2006) revealed the presence of *Culex pipiens pipiens* and *Cx. p. molestus*. No new mosquito species had invaded or emerged over these years; except for the fact that rapid urbanization and human activities have increased the chances and abundance of conducive habitats or breeding sites of mosquito species especially *Cx. p. quinquefasciatus*.

The major habitats positive for mosquito species breeding are; concrete gutters, Peridomestic run offs (PDRF) pools/ponds and abandoned tyres respectively. Months of mosquito abundance were March and October. It has already been established that the rainy seasons provides available breeding habitats for mosquito species.

This study was conducted due to paucity of knowledge about the mosquito species abundance and breeding sites in Kaduna metropolis; also so that control measures may be put in place. This is in line with the Roll back Malaria (RBM) initiatives 2000.

Recommendations

This study was conducted due to paucity of information about the mosquito species and their abundance in Kaduna metropolis. The study was concluded with the following recommendations:

1. *Culex pipiens* complex were the most abundant mosquito species encountered in Kaduna metropolis, thus the need for new or improved control measures be put in place to curb their menaces, nuisance or biting effects upon the inhabitants of Kaduna metropolis.
2. One of the many challenging problems facing cities undergoing rapid urbanization is environmental management especially the aspect of waste management, water channels and sewage disposal; thus, environmental sanitation which includes clearing all standing water/stagnant pools and concrete gutters should be encouraged to reduce the high breeding rates of these mosquito species encountered, especially *Culex pipiens quinquefasciatus*.
3. Further studies in Kaduna metropolis in this particular field of research is necessary and therefore should continue due to the epidemiological importance of the mosquito species encountered during this study.

REFERENCES

Amusan, A.S., Adeleke, M.A and Soniran, O.D (2005): The effect of colour on oviposition of container breeding mosquitoes in Abeukuta, Ogun state Nigeria. A paper presented at the 36th Annual Conference of Entomological society of Nigeria. Book of Abstracts ESN/36/27 page 27:

Amusan, A.S., Mafiana, C.F., Idowu, A.B and Olatunde, G.O (2004): Mosquito species breeding in ground pools and artificial containers in Ajana, Ogun state, Nigeria. *Nigeria Journal of Entomology* (2004) 21:11- 21

Anonymous (2007): National Population Commission (NPC): Legal Notice on Population Details, 2006 CENSUS. Federal Republic of Nigeria Official Gazette No.24 printed; FGP71/52007/2,500(OL24).

Anonymous (2000): Nigeria Medical Association (NMA) makes a case For free treatment of Malaria; New Nigeria Newspaper Ltd. P.O Box 254 Kaduna July 31st 2000.pp 15

Anosike, J.C and Onwuliri, C.O (1992): Experimental *Wuchereria bancrofti* Infection of *Culex Pipiens quinquefasciatus* and *Aedes aegypti*. Angew (Germany) 33; (3) 139 -142.

Anyanwu, I.N., Agbede, R.I.S., Ajanusi, O.J and Umuh, J.U (1999):A Survey of Culicids (Mosquitoes) in a Northern Guinea Savannah town of Zaria, Kaduna State. *The Nigeria Journal of Parasitology*, Vol.20 pp.137-148

Atere, P Mekamagba (1991): An Analysis of the Internal Structure of Kaduna Metropolis. Unpublished PhD. Thesis Geography Departmental Library, A.B.U Zaria.

Awolola, T.S., Brooke, B.D., Hunt, R.H and Coetzee, M. (2002): Resistance of the malaria vector *Anopheles gambiae s.s* to pyrethroid insecticide in South –western Nigeria. *Annals of Tropical Medicine and Parasitology*.

Bang, Y.H., Sabuni, I.B and Tonn, R.J (1975): Integrated control of urban mosquitoes in Dar-es-Salam, using sanitation supplemented by Larviciding. *East Africa Medical Journal;* 52 pp 578-588

Bates, M (1949): The Natural History of Mosquitoes. Macmillan Co. New York 379 pp

Brodgon, W.G and Mc Allister, J.C (1998): Insecticide resistance and vector control. Emerging Infectious Diseases: 4; 605- 613.

Brown, A.W. and Pal, R. (1971): Insecticide Resistance in Arthropods. World Health Organization Monographs Series 38 WHO Geneva.

Bruce-chwatt (1949): Studies on Insect Vectors of Yellow Fever and Malaria in British West Africa. Proceeding of 3rd International West Africa Conference. 144 pp 27-39

Chandre, F., Darriet, F., Mango L., Akogbeto, M., Faye, O., Mahet, J and Guillet, P (1999): Status of Pyrethroid Resistance in *Anopheles gambiae s.l.* *Bulletin of World Health Organization*, 77, 230-234.

Chang, T.T., Chang, T., Chen, C.C., Young, K.C., Roan, J., Lee, Y., Cheng, P.N and Wu, H.L (2001): Existence of Hepatitis C virus in *Culex quinquefasciatus* after ingestion of infected blood: Experimental approach to evaluating transmission by Mosquitoes. *Journal of Clinical Microbiology* Sept. 2001 Vol. 39 No. 3 Page 3353-3355.

Climate Change (2001): Impacts, Adaptation and vulnerability. Http:// www.grida /no/climate /ippc tar / wg//360.htm

Collins, E. L. and Black well, A. (2000): The Biology of Toxorhynchites Mosquitoes and Their Potential as Biocontrol Agents. *Biocontrol News and Information., vol. 21: No.4, 105n-116N.*

Di Deco M. A, Rishikesh. N, Petrarca V., Coluzzi M. (1981): Variazioni Stagionali in *An. arabiensis* a Kaduna, Nigeria. *Parasitologia 23, 169-172.*

Ehindero, R. (2006): Observation on Mosquito Breeding in Discarded Automobile tyres in Kaduna metropolis. An unpublished B.Sc thesis in the Library of Department of Biological Sciences Ahmadu Bello University, Zaria.

Gadzama N.M (1977): The distribution of population of adult mosquito At Ahmadu Bello University, Zaria, Nigeria, *Savannah Vol 6 No.2 page 179- 189.*

Gazetta, (1965): Federal Republic of Nigeria; Northern Nigeria. Published by Directorate of survey Lagos page 86.

Gillies, M.T and Coetzee, M (1987): A Supplement to the Anophelinae of Africa south of the Sahara Research. Johannesburg no 55, pp 1-119.

Gillet, J.D (1971): Common Africa Mosquitoes and Their Medical Importance with color illustration. William Heinemann medical books Ltd London pp 1-106

Hanney, P.W (1960): The Mosquitoes of Zaria Province Northern Nigeria. *Bulletin of Entomological Research* 51, pp 145 –171

Hopkins, G.H.E (1952): Mosquitoes of the Ethiopian region. Larval Bionomics of Mosquitoes and Taxonomy of *Culicines* Larva, 2nd edition, British Museum London 355pp.

Ideozu, E. (1987): A study of The Relative Abundance of Different Species of Adult Mosquitoes in Samaru, Kaduna State. An Unpublished MSc Thesis in the Library of Department of Biological Sciences Ahmadu Bello University Zaria.

Joana, R.M., Armstrong, S., Salim, A., Rose, N., Oscar, M., Tanya, J.M., Nasser, K., Adeel, K.M., Haji, M.,Hassan, M., Marcel, T. and Christian, L (2001) Effect of Large scale social Marketing of Insecticide Treated Net on Child Survival in Rural Tanzania. *The Lancet*, 357., 1241-1247.

Johnson, K.M (1979): Arthropod – Borne Viral Encephalitis in Becton Mc Dermott wyndgarrden (eds) Cecil textbook of Medicine. Sanders coy London pp. 279- 292.

Kristina Luno –berg (2002): An Environmental Impact Assessment Model for Malaria Control in Developing Countries (A Thesis for the degree of Masters in Biology).

Lenhart Audrey, Eigege .A, Kal. A, Pam. D, Miri. E. S, Gerlong. G, Onyeka. J, Danboyi. J, Ibrahim. B, Dahl. E, Kumbak. D, Dakul. A, Jinadu. M Y, Umaru. J, Richards. F O and Lehmann. T. (2007): Contributions Of Different Mosquito Species to the Transmission of Lymphatic Filariasis in Central Nigeria: Implications For Monitoring Infection by PCR in Mosquito Pools. pp 1-6. http://www.filariajournal.com/content/6/1/14.

Lindsay, S.W., and Marten, W.Y.M (1998) Epidemiology and control: Issues related to Malaria in Pregnancy. *Annals of Tropical Medicine and Parasitology;* 93 supplement; 19 pp 511 -517.

Lindsay, S.W., Parson, L and Thomas, C.J. (1998): Mapping The Ranges and Relative Abundance of the two Principal African Malaria Vectors, *Anopheles gambiae s.s* and *Anopheles arabiensis*, Using climate data. *Proceedings of the Royal society of London*. 256; 847- 854.

Logan, T.M., Linticum, K.J., Thande, P.C., Wagateh, J.N. AND Roberts, C.R (1991): Mosquito Species collected from a marsh in Western Kenya during the long rains. *Journal of American Mosquito Control Association* 7, 3: 395-399

Malaria Unit, (1976) Records of National Malaria Control Unit Kaduna; Federal Ministry of Health. Malaria Control Unit, Ministry of Health Kaduna, Northern Region, Nigeria.

Martinez–torres, D., Chandre, F and Williamson, M.S. (1998): Molecular Characterization of Pyrethroid Knock down residence (Kdr) in the Major Malaria Vector, *Anopheles gambiae s.s*. Insect Molecular Biology 7; 179 –184

.

Ndams, I.S. (2004): Morphological and Molecular Characterization Of *Anopheles* Species and Infection By *Plasmodium* Species in Parts of Kaduna and Benue States, Nigeria. PhD Thesis. Department of Biological Sciences Ahmadu Bello University Zaria, Nigeria.Pp.132.

NNN; (2005) Malaria is a big Threat …. Lambo Warns. New Nigerian Newspaper, Tuesday April 26th 2005 page one.

Omale, D.U (2005): Studies on Mosquito (Diptera: Culicidae) Breeding in Wells, in Villages in Zaria. An unpublished B.Sc thesis in the Library of Department of Biological Sciences, Ahmadu Bello University Zaria.

Okogun, G.R..A., Nwoke, B.E.B., Anosike, J.C., Okere, A.N and Esekhegbe, C.A.(2003): Epidemiological Implications of Preferences of Breeding Sites of Mosquito Species in Midwestern Nigeria. *Annual Agricultural Environmental Med*.10.217- 222.

Okogun, G.R.A., Anosike, J.C., Okere, A.N and Nwoke, B.E.B (2005): Ecology of Mosquitoes of Midwestern Nigeria. *Journal of Vector Borne Diseases.* 42., Page 1 – 8.

Roa C.K., Sundarm, R.M., Venkatanarayane M., Rao S.J and Chanderasekhren.(1981): Epidemiological studies of Bancroftian filariasis in East Godawari District (Andhar Paradesh, India.). Entomological Aspects. *Journal of Community Disease,* 13:81

R.B.M (2000) Roll Back Malaria (RBM) Minutes of Meeting Held on 25th April 2000. During the African Malaria Day. RBM website.

Richards, F.O., Pam, D.D., Kal, A., Gerlong, G.Y., Onyeka, J., Sambo, Y., Danboyi, J., Ibrahim, B., Terranella, A., Kumbak, D., Dakul, A., Lenhart, A., Rakers, L., Umaru, J., Amadiegwu, S., Withers, P.C., Mafuyai, H., Jinadu, M.Y., Miri, E.S. and Eigege, A: (2005). Significant Decrease in The Prevalence Of *Wuchereria bancrofti* Infection in Anopheline Mosquitoes Following The Addition Of Albendazole To Annual Ivermectin-based Mass Treatment in Nigeria. *Annals Of Tropical Medicine and Parasitology,* Vol. 99, No.2, 155-164.

Rishikesh N., Di Deco M. A., Petrataca V and Coluzzi, M. (1985): Seasonal Variations in Indoor Resting *Anopheles gambiae* and *Anopheles arabiensis* in Kaduna, Nigeria. *Acta Tropica* 42, 165 – 170 .

Service, M.W (1963) Ecology of Mosquitoes of Northern Guinea Savannah of Nigeria. *Bulletin of Entomological Research* 54; 601 – 632.

Service, M.W (1966): The Replacement of *Culex nebulosus* (Theo) By *Culex pipiens fatigans* Wied (*Diptera culicidae*) in Towns in Nigeria. *Bulletin of Entomological Research.* 58., 407 – 415.

Service, M.W (1970): Identification of the *Anopheles gambiae* Complex in Nigeria by Larval And Adult Chromosomes. *Annals of Tropical and Medical Parasitology.* 64., 131 – 136.

Service, M.W (1974): Survey of the Relative Prevalence of Potential Yellow Fever Vectors in North West Nigeria. *Bulletin of World Health Oragnization*. 54., 487 – 494.

Service, M.W (1976): Mosquito Ecology: Field Sampling Methods. Applied Science Publishers Ltd. London pp 583.

Service, M.W (1980) A guide to Medical Entomology Macmillan Tropical and sub-Tropical Medical Text. Macmillan press Ltd 266 pp.

Service, M.W (1993): Mosquitoes (Culicidae) in: R.P. Lane and R.W. Cross Key (eds) Medical insects and Arachnids pp. 120 – 240 Chapman and Hall, London.

Shaman, J. and Day, F.J. (2005): Achieving Operational Hydrologic Monitoring of Mosquito Borne Disease, Emerging Infections Diseases, vol. 11 No. 9; Sept, 2005.

Shanks, G.O., Hay, S.I., Stern, D.I., Biomndo, K. And Snow, R.W (2002) Meteorological Influences on *Plasmodium Falciparum* Malaria in the High Land Tea Estates of Kerioch, Western Kenya. Emerging infectious Diseases. Vol. 8; 1044 – 1408.

Sow, G. J., Ndams, I. S., Vajime, G. C., Kogi, E. and Tukur, Z. (2008): Distribution and Susceptibility of *Anopheles* Mosquitoes to Permethrin Insecticide in Some Selected Localities Within Southern Guinea Savannah Zone of Kaduna State, Nigeria.

Smith, K.G.V (1980): Insect and Other Arthropods of medical importance: K.G.V Smith (ed) British Museum of Natural History London. 561 pp.

Subra, R.(1980): Biology and Control of *Culex quinquefasciatus* Say; 1823 With special reference to Africa. WHO/ VBC. 80- 781

Surtees, G. (1959): On The Distribution and Seasonal Incidence of Culicine Mosquitoes in Southern Nigeria. *Proceedings of the Entomological Society of London* (A) 34; 110-120.

Tom, Floore (2004): Mosquito Information: Public Health Entomology Research and Education centre. Florida Agricultural and Mechanical University.

Vinogradova, B. Elena (1997): *Culex pipiens* Mosquitoes: Taxonomy, Distribution, Ecology, Physiology, Genetics, Applied importance and Control.Pensoft.Pp1-14;79 – 107

White G.B and Rosen P. (1973). Comparative studies on sibling species Of the *Anopheles gambiae* Giles complex (Dipt; Culicidae) II Ecology of species A and B in Savannah Around Kaduna Nigeria, during transition from wet to dry Season. *Bulletin of Entomological Research* 62,613-625

World Health Organization, (1967): Seminar on the Ecology, Biology, control and Eradication of *Aedes aegypti*. *Bulletin of World Health Organization*, Vol, 36,pg. 519-702.

World Health Organization, (1972): Technical Report Series on "Vector Ecology" number 507; pp17-21, Geneva.

World Health Organization, (1982): Manual on Environmental Management for Mosquito Control, with Special Emphasis on Malaria vectors. *WHO offset publication* No.66. Geneva.

World Health Organization (1980): Environmental Management for Vector Control 4th Report of *W.H.O.Technical Report series*, No. 649 pp. 14-35,Geneva.

World Health Organization (1988): Urban vector and pest control 11th report of the WHO Expert committee on Vector Biology and Control, Geneva. 767: 1-77pp.

World Health Organization, (1992): Vector Resistance to Insecticide; 15th Report of the WHO Expect Committee on Vector Biology and Control, Geneva. 818, 1-62pp.

World Health Organization, (1993): Implementation of the Global Malaria Control Strategy. *Technical Report Series*, Geneva. 839., 1-3 pp.

World Health Organization, (1995): Vector Control for Malaria and other Mosquito Borne Diseases. *Technical Report Series* Geneva. 857; 97 pp.

World Health Organization, (2000): WHO Expert Committee on Malaria. 20th Report *Technical Report Series*, Geneva. 892; 1-70 pp.

World Health Organization, (2003): Comparative Performances, Under Laboratory Conditions of Seven Pyrethroid Insecticides Used for Impregnation of Mosquito Bed Nets. *Bulletin of World Health Organization.* 81; 324-333