

Biodiversity of Mosquitoes (Diptera: Culicidae) from Khyber Pakhtunkhwa, Pakistan



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Biodiversity of Mosquitoes (Diptera: Culicidae) from Khyber Pakhtunkhwa, Pakistan



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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

IN THE NAME OF ALLAH

THE MOST BENEFICENT

THE MOST MERCIFUL

Dedicated

*With profound love & deep respect
this dissertation is dedicated to my*

Parents and

my honorable supervisor

Dr Naveeda Akhtar Zureshi.

CERTIFICATE

This is certified that thesis entitled “**Biodiversity of Mosquitoes (Diptera: Culicidae) from Khyber Pakhtunkhwa, Pakistan**” submitted by Negah Aslam, is accepted in its present form by the Department of Zoology, Faculty of Biological Sciences, Quaid-i-Azam University, Islamabad as satisfying the thesis requirement for the degree of Master of Philosophy in Parasitology.

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Date:

Declaration

I hereby declare that the work presented in the following thesis is my own effort, except where otherwise acknowledged, and that the thesis is my own composition. No part of this thesis has been previously presented for any other degree.

Negah Aslam

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List of Abbreviation

LF	Lymphatic filariasis
WNV	West Nile virus
MDA	Mass drug administration
NTDs	Neglected tropical diseases
RVF	Rift valley fever
RVFV	Rift valley fever virus
WHO	World Health Organization
JEV	Japanese encephalitis virus
LLINs	Long-lasting insecticidal nets
IRS	Indoor residual sprays
ITN	Insecticidal treated nets

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ABSTRACT

Mosquito belongs to the class Insecta, order Diptera and family Culicidae. There are about 3500 species of mosquitoes present worldwide. Obligatory blood feeding insects like mosquitoes have significant impact on humans as well as on animal health, as they are responsible for the transmission of vector borne diseases. *Anopheles*, *Aedes* and *Culex* species are of much importance as they are involved in transmission of deadly diseases such as malaria, dengue fever, yellow fever, rift valley fever, Japanese encephalitis, West Nile virus and lymphatic filariasis. Besides, they play an important role in food chain and also in pollination. As mosquitoes are the medically important insects, the present research aimed to study the biodiversity of mosquito species in different Districts of Khyber Pakhtunkhwa, Pakistan.

Samples were collected from indoor places as well as outdoor places like parks, animal sheds, woodlands, and standing water using insecticidal sprays, hand nets, light snares etc. Specimens were observed and photographed using stereomicroscope and measurements were taken using ocular scales and ImageJ software. Species were identified using different taxonomic keys. In the present study 18 species belonging to 3 genera viz *Anopheles*, *Culex* and *Armigeres* were identified from Bannu, Lakki Marwat, Waziristan, Karak, Peshawar, Mardan, Swabi, Swat, Lower Dir and Upper Dir Districts of Khyber Pakhtunkhwa. Relative abundance and distribution status was also observed. The species identified were *An. culicifacies* (5.5%), *An. annularis* (4.81%), *An. sinensis* (8.04%), *An. stephensi* (11.52%), *An. fluviatilis* (4.23%), *An. tessellatus* (2.28%), *An. subpictus* (3.89%), *An. aconitus* (1.01%), *Cx. quinquefasciatus* (16.93%), *Cx. tritaeniorhynchus* (14.23%), *Cx. bitaeniorhynchus* (3.73%), *Cx. gelidus* (3.47%), *Cx. fuscocephala* (5.08%), *Cx. vishnui* (7.87%), *Cx. pseudovishnui* (0.84%), *Cx. whitmorei* (0.93%), *Ar. obturbans* (3.47%), and *Ar. kuchingensis* (2.12%). The present and the former studies illustrates that the climatic factors along with urbanization are greatly influencing the mosquito fauna, so further entomological surveys of mosquitoes using different sampling techniques should be performed to understand the feeding, resting behaviors and transmission of disease.

INTRODUCTION

Mosquitoes belong to the class Insecta, order Diptera and family Culicidae. In Spanish, the word mosquito signifies “little fly”. The word Diptera signifies "two wings", the distinctive characters that separate flies from different creepy crawlies. The proboscis (rounded, prolonged and puncturing mouthparts) and hair-like scales on the assortment of mosquitoes are the characters that distinguish it from different kinds of flies. The males, and sometimes the female mosquitoes feed on the plant juices and nectar. However, the female mosquitoes of certain species feed on the blood to achieve the protein they needed for egg development (Börstler *et al.*, 2016).

The existence of the female mosquito is typically estimated in weeks or months while the male mosquitoes live just for seven days. Mosquitoes incubate from the eggs that are laid in dwellings and places that are loaded up with water. The worm-like hatchlings rise up out of the eggs and lie underneath the water's surface. The larvae feed on microscopic organisms like bacteria and breathe through tubes present on the abdominal end of their bodies (Benelli, 2016).

Obligatory blood-feeding insects such as the family Culicidae may have an important impact on humans as well as on animal health, as they are the major factors that transmit vector borne diseases. Their bites cause significant nuisance and irritation. (Wilke *et al.*, 2016). *Anopheles*, *Culex*, and *Aedes* genera are vital as they are responsible for the transmission of irresistible sicknesses like dengue fever, malaria, Japanese encephalitis, lymphatic filariasis, yellow fever and West Nile fever. (Ali and Rasheed, 2009).

1.1 Biological significance of mosquitoes

Mosquitoes have been on the planet Earth for more than 100 million years. Out of 3,500 types of mosquitoes, only few hundred species bite people and causing disease. They are found almost everywhere on the planet and perform important roles. Although they are beneficial for the ecosystem they also have adverse effects as they are responsible for the transmission of deadly diseases (Fang, 2010; Usman *et al.*, 2017).

Mosquitoes are known as the generalist pollinators as they are involved in pollination of some flowering plants while looking for the floral nectar (Britannica, 2020). Hatchlings of mosquitoes develop by overwhelming microorganisms and algae that deteriorate rotting plant material. These larvae contribute to the aquatic and

terrestrial food chains for many predators like fish and birds by serving as food sources. Adult mosquitoes are eaten by bats, winged animals, frogs, and different creepy crawlies. When these mosquitoes die (or are eaten and discharged), they deteriorate and transform the organisms that they consumed as hatchlings into supplements for plants, performing another environmental role (Daugherty and Juliano, 2003).

1.2 Global biodiversity and distribution pattern

The genus *Anopheles* has 460 species belonging to 7 subgenera. *Culex* genus has 763 species, which belong to 26 subgenera. The genus *Aedes* has 70 subgenera and 927 species. Most individuals from the family Culicidae are public health concern (Freitas *et al.*, 2015; Wilkerson *et al.*, 2015). In the family Culicidae, subfamily Anophelinae, class *Anopheles*, around 424 morphologically recognizable species have been recorded. Around 70 species out of 424 *Anopheles* are known to be associated with malaria parasite (WHO, 2007). Some members of the genus *Anopheles* are known to form a variety of complexes of cryptic species with uncertain taxonomic traits and hence when these cryptic species are also considered, the species number escalates up to 500. For arising vector control methodologies, species identification is one of the significant advances. However, the grouping of new *Anopheline* species and inner characterization of subfamily Anophelinae is basically founded on morphology (Chhilar, 2014).

From various regions, in 111 genera there are around 3532 species have been recorded up till now (Harbach, 2013). This family involves three subfamilies viz., Anophelinae (Anophelines), Culicinae (Culicines) and Toxorhynchitinae (Suhasini and Sammaiah, 2014). Mosquitoes live in various natural surroundings yet generally live in freshwater environments and play out a fundamental part in the evolved way of life. Variable types of mosquitoes have been accounted from different territories of the world. From Pakistan, 114 species were recorded, of which 89 species from East Pakistan (presently Bangladesh) (Ali *et al.*, 2013). Also, 91 species from West Pakistan, from India 22 species of *Culex*, *Aedes*, and *Anopheles*, from southern Israel 25 species, from Egypt 39 species, from Lombok Island 41 species and 29 species from Turkey were recorded.

43 *Anopheles* species and 252 *Culex* types of mosquitoes were depicted by Barraud and Christopher in the Indian subcontinent including 34 *Anopheles* species and

66 *Culex* species from Pakistan. From 1934 to 1971, one *Anopheles* specie and three *Culex* species were added to Pakistan's mosquito fauna (Aslamkhan, 1971). From Pakistan, 24 Anopheline (17 types of subgenus *cellia* and 7 types of subgenus *Anopheles*) were recorded. Suleman *et al.* recorded thirty mosquito species from Changa Manga Lahore, and portrayed *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, and *Aedes lineatopennis* as a significant source in the transmission of the West Nile Virus (Suleman *et al.*, 1993). 29 mosquito species were recorded for the first time from Lahore, Pakistan (Manzoor *et al.*, 2020). (Suleman *et al.*, 1993) detailed distinctive mosquito species from Peshawar valley and adjoining territories alongside their relative abundance. For the up-grading of Pakistan's mosquito fauna, a review of Murree hills was done to investigate mosquitoes. Murree hills are very rich in species variety and it falls in the Himalayan lower regions or sub-Himalayan tract, which is around at the rise of 2200 m over the ocean level (Qasim *et al.*, 2014).

Commonly found mosquito genera in Pakistan

1. *Anopheles*
2. *Aedes*
3. *Culex*
4. *Armigeres*

1.3 Genus *Anopheles*

The genus *Anopheles*, the only known carrier of malaria, and also transmits filariasis and encephalitis. *Anopheles* species can easily be perceived in their resting position, in which the body, head, and proboscis are held on a straight line to each other but at an angle to the surface. The spotted colouring on the wings results from coloured scales (Britannica, 2020). *Anopheles* are the large, dark brown mosquitoes. Their legs may be entirely dark or may have banded patterns. All *Anopheles* adults (both male and female) are characterized by an evenly rounded scutellum and have palpi as long as the proboscis but in males palpi are club-shaped (O'Malley, 1992). Depending on species, the proboscis may be entirely dark, or have a white patch of scales on the ventral surface towards the apex, or it may have an apical half of the proboscis with white scales (WHO, 2020). Mosquitoes usually lay eggs in water containing heavy vegetation. The female accumulate her eggs separately on the water surface. The larvae of *Anopheles* lie parallel to the water surface and breathe through posterior spiracular plates present

on the abdomen rather than through a tube, as do most other mosquito larvae. The life cycle is from 18 days to several weeks (Britannica, 2020).



Figure 1.1: Structure of *Anopheles* mosquito

<https://animaldifferences.com/difference-between-aedes-and-anopheles-mosquito/>

1.3.1 Medical importance of genus *Anopheles*

Anopheles is medically important in transmission of Malaria that is caused by the parasite of the genus *Plasmodium*. It is disseminated by the bite of blighted or diseased female *Anopheles* mosquito. Malaria is a high burden yet preventable disease (Mace *et al.*, 2018). Malaria remains the primary cause of morbidity and mortality around the world, but the quick diagnosis and fast-acting treatments intercept unwanted results. It is still prevalent in the WHO regions of South-East Asia, Africa, and the Eastern Mediterranean. Despite decreasing incidence since 2000, cases in 2015 were still an incredible 214 million with approximately 438,000 deaths (WHO, 2018).

Anopheles culicifacies and *Anopheles stephensi* are the two known vectors while others are suspected vectors in Pakistan (Herekar, 2020). From Pakistan, 1,000,000 cases were recorded in a year regardless of decreasing trends between 2010-2015 when 400,000 less malarial cases were yearly seen from earlier years. Malaria influenced roughly 219 million individuals causing 435,000 deaths in 2017 around the globe (WHO, 2018). It is the most widely recognized disease in certain countries of Asia and Africa with the largest number of local cases. The death pace of malaria goes from 0.3-2.2% universally, 11-30% of serious malarial cases are in areas with the tropical climate (Talapko *et al.*, 2019).

1.4 Genus *Aedes*

The *Aedes* species have narrow and ordinarily dark body having elite varieties of light and dark scales on thorax and abdomen, and sporadic dark and light bands on legs. Their maxillary palps are shorter than proboscis. *Aedes* mosquitoes naturally hold their bodies low and corresponding to the ground with the proboscis angled downward when landed (Rueda, 2004; Rogers and Kara, 2019).



Figure 1.2: Structure of *Aedes* mosquito

<https://www.vcstar.com/story/news/local/2020/10/01/aedes-mosquitoes-ventura-county-found-ventura-fillmore-thousand-oaks/5875240002/>

1.4.1 Medical importance of genus *Aedes*

The *Aedes* species i.e *Aedes aegypti* and *Aedes albopictus*, are the vectors chiefly responsible for the transmission of dengue fever and are also responsible for transmitting other viral diseases, such as zika fever, chikungunya, and yellow fever. In Pakistan, chikungunya virus infections were reported in 776 patients from 2016-2018. Vectors population is increasing in areas globally but it is not only the result of climate change. Other environmental factors like growing population, increasing agriculture, urbanization, and deforestation significantly and equally contribute to increasing population of mosquitoes. Despite this squabble, Pakistan has all the essentials that are mandatory for the increase in the number of infections transmitted by mosquitoes (Zareen, 2019).

Dengue causes spacious range of diseases. This may range from mild to severe flu-like symptoms in infected persons. People with severe dengue results in complications linked with organ impairment, severe bleeding and plasma leakage. If not controlled appropriately, severe dengue has a greater risk of death. In 1950's, severe

dengue was first perceived during dengue epidemics in the Thailand and Philippines (WHO, 2020).

Above 50% of the human population lives in dengue-endemic regions. About 50 to 200 million dengue cases with 500,000 extents of dengue hemorrhagic fever and more than 20,000 deaths are being reported every year around the world. The Ministry of National Health Services, Regulations and Coordination (MNHSR&C) of Pakistan recorded 52,485 dengue cases accompanying 91 deaths in 2019. The largest number of cases were reported from the Sindh (79%), and the remaining 20% of cases were reported from the regions of Punjab, Baluchistan, Khyber Pakhtunkhwa, Islamabad, and Azad Jammu & Kashmir (AJK). Within the Sindh, the large number of cases were reported from Karachi. There were about 147,200 cases of dengue infection, and more than 800 deaths were recorded from 1995-2019 (WHO, 2019).

1.5 Genus *Culex*

The most widespread mosquito species across the world are *Culex* species (Bhattacharya, 2016). *Culex* mosquito is responsible for disseminating West Nile virus. *Culex* are light brown in colour having whitish markings on the abdomen, and are medium-sized mosquitoes. They rest in day time and bite at dusk and after dark (WHO, 2020). They feed on both animals and humans that's why they are also known as opportunists. They are responsible for the spread of zoonotic diseases and are a great threat to the public health, (Weissenböck, 2010). *Culex* species have been adapted to the man-made habitats. The cardinal group of the genus *Culex* is *Culex pipiens* complex that consists of six members i.e *Cx. quinquefasciatus*, *Cx. australicus* Dobrotworsky & Drummond, *Cx. pallens* Coquillet, *Cx. pipiens* Linnaeus, *Cx. Globocoxitus* Dobrotworsky, and *Cx. molestus* Forskll, (Zittra, 2016).

Cx. quinquefasciatus is the predominant and widespread species of all types and unplanned urbanization contributes to the proliferation of these species. They can establish in all types of water collections consisting of temporary and permanent stagnant water bodies like septic tanks, drains, puddles, organically polluted sites, and wet pit latrines (Nchoutpouen *et al.*, 2019).



Figure 1.3: Structure of *Culex* mosquito

<https://www.infectioncontroltoday.com/view/does-recent-isolation-zika-virus-culex-mosquitoes-point-new-transmission-source>

1.5.1 Medical importance of genus *Culex*

Besides the annoyance that *Culex* species could persuade, they also spread diseases such as Rift valley fever, Japanese and Saint Louis encephalitis, lymphatic filariasis (LF), and West Nile Virus (Tsai *et al.*, 1989).

The lymphatic filariasis is caused by the parasite *Wuchereria bancrofti*, and is largely prevalent in sub-Saharan Africa and Asia. WHO has targeted LF for elimination by 2020 using mass drug administration (MDA) as LF is among the most debilitating and oldest neglected tropical diseases (NTDs). LF is mainly instigated by nematodes of the family Filariodidae. About 90% of the infections are instigated by *Wuchereria bancrofti* and the remaining 10% are instigated by *Brugia malayi* (WHO, 2010). Mosquito species are the major vectors for the transmission of LF. *Aedes* (in endemic islands of Pacific), *Anopheles* (in rural areas) and *Culex* (in urban and semi urban areas) are responsible for the transmission of *W. bancrofti* whereas numerous species of *Mansoni* genus are responsible for the transmission of *B. malayi*. *Culex* species chiefly *Cx. quinquefasciatus* is recognized to have an important effect on LF transmission (Derua *et al.*, 2017).

RVF, a viral infection that influence human beings, domestic and wild ruminants. Rift valley fever virus (RVFV) belongs to the genus Phlebovirus and family Bunyaviridae (Abdelgadir *et al.*, 2010). RVFV is transmitted through mosquito bites, and also by the close contact with viremic sap and tissues of diseased ruminants to the healthy humans or ruminants. RVFV has been separated from more than 53 species in

8 genera within the family Culicidae in areas where epizootics have transpired (Linthicum *et al.*, 2016).

Human cases are categorized by 'Dengue-like' ailment but in critical form, the ailment may lead to hemorrhagic fever, ocular disease, or encephalitis with substantial mortality rate. Animals like goats, sheep, and cattle are mostly affected. In pregnant females, RVF causes abortions (90- 100%) and elevate mortality rate in newborns (Anyamba *et al.*, 2010). The earlier studies shows that the only operational method to intrude RVF and RVFV transmission to animals is to move animals to high elevations away from flooded regions that nurture mosquito populations (Daubney *et al.*, 1933).

West Nile Virus belongs to family flaviviradae and genus flavivirus, and cause significant human infections. Flaviviruses normally causes neuroinvasiveness, and are transmitted through the vector i.e *Culex* mosquitoes. Non-vector method of transmission also occur through oral transmission in birds, cats, and different vertebrates. As humans are generally infected by mosquito bites, however other modes of transmission are also present like through intrauterine transmission, blood transfusion, transplantation, and breast milk (DeSalvo *et al.*, 2004).

Japanese encephalitis virus (JEV) belongs to family flaviviridae. *Culex* mosquitoes act as a vector for transmission of JEV between human and animal hosts. Japanese encephalitis is endemic all through Southern and Eastern Asia and the Pacific Rim. The allied neurotropic flaviviruses are present throughout the world: West Nile virus in Africa and the Middle East, St. Murray Valley encephalitis virus in Australia, Louis encephalitis virus and Equine encephalitis virus in North America, Roccio virus in South America and Tick borne encephalitis virus in Russia. These viral encephalitides have many epidemiological, virological, and clinical features in common (Winter *et al.*, 2004). More than 50,000 cases and 15,000 deaths occur yearly due to JE exclusively in the rural areas. The mainstream of JE fatalities are children and nearly half of the surviving patients have cognitive or motor sequelae (Misra *et al.*, 2010).

1.6 Genus *Armigeres*

The genus *Armigeres* comprises of 58 large species further divided into two subgenera: *Armigeres* that contains 40 species and *Leicesteria* having 18 species. As adult females, *Armigeres* are simply recognized by two long distinct rows of scales that

separate their eyes and laterally flattened and down-turned proboscis. *Armigeres* larvae are differentiated from all other Aedines by the lack of pecten. The male palpus is equal in length to that of proboscis where female proboscis is somewhat down-turned at tip and laterally compressed and palpus is long and upturned. Alula and upper calypter with marginal hair-like scales are present on the wings. Setae may be present or absent.

Armigeres species are commonly found near the human dwellings mainly in sub-urban areas having poor sanitation that comprises of contaminated water like septic tanks. *Armigeres* species such as *Ar. subalbatus* and *Ar. obturbans* have been reported to be a vector of *Wuchereria bancrofti*, the filarial worm and the dog heartworm *Dirofilaria immitis* in Peninsular Malaysia and also responsible for transmission of Japanese encephalitis (Muslim *et al.*, 2013).



Figure 1.4: Structure of *Armigeres* mosquito

<https://www.wrbu.si.edu/vectorspecies/genera/armigeres>

1.7 Life Cycle of Mosquitoes

There are four distinct stages in mosquito's life cycle i.e egg, larva, pupa, and adult. Female mosquito lays the eggs directly on or near the water surface, soil or at the base of some plants, and in the places that contain water. The eggs can endure hot and dry conditions for few months. When exposed to water, the egg hatches into larva also known as "wiggler". The size of the larvae depends on the type of mosquito, temperature and food. Larvae lives in water, molts many times and develop into the third stage of mosquito life cycle that is pupa also known as "tumbler". The pupa does not feed and lives in the water. After two days to a week in pupal stage, adult mosquito emerges from the pupal case. The adult emerges on the water surface and flies away to

continue its life cycle. The life cycle completes usually in two weeks, but depending on environmental conditions, it may range from 4 days to a month.

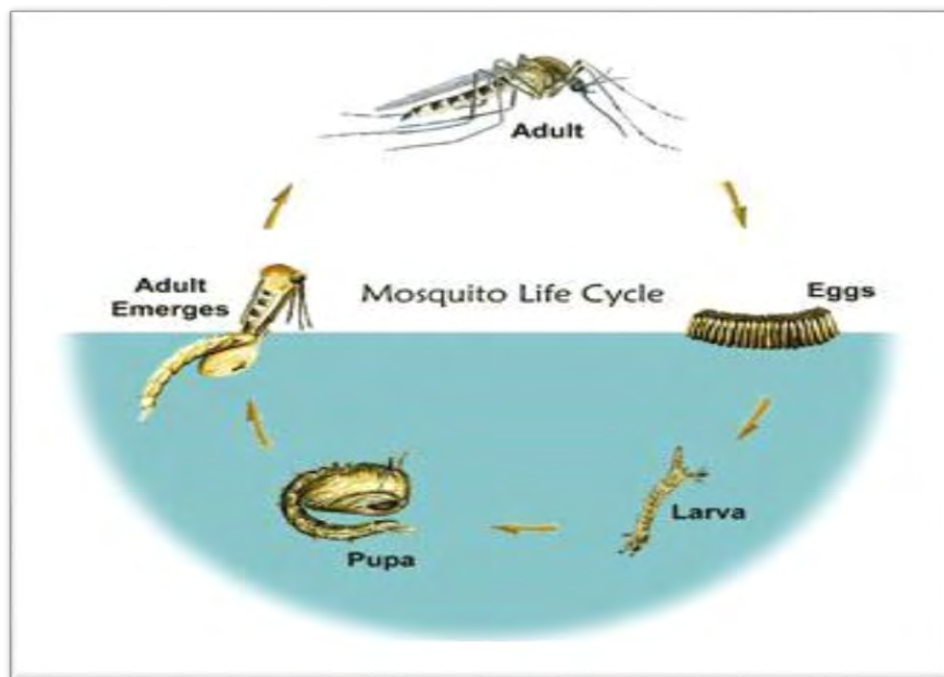


Figure 1.4: Life cycle of Mosquito.

<https://www.mosquito.org/page/lifecycle>

1.7 Mosquito control strategies

Different species of *Anopheles* are disseminated into different biogeographical regions, the main *Culex* and *Aedes* vector species have a universal distribution patterns. Each landmass has different malaria vectors (Hay *et al.*, 2010), among them *An. funestus*, *Anopheles gambiae* and *An. arabiensis* are the most effective ones in sub-Saharan Africa (Sinka *et al.*, 2010a); in Latin America, *An. darling* is the key vector (Sinka *et al.*, 2010b); and *An punctulatus*, *An. koliensis* and *An. farauti* s.l. in the Australian-Pacific region; and *An. fluviatilis* s.l., *An. dirus* s.l., *An. culicifacies* s.l., *An. stephensi*, *An. minimus* s.l., and *An. maculatus* in Asia (Sinka *et al.*, 2011). In contrast, the dispersal of species like *Aedes aegypti* usually covers the tropical regions in all continents or may be cosmopolitan like *Culex quinquefasciatus* (WHO, 1989). This fundamental variance has significant consequences on vector control approaches. Vector control strategies are primarily raised on three vital techniques: (1) physical control (2) chemical control and (3) biological control (Mangui and Boëte, 2011).

1.7.1 Physical control

Physical control is encouraging by eliminating larval sites (water deposits, containers), especially effective against *Culex* or *Aedes* species. Larval habitations can also be changed such as intermittent irrigation, drainage operations, removal of algae or water plants, change in river discharge, and making habitats unsuitable (Manguí and Boëte, 2011).

1.7.2 Chemical control

In chemical control method, insecticidal and larvicidal sprays are used according to the size and nature of mosquito species. Anopheles can be controlled by using long-lasting insecticidal nets (LLINs), indoor residual spraying (IRS), or insecticide-treated nets (ITN). These methods can be proved fruitful if used properly. The drawback of chemical control is the development of resistance against these insecticidal and larvicidal sprays and these are not eco-friendly. So, to evade the complications of resistance, diverse insecticides should be used in rotation (Hemingway *et al.*, 1997; Lenormand & Raymond, 1998). Two pyrethroid insecticides viz lambda-cyhalothrin and alphacypermethrin are mainly used to control *Aedes* species (Pettit *et al.*, 2010).

1.7.3 Biological control

Some organisms have verified to be effectual against larvae of mosquitoes like predatory insect larvae (*Toxorhynchites* mosquitoes, dragonfly), larvivorous fish (*Poecilia*, *Gambusia*), nematode worms, copepods, fungi, and bacterial larvicides. Bacterial larvicides have determined much attention. Thus, high doses of dry preparations of *Bacillus thuringiensis* subspecies *israelensis* (Bti) is used for the residual control of *Ae. aegypti* (Ritchie *et al.*, 2010), while, *Bacillus sphaericus* is mainly used against species of *Culex* (Skovmand *et al.*, 2009). In recent studies entomopathogenic fungi have shown to offer effective control strategies against these vectors (Read *et al.*, 2009).

AIMS AND OBJECTIVES

In consideration to the importance of mosquitoes as medical insects, the current research aimed to study the biodiversity of mosquito species (Diptera; Culicidae) in different Districts of Khyber Pakhtunkhwa-Pakistan. The objectives of the study are:

- Sample collection from different sites of study area.
- Microscopic and morphometric identification of different mosquito species.

MATERIALS AND METHODS

2.1 Study area

The present study was conducted in different districts of Khyber Pakhtunkhwa (KPK). The KPK (longitude 34.9526 ° N and latitude 72.3311 ° E) is located in the northwestern region of Pakistan. The Khyber Pakhtunkhwa is bounded by Afghanistan in the west in the north; it is bounded by Gilgit-Baltistan, in the east by Azad Jammu and Kashmir (AJK), and in the South by Punjab and Baluchistan provinces (Figure 2.1). The province spreads over 101,741 km² and is the 3rd largest province of Pakistan by population and smallest province by area.

Geographically, Khyber Pakhtunkhwa could be divided into two zones: the southern one extending from Peshawar to South Waziristan where the northern one extending from district Chitral to the borders of Peshawar basin. The southern zone is arid with relatively cold winters, hot summers, and scanty rainfall. The northern zone has cold and snowy winters with heavy rainfall and pleasant summers except few districts (Peshawar, Mardan, Swabi, etc.) that are cold in winter and hot in summer with moderate rainfall. The current study was conducted in ten districts of Khyber Pakhtunkhwa including the district Upper Dir, Lower Dir, Swat, Mardan, Swabi, Peshawar, Karak, Bannu, Lakki Marwat, and South Waziristan (Figure 2.1).

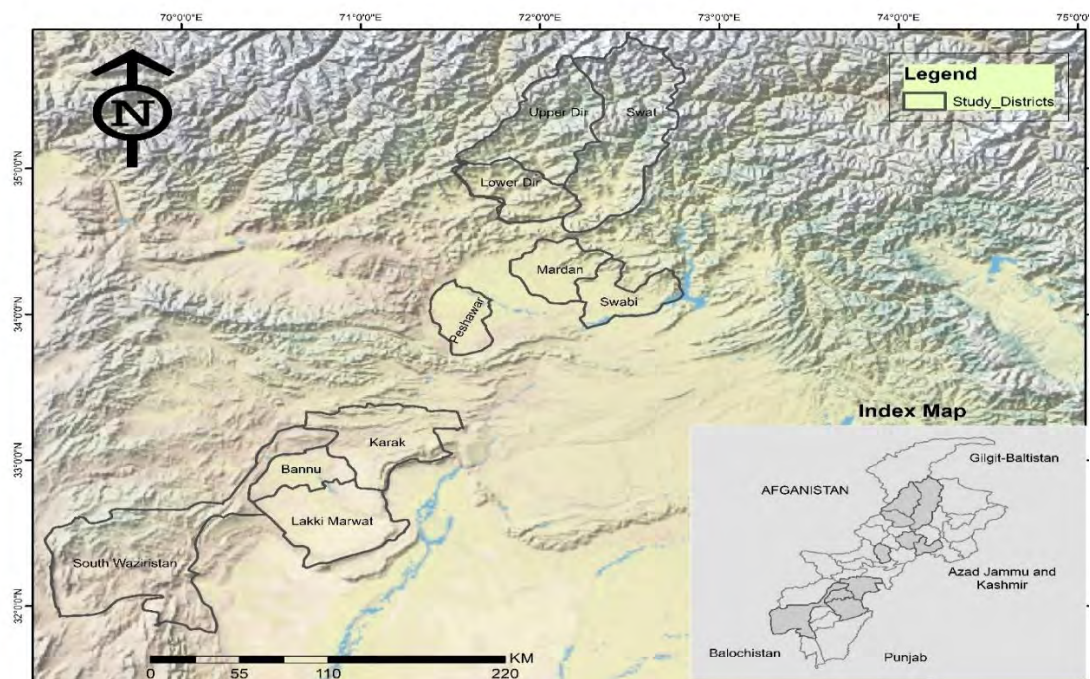


Figure 2.1: Map of study area, KPK, Pakistan.

2.2 Sample collection

The exploration study was led from June to September 2020. Samples were gathered from ten distinct areas of Khyber Pakhtunkhwa. The testing locales, the spots which mosquitoes like to live and raise were visited. The destinations incorporate human abodes, wood territories, parks, creature sheds, and standing water. Adult mosquitoes were gathered from inside just as outside. Indoor assortments were produced using homes and creature sheds though open air collections were made using parks, open regions, standing water and woodland territories (Baboo *et al.*, 2021).

Suction apparatuses, hand nets, light snares, insecticidal splashes and Electric mosquito swatter racket (electric snares) were used for the assortment of mosquitoes. Indoor collections were made using splashes and electric mosquito swatter racket and the specimens were gathered using entomological forceps. During night, light snares were used for collection. Hand nets and suction apparatuses were used during daytime collections.

2.3 Mosquito morphological identification

Specimens from these collections were observed and photographed using the Olympus Light microscope paired with Cannon Digital Camera. The morphometric data was obtained from imaged specimens taken by 12 megapixels digital CCD camera on the trinocular Optika microscope by using ImageJ software version 1.51j8. Taxonomic terms and measurements used in the present study were explained by Reuda (2004), Becker *et al.* (2010), Mehmood (2016) and WHO (2020). The following characteristics were studied: full body length, length of proboscis, length of palpi, length of antennae, fore leg measurements (length of femur, tibia, tarsals), middle leg measurements (length of femur, tibia, tarsals) and hind leg measurements (length of femur, tibia, tarsals). The data was analyzed for various statistical parameters like mean, standard deviation, standard error and coefficient of variance.

2.4 Data Analysis

All the analysis was performed on adult mosquitoes. Relative abundance and distribution were calculated using following formulas.

$$\text{Relative abundance} = \frac{n}{\text{Total number of species}(N)} \times 100$$

Where “n” is the number of specimens of each mosquito species and “N” is the total number of specimens of all species.

The mosquito species were classified according to the following relative abundance classes: if relative abundance is greater than 10% then species are dominant, if relative abundance is from 3-10% then species are subdominant and if the relative abundance is less than 3% then species are satellite (Manzoor *et al.*, 2020).

$$\text{Distribution}(C) = \frac{n}{N} \times 100$$

Where “n” is the number of sites where species found and “N” is the total number of sites.

Distribution status of species were classified using following classes: 0-20% sporadic, 20.1-40% infrequent, 40.1-60% moderate, 60.1-80% frequent and 80.1-100% constant species (Ali *et al.*, 2013).

RESULTS

Total of 18 species were identified under two subfamilies and three genera i.e *Anopheles*, *Culex* and *Armigeres* from the given localities. From Southern KPK (Bannu, Lakki Marwat, Waziristan and Karak) 6 species of *Anopheles* namely *An. culicifacies*, *An. annularis*, *An. sinensis*, *An. stephansi*, *An. fluviatilis* and *An. aconitus*, 6 species of *Culex* namely *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, *Cx. bitaeniorhynchus*, *Cx. gelidus*, *Cx. fuscocephala*, *Cx. whitmorei*, and 2 species of *Armigeres* namely *Ar. obturbans* and *Ar. kuchingensis* were collected. *Ar. obturbans* and *Ar. kuchingensis* were collected for the first time from Karak (Table 3.1).

From Central KPK (Peshawar, Mardan and Swabi) 4 *Anopheles* species i.e *An. culicifacies*, *An. stephansi*, *An. tessellatus*, *An. subpictus* and 4 *Culex* species i.e *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, *Cx. bitaeniorhynchus* and *Cx. vishnui* were collected (Table 3.1).

From Northern KPK (Swat, Lower Dir and Upper Dir) 5 *Anopheles* species namely *An. culicifacies*, *An. annularis*, *An. stephansi*, *An. fluviatilis*, *An. tessellatus*, 5 *Culex* species namely *Cx. quinquefasciatus*, *Cx. gelidus*, *Cx. fuscocephala*, *Cx. vishnui*, *Cx. pseudovishnui* and one *Armigeres* species i.e *Ar. obturbans* was collected (Table 3.1).

The coordinates (longitude, latitude) and elevation of the different districts of KPK, Pakistan are given in (Table 3.2).

Table 3.2: Coordinates of the study area in KPK

Localities	Coordinates	Elevation (m)
Bannu	32.9910° N, 70.6455° E	1297
Lakki Marwat	32.6135° N, 70.9012° E	255
Waziristan	32.3202° N, 69.8597° E	2010
Karak	33.1105° N, 71.0914° E	548
Peshawar	34.0151° N, 71.5249° E	331
Mardan	34.1989° N, 72.0231° E	310
Swabi	34.1241° N, 72.4613° E	340
Swat	35.2227° N, 72.4258° E	980
Lower Dir	34.9161° N, 71.8097° E	823
Upper Dir	35.3356° N, 72.0486° E	1420

3.1 Taxonomic classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Diptera

Family: Culicidae

Subfamilies: Anophelinae/ Culicinae

Genus: *Anopheles/ Culex/ Armigeres*

3.2 Genus identification

Genus: *Anopheles*

- *Anopheles* genus is worldwide in distribution and it belongs to the subfamily Anophelinae.
- The distinguishing character of this genus is spotted wings and they also make definite angel while sitting on wall.
- The males and females both have palps equal to proboscis but males have swollen apical segments of palps.
- Forelegs of male have long segments with claws and spur.

Genus: *Culex*

- *Culex* genus belongs to the subfamily culicinae.
- The key characters of this genus are the length of palps and structure of wings.
- In females the palps are shorter than the proboscis while in males palps are equal to the size of proboscis but are thin and erect.
- Wings are clear, without spots and while feeding, culicinae females keep their bodies erect.

Genus: *Armigeres*

- *Armigeres* genus belongs to subfamily culicinae.
- Proboscis stout and tip turn downward.
- White scales and several bristles present at postspiracular area.
- One lower mesepimeral bristle.
- Palps in female are one third length of the proboscis

3.3 Species identification

3.3.1 *Anopheles*

1. Tarsomere 3rd, 4th, and 5th white in colour, white scales present, front femur swollen and cerci contain dark scales (Fig 3.1).....*Anopheles annularis*

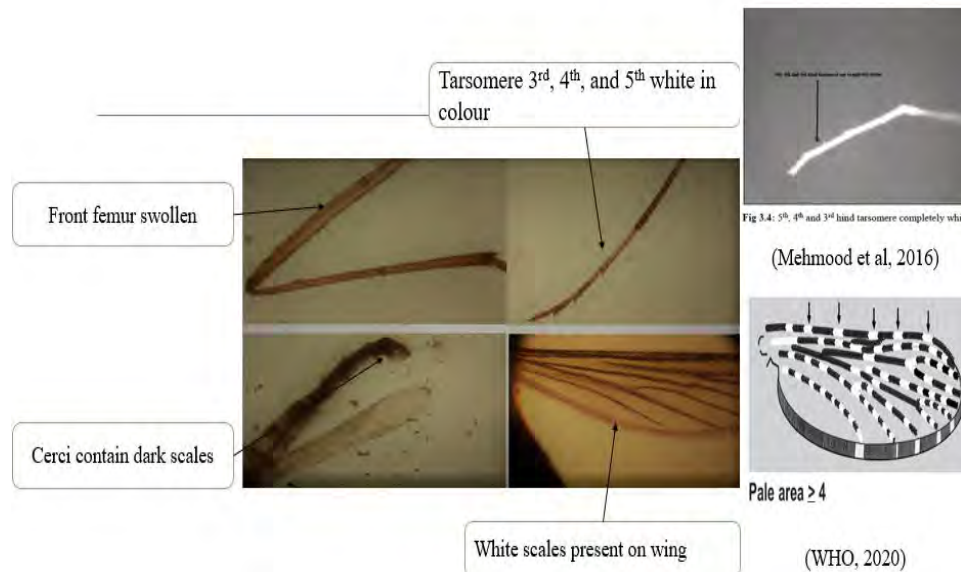


Figure 3.1: Identifying features of *An. annularis*

2. Scales on antennae are absent or rudimentary, femur not swollen, tibia dark, tarsomeres not banded, abdominal scales absent and have no scales on cerci, dark black legs without banding patterns (Fig 3.2).....*Anopheles culicifacies*

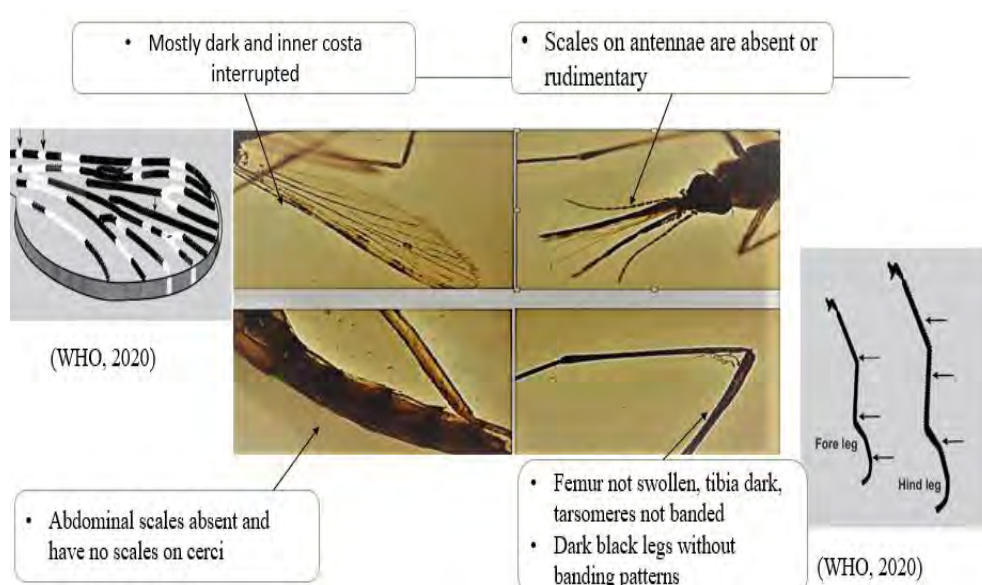


Figure 3.2: Identifying features of *An. culicifacies*

3. Male palpi are swollen and equal in length to that of proboscis, fore femur swollen, hind femur and tibia dark colored, narrow scales are present on 2nd, 3rd, and 8th tergites, covered with dark spots, cerci covered with dark scales (Fig 3.3) *Anopheles stephensi*

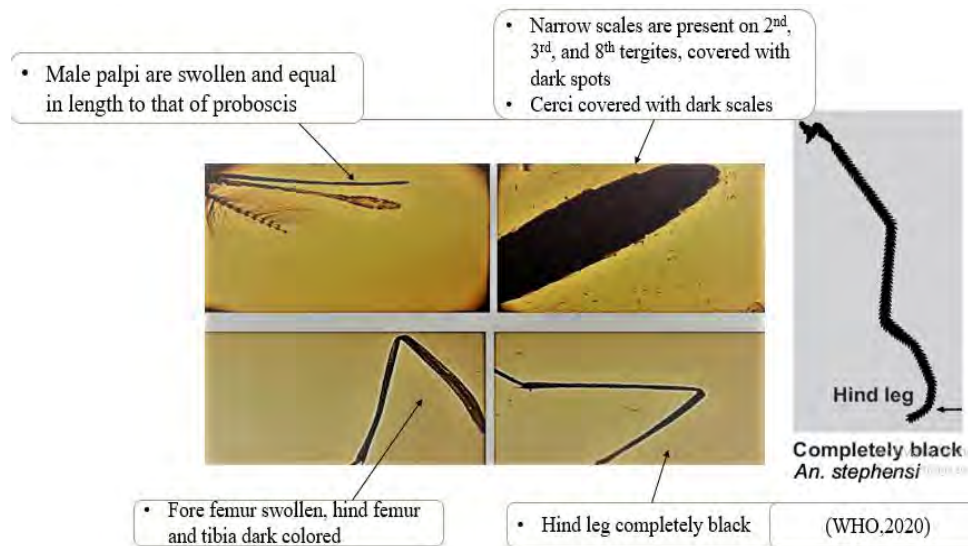


Figure 3.3: Identifying features of *An. stephensi*

4. Antennae have no scales, straight, cylindrical and thin palpi, abdominal scales absent and have no scales on cerci, no bands on legs (Fig 3.4)

Anopheles fluviatilis

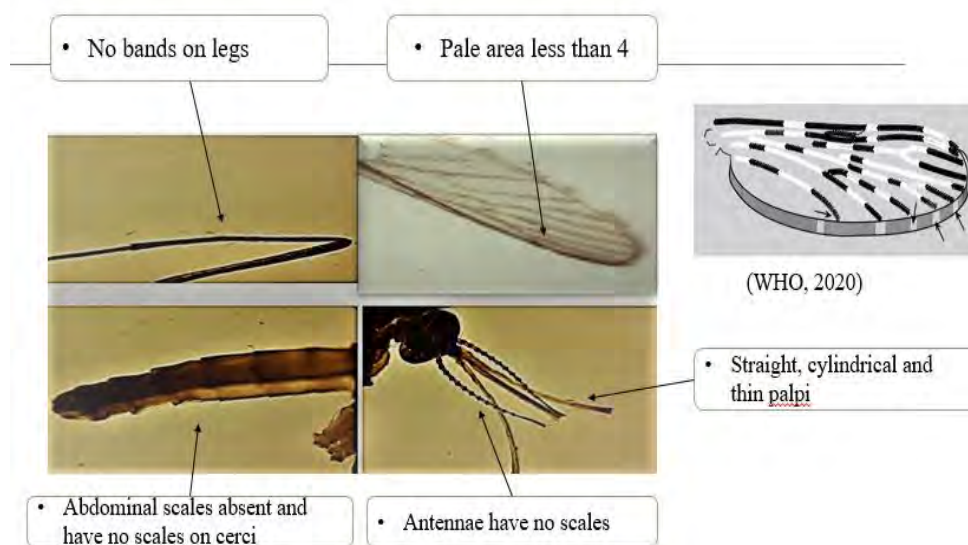


Figure 3.4: Identifying features of *An. fluviatilis*

5. Apical segment of palpi long, spots present on femora and tibia, hind tarsomere 5th not white, abdomen dark colored having hairs and cerci have no scales (Fig3.5) *Anopheles tessellatus*

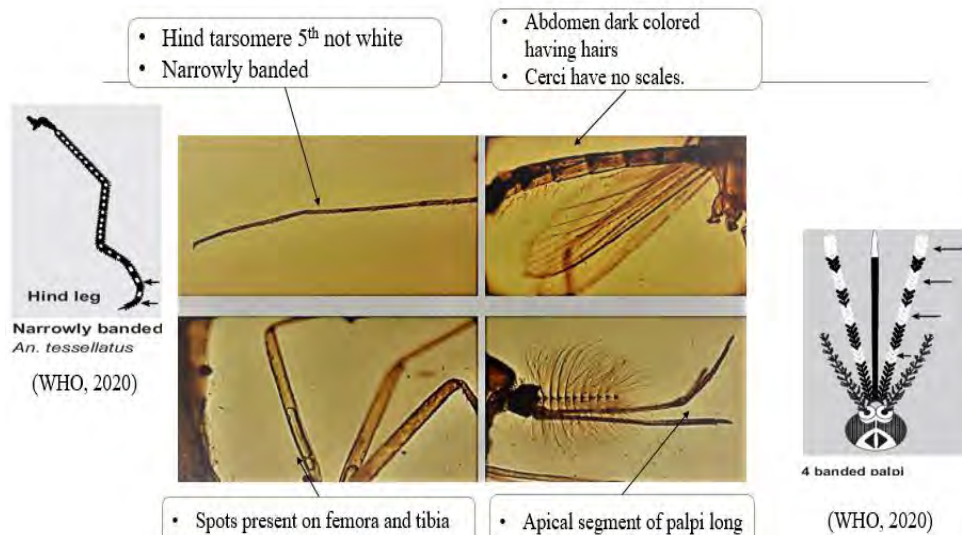


Figure 3.5: Identifying features of *An. tessellatus*

6. Tip of the palpi pale, wings spotted, vein 2 is scaled, femur and tibia having spherical and round white spots, hind tarsal segments white, abdomen dark colored and cerci contain black scales (Fig 3.6).....*Anopheles sinensis*

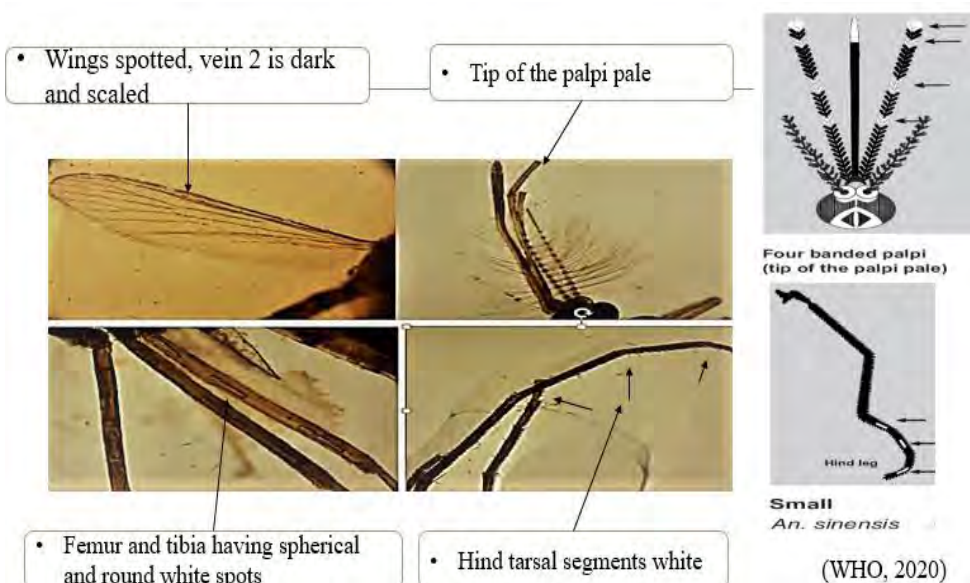


Figure 3.6: Identifying features of *An. sinensis*

7. Intervening dark and pale bands on palpi, complete dark legs, apical and subapical pale bands on palpi are equal in length (Fig 3.7)...*Anopheles aconitus*



Figure 3.7: Identifying features of *An. aconitus*

8. Broad pale bands on foreleg tarsomeres, speckling in legs is absent, apical pale band nearly equal to pre-apical dark band (Fig 3.8).....*Anopheles subpictus*

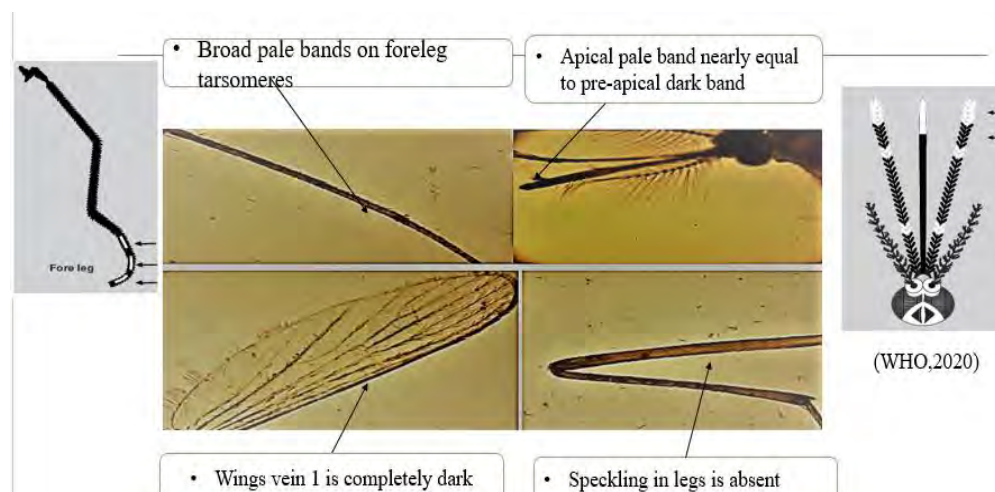


Figure 3.8: Identifying features of *An. subpictus*

3.3.2 Culex

1. Scales absent on cerci, small/ narrow pale bands or absence of banding on abdomen, proboscis without pale band, dark in colour (Fig 3.9)

Culex fuscocephala

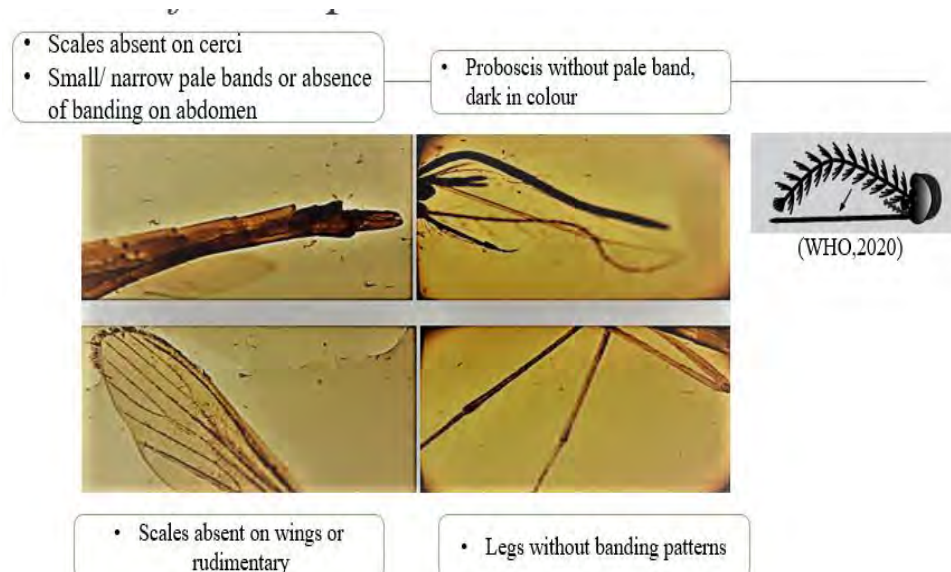


Figure 3.9: Identifying features of *Cx. fuscocephala*

2. 8th terga and cerci without scales, blunt abdomen, presence of basal pale bands on terga, head light brown in color, thorax, abdomen and proboscis darker (Fig 3.10) *Culex quinquefasciatus*

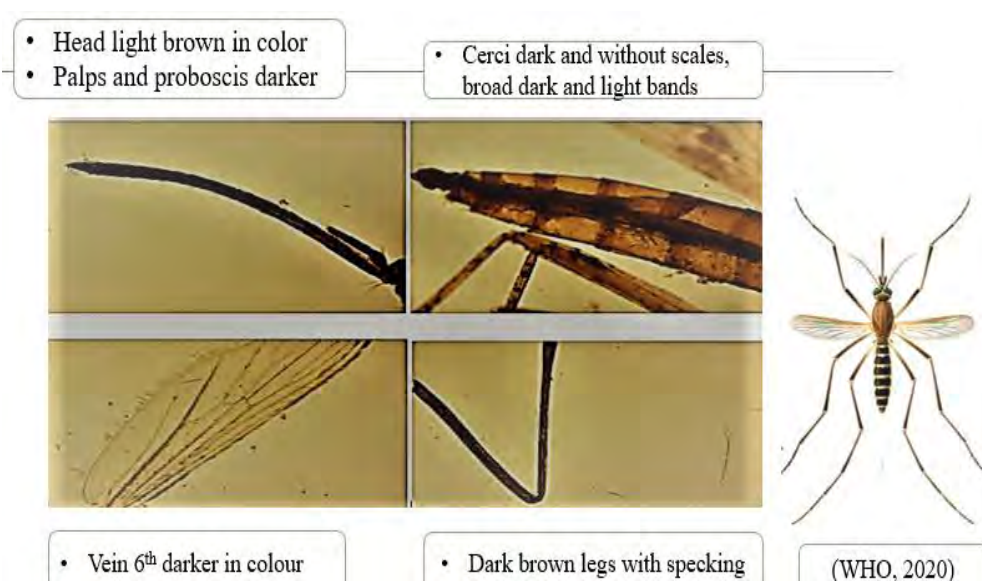


Figure 3.10: Identifying features of *Cx. quinquefasciatus*

3. White spots on wings are present, wing 3.8-5.2mm, heavily speckled with dark and pale scales, abdominal terga speckled with pale bands (Fig 3.11) *Culex bitaeniorhynchus*

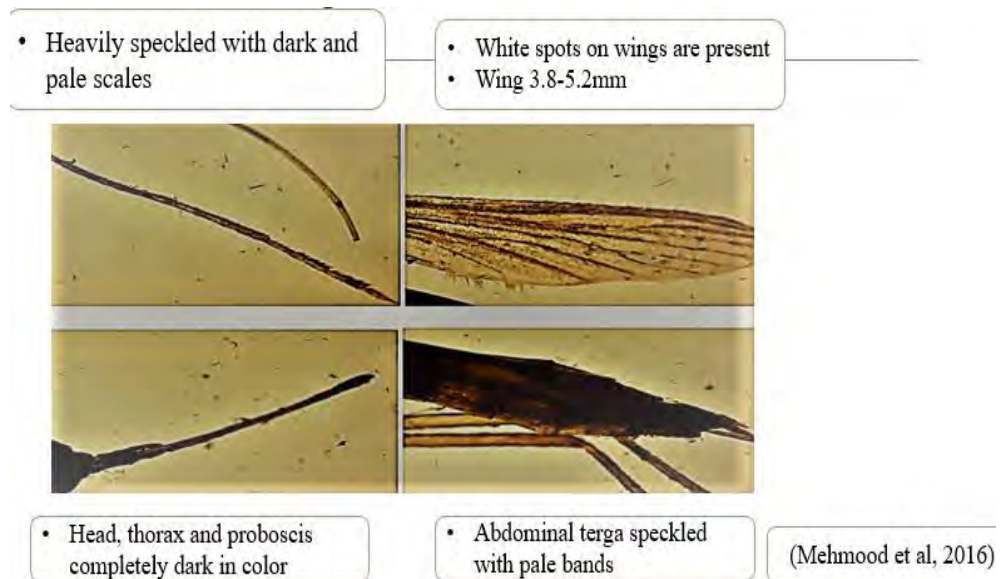


Figure 3.11: Identifying features of *Cx. bitaeniorhynchus*

4. White spots on the wings are absent, wings with broad scales, complete dark leg, without bands, proboscis having alternate pale and dark bands (Fig 3.12)

Culex gelidus

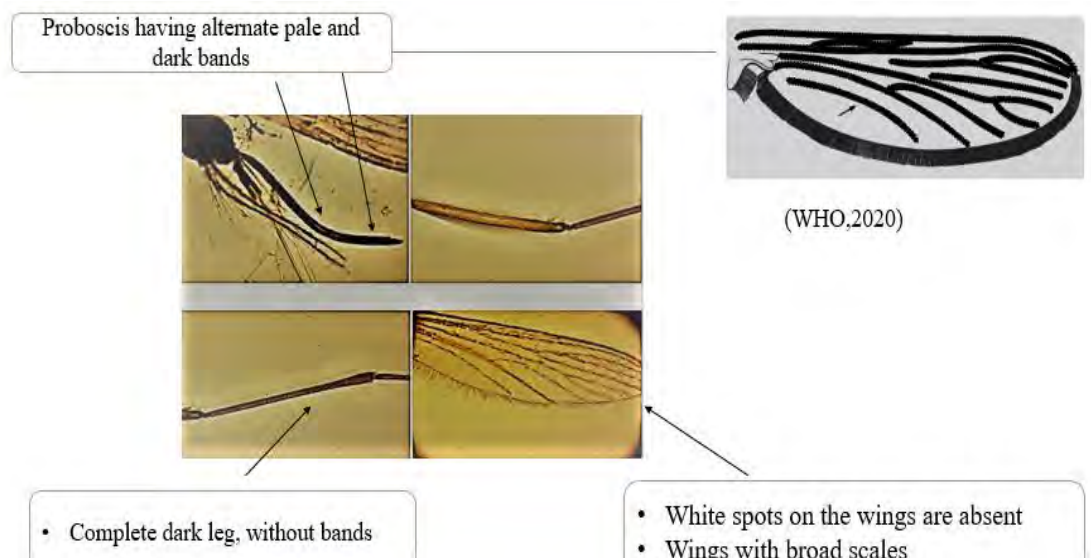


Figure 3.12: Identifying features of *Cx. gelidus*

5. Scales are absent on the wings, dark stripe on the anterior dorsal surface of hind femur (Fig 3.13) *Culex pseudovishnui*

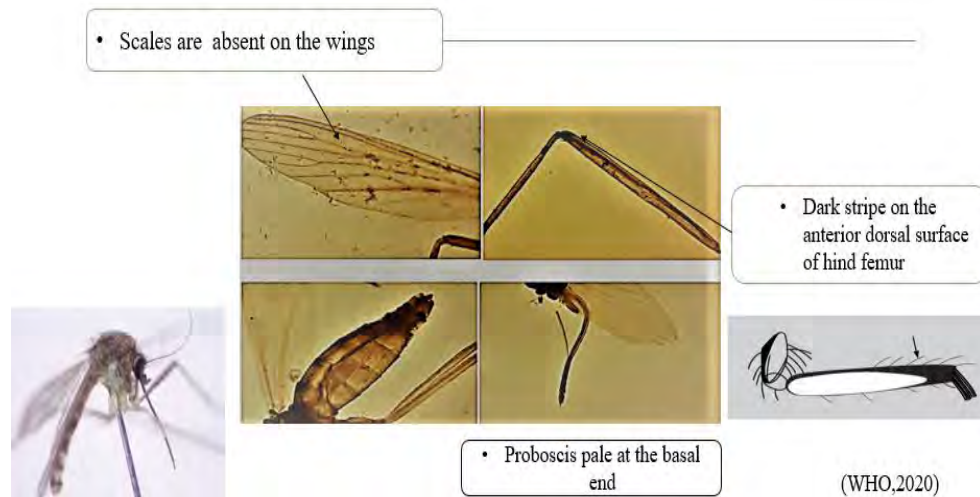


Figure 3.13: Identifying features of *Cx. pseudovishnui*

6. Narrow apical dark ring on hind femur, proboscis with accessory pale patches present (Fig 3.14) *Culex tritaeniorhynchus*

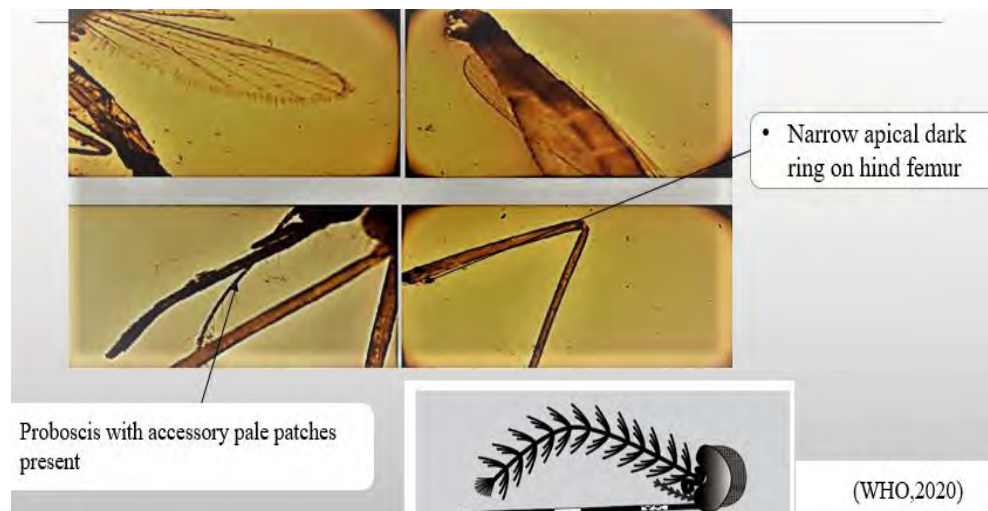


Figure 3.14: Identifying features of *Cx. tritaeniorhynchus*

7. Dark pale scale area present on hind femur, speckling of pale scales on wings and femora (Fig 3.15) *Culex vishnui*

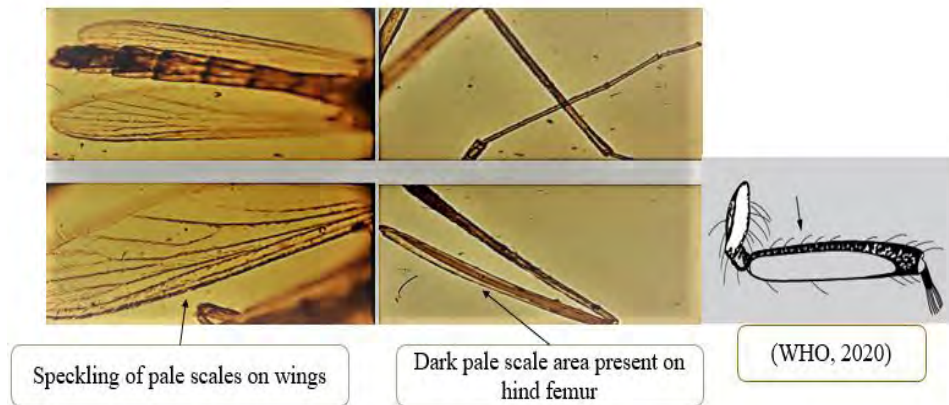


Figure 3.15: Identifying features of *Cx. vishnui*

8. Speckling of pale scales on the fore and mid femora, dark pale scaled area on hind femur, pale band on proboscis broad, as long as or longer than basal dark band, scales on prescutellar space, wings without white scales (Fig 3.16)

Culex whitmorei

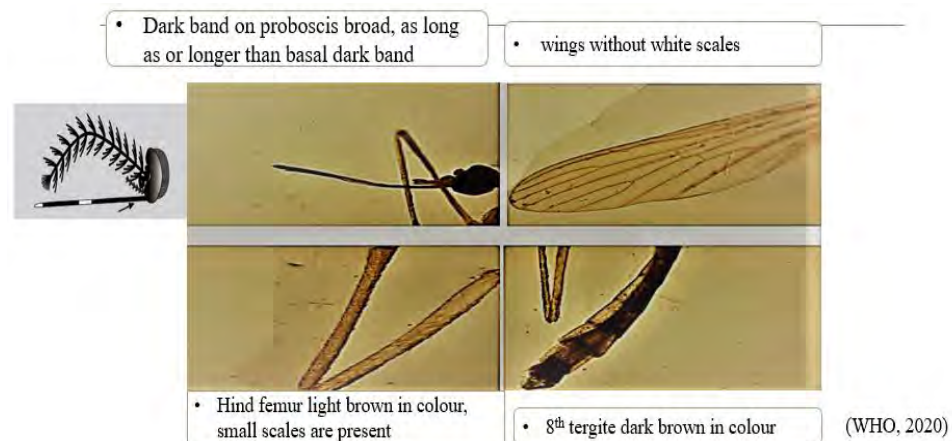


Figure 3.16: Identifying features of *Cx. whitmorei*

3.3.3 *Armigeres*

1. Proboscis and palpi brownish black in colour, palpi one third to the length of proboscis, dark scales on wings, brownish black abdomen, abdominal sternite 3rd and 4th segments with apically black band, claws on the middle leg are unequal in size (Fig 3.17) *Armigeres obturbans*

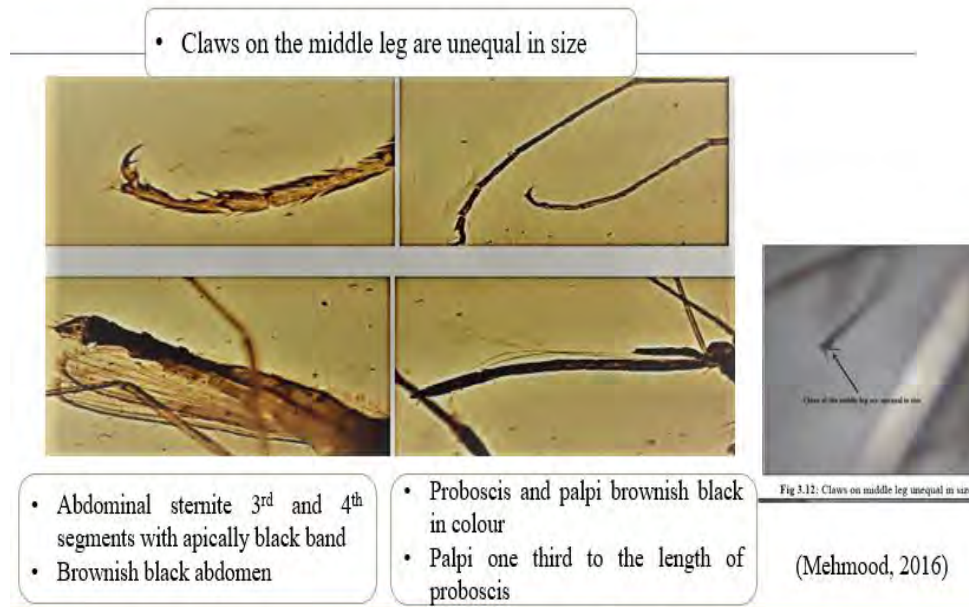


Figure 3.17: Identifying features of *Ar. obturbans*

2. Wings have few dark scales, same size of claws on the middle leg (Fig 3.18)

Armigeres kuchingensis

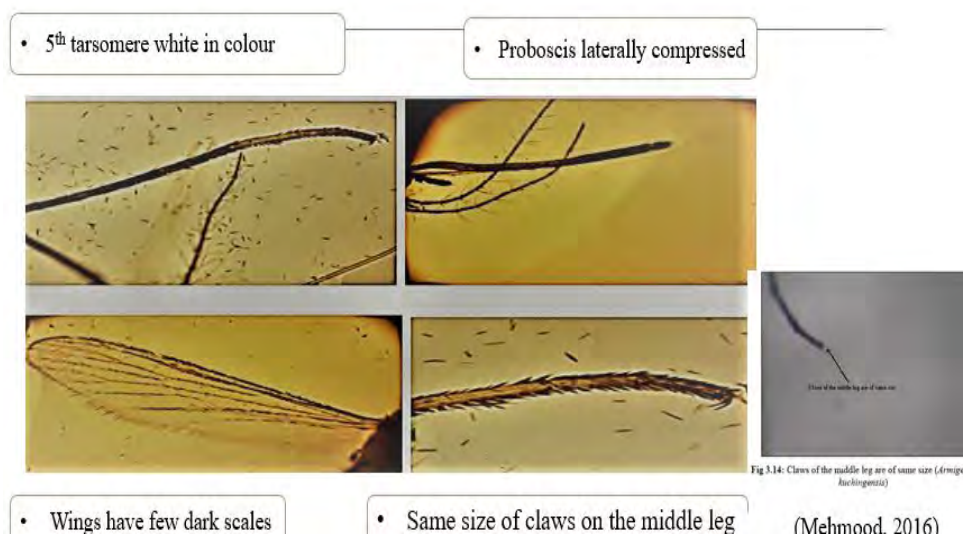


Figure 3.18: Identifying features of *Ar. kuchingensis*

3.4 Morphometric measurements of different parameters of mosquito species

3.4.1 *An. culicifacies*

Full body length: The length of *Anopheles culicifacies* body ranges from 3.2mm to 5.01mm and it has a mean value of 4.1565mm whereas the standard deviation, standard error, and coefficient of variability have values 1.216931, 0.8605, and 29.27778 respectively.

Length of proboscis: length of proboscis varied from 1.56 to 2.46 mm with a mean value of 2.01mm and SD, SE, and CV values 0.636369, 0.45 and 31.6615 respectively.

Length of palpi: length of palpi varied from 1.499 to 2.576 mm with a mean value of 2.037 mm and 0.761554, 0.5385, and 37.37688 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.32-1.99mm with mean value of 1.655mm and SD, SE and CV have the values 0.473762, 0.335 and 28.62608 respectively.

Length of wings: length of the wings varied from 3.254-4.786mm with 4.02mm mean value where SD, SE and CV have the values 1.083288, 0.766 and 26.94745 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.296-2.333mm and the mean value is 1.8145mm where the values of SD, SE and CV were 0.73327, 0.5185 and 40.41167 respectively.

The observed range in the length of tibia was 1.309-2.338mm with 1.8235mm mean value where SD, SE and CV had the values 0.727613, 0.5145 and 39.90199 respectively. The observed range in the length of tarsals was 2.448-3.628mm with 3.038mm mean value where SD, SE and CV had the values 0.834386, 0.59 and 27.46498 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.322-2.576mm and the mean value is 1.949mm where the values of SD, SE and CV were 0.886712, 0.627 and 45.49574 respectively.

The observed range in the length of tibia was 1.304-2.621mm with 1.9625mm mean value where SD, SE and CV had the values 0.93126, 0.6585 and 47.45272 respectively. The observed range in the length of tarsals was 2.339-3.783mm with 3.061mm mean value where SD, SE and CV had 3.061, 0.722 and 33.35714 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.047-2.515mm and the mean value is 2.281mm where the values of SD, SE and CV were 0.330926, 0.234 and 14.50793 respectively.

The observed range in the length of tibia was 1.998-2.778mm with 2.388mm mean value where SD, SE and CV had 0.551543, 0.39 and 23.09645 values respectively. The observed range in the length of tarsals was 3.215-4.323mm with 3.769mm mean value where SD, SE and CV had 0.783474, 0.554 and 20.78733 values respectively (Table 3.3)

Table 3.3: Morphometric measurements of *An. culicifacies*

Parameters	N	O.R	\bar{X}	SD	SE	CV
Full body length	6	3.296-5.017	4.1565	1.216931	0.8605	29.27778
Length of proboscis	6	1.56-2.46	2.01	0.636396	0.45	31.6615
Length of palpi	6	1.499-2.576	2.0375	0.761554	0.5385	37.37688
Length of antennae	6	1.32-1.99	1.655	0.473762	0.335	28.62608
Length of wings	6	3.254-4.786	4.02	1.083288	0.766	26.94745
Length of foreleg						
Femur	6	1.296-2.333	1.8145	0.73327	0.5185	40.41167
Tibia	6	1.309-2.338	1.8235	0.727613	0.5145	39.90199
Tarsals	6	2.448-3.628	3.038	0.834386	0.59	27.46498
Length of middle leg						
Femur	6	1.322-2.576	1.949	0.886712	0.627	45.49574
Tibia	6	1.304-2.621	1.9625	0.93126	0.6585	47.45272
Tarsals	6	2.339-3.783	3.061	1.021062	0.722	33.35714
Length of hind leg						
Femur	6	2.047-2.515	2.281	0.330926	0.234	14.50793
Tibia	6	1.998-2.778	2.388	0.551543	0.39	23.09645
Tarsals	6	3.215-4.323	3.769	0.783474	0.554	20.78733

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.2 *An. annularis*

Full body length: The length of *Anopheles annularis* body ranges from 3.127-4.956mm and it has a mean value of 4.0415mm whereas the standard deviation, standard error, and coefficient of variance have 1.293298, 0.9145 and 32.00045 values respectively.

Length of proboscis: length of proboscis varied from 1.935-2.657mm with a mean value of 2.296mm and SD, SE, and CV values 0.510531, 0.361 and 22.23567 respectively.

Length of palpi: length of palpi varied from 2.315-2.989mm with a mean value of 2.652mm and 0.47659, 0.337 and 17.97096 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.675-2.261mm with mean value of 1.968mm and SD, SE and CV have the values 0.414365, 0.293 and 21.05511 respectively.

Length of wings: length of the wings varied from 2.978-3.965mm with 3.4715mm mean value where SD, SE and CV have the values 0.697914, 0.4935 and 20.10412 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.097-2.995mm and the mean value is 2.546mm where the values of SD, SE and CV were 0.634982, 0.449 and 24.94037 respectively.

The observed range in the length of tibia was 1.757-2.992mm with 2.3745mm mean value where SD, SE and CV had the values 0.873277, 0.6175 and 36.7773 respectively.

The observed range in the length of tarsals was 2.876-3.845mm with 3.3605mm mean value where SD, SE and CV had the values 0.685186, 0.4845 and 20.38942 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.177-2.998mm and the mean value is 2.5875mm where the values of SD, SE and CV were 0.580535, 0.4105 and 22.43612 respectively.

The observed range in the length of tibia was 1.933-2.879mm with 2.406mm mean value where SD, SE and CV had the values 0.668923, 0.473 and 27.80229 respectively.

The observed range in the length of tarsals was 2.957-3.765mm with 3.361mm mean value where SD, SE and CV had values 0.571342, 0.404 and 16.99918 respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.209-2.978mm and the mean value is 2.5935mm where the values of SD, SE and CV were 0.543765, 0.3845 and 20.96646 respectively.

The observed range in the length of tibia was 2.043-3.008mm with 2.5255mm mean value where SD, SE and CV had values 0.682358, 0.4825 and 27.01873 respectively. The observed range in the length of tarsals was 3.098-4.294mm with 3.696mm mean value where SD, SE and CV had values 0.8457, 0.598 and 22.88149 respectively (Table 3.4).

Table 3.4: Morphometric measurements of *An. annularis*

Parameters	N	O.R	\bar{X}	SD	SE	CV
Full body length	6	3.127-4.956	4.0415	1.293298	0.9145	32.00045
Length of proboscis	6	1.935-2.657	2.296	0.510531	0.361	22.23567
Length of palpi	6	2.315-2.989	2.652	0.47659	0.337	17.97096
Length of antennae	6	1.675-2.261	1.968	0.414365	0.293	21.05511
Length of wings	6	2.978-3.965	3.4715	0.697914	0.4935	20.10412
Length of foreleg						
Femur	6	2.097-2.995	2.546	0.634982	0.449	24.94037
Tibia	6	1.757-2.992	2.3745	0.873277	0.6175	36.7773
Tarsals	6	2.876-3.845	3.3605	0.685186	0.4845	20.38942
Length of middle leg						
Femur	6	2.177-2.998	2.5875	0.580535	0.4105	22.43612
Tibia	6	1.933-2.879	2.406	0.668923	0.473	27.80229
Tarsals	6	2.957-3.765	3.361	0.571342	0.404	16.99918
Length of hind leg						
Femur	6	2.209-2.978	2.5935	0.543765	0.3845	20.96646
Tibia	6	2.043-3.008	2.5255	0.682358	0.4825	27.01873
Tarsals	6	3.098-4.294	3.696	0.8457	0.598	22.88149

N =Number of samples; O.R =Observed range; \bar{X} = Mean; SD= Standard deviation; SE =Standard error; CV =Coefficient of variability

3.4.3 *An. sinensis*

Full body length: The length of *Anopheles sinensis* body ranges from 3.098-4.675mm and it has a mean value of 3.8865mm whereas the standard deviation, standard error, and coefficient of variance have 1.115107, 0.7885 and 28.69182 values respectively.

Length of proboscis: length of proboscis varied from 1.581-2.035mm with a mean value of 1.808mm and SD, SE, and CV values 0.321026, 0.227 and 17.75589 respectively.

Length of palpi: length of palpi varied from 1.508-2.487mm with a mean value of 1.9975mm and 0.692258, 0.4895 and 34.6562 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.278-1.743mm with mean value of 1.5105mm and SD, SE and CV have the values 0.328805, 0.2325 and 21.76793 respectively.

Length of wings: length of the wings varied from 2.579-3.912mm with 3.2455mm mean value where SD, SE and CV have the values 0.942573, 0.6665 and 29.04247 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.909-2.132mm and the mean value is 2.0205mm where the values of SD, SE and CV were 0.157685, 0.1115 and 7.804247 respectively.

The observed range in the length of tibia was 2.135-2.443mm with 2.289mm mean value where SD, SE and CV had the values 0.217789, 0.154 and 9.514587 respectively.

The observed range in the length of tarsals was 2.768-3.167mm with 2.9675mm mean value where SD, SE and CV had the values 0.282136, 0.1995 and 9.507518 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.009-2.876mm and the mean value is 2.4425mm where the values of SD, SE and CV were 0.613062, 0.4335 and 25.09976 respectively.

The observed range in the length of tibia was 2.087-2.901mm with 2.494mm mean value where SD, SE and CV had the values 0.575585, 0.407 and 23.07879 respectively.

The observed range in the length of tarsals was 2.993-3.798mm with 3.3955mm mean value where SD, SE and CV had values 0.569221, 0.4025 and 16.76398 respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.034-2.889mm and the mean value is 2.4615mm where the values of SD, SE and CV were 0.604576, 0.4275 and 24.5613 respectively.

The observed range in the length of tibia was 2.209-2.541mm with 2.375mm mean value where SD, SE and CV had 0.234759, 0.166 and 9.884608 values respectively. The observed range in the length of tarsals was 3.707-4.069mm with 3.888mm mean value where SD, SE and CV had 0.255973, 0.181 and 6.583659 values respectively (Table 3.5).

Table 3.5: Morphometric measurements of *An. sinensis*

Parameters	N	O.R	\bar{X}	SD	SE	CV
Full body length	6	3.098-4.675	3.8865	1.115107	0.7885	28.69182
Length of proboscis	6	1.581-2.035	1.808	0.321026	0.227	17.75589
Length of palpi	6	1.508-2.487	1.9975	0.692258	0.4895	34.6562
Length of antennae	6	1.278-1.743	1.5105	0.328805	0.2325	21.76793
Length of wings	6	2.579-3.912	3.2455	0.942573	0.6665	29.04247
Length of foreleg						
Femur	6	1.909-2.132	2.0205	0.157685	0.1115	7.804247
Tibia	6	2.135-2.443	2.289	0.217789	0.154	9.514587
Tarsals	6	2.768-3.167	2.9675	0.282136	0.1995	9.507518
Length of middle leg						
Femur	6	2.009-2.876	2.4425	0.613062	0.4335	25.09976
Tibia	6	2.087-2.901	2.494	0.575585	0.407	23.07879
Tarsals	6	2.993-3.798	3.3955	0.569221	0.4025	16.76398
Length of hind leg						
Femur	6	2.034-2.889	2.4615	0.604576	0.4275	24.5613
Tibia	6	2.209-2.541	2.375	0.234759	0.166	9.884608
Tarsals	6	3.707-4.069	3.888	0.255973	0.181	6.583659

N =Number of samples; O.R= Observed range; \bar{X} = Mean; SD =Standard deviation; SE =Standard error; CV= Coefficient of variability

3.4.4 *An. stephensi*

Full body length: The length of *Anopheles stephensi* body ranges from 3.709-5.342mm and it has a mean value of 4.5255mm whereas the standard deviation, standard error, and coefficient of variance have 1.154705, 0.8165 and 25.51553 values respectively.

Length of proboscis: length of proboscis varied from 1.531-3.879mm with a mean value of 2.705mm and SD, SE, and CV values 1.660287, 1.174 and 61.37844 respectively.

Length of palpi: length of palpi varied from 1.566-3.998mm with a mean value of 2.782mm and 1.719684, 1.216 and 61.81465 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.348-2.826mm with mean value of 2.087mm and SD, SE and CV have the values 1.045104, 0.739 and 50.07685 respectively.

Length of wings: length of the wings varied from 3.389-4.667mm with 4.028mm mean value where SD, SE and CV have the values 0.903682, 0.639 and 22.43502 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.867-2.989mm and the mean value is 2.428mm where the values of SD, SE and CV were 0.793374, 0.561 and 32.67602 respectively.

The observed range in the length of tibia was 2.011-2.912mm with 2.4615mm mean value where SD, SE and CV had the values 0.637103, 0.4505 and 25.88272 respectively.

The observed range in the length of tarsals was 2.957-3.711mm with 3.334mm mean value where SD, SE and CV had the values 0.533159, 0.377 and 15.99156 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.109-2.943mm and the mean value is 2.526mm where the values of SD, SE and CV were 0.589727, 0.417 and 23.34628 respectively.

The observed range in the length of tibia was 2.324-2.827mm with 2.5755mm mean value where SD, SE and CV had the values 0.355675, 0.2515 and 13.80993 respectively.

The observed range in the length of tarsals was 2.988-3.943mm with 3.4655mm mean value where SD, SE and CV had 0.675287, 0.4775 and 19.48599 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.091-2.939mm and the mean value is 2.515mm where the values of SD, SE and CV were 0.599627, 0.424 and 23.84201 respectively.

The observed range in the length of tibia was 2.156-2.933mm with 2.5445mm mean value where SD, SE and CV had 0.549422, 0.3885 and 21.59253 values respectively. The observed range in the length of tarsals was 3.597-4.667mm with 4.132mm mean value where SD, SE and CV had 0.756604, 0.535 and 18.31085 values respectively (Table 3.6).

Table 3.6: Morphometric measurements of *An. stephensi*

Parameters	N	O.R	\bar{X}	SD	SE	CV%
Full body length	6	3.709-5.342	4.5255	1.154705	0.8165	25.51553
Length of proboscis	6	1.531-3.879	2.705	1.660287	1.174	61.37844
Length of palpi	6	1.566-3.998	2.782	1.719684	1.216	61.81465
Length of antennae	6	1.348-2.826	2.087	1.045104	0.739	50.07685
Length of wings	6	3.389-4.667	4.028	0.903682	0.639	22.43502
Length of foreleg						
Femur	6	1.867-2.989	2.428	0.793374	0.561	32.67602
Tibia	6	2.011-2.912	2.4615	0.637103	0.4505	25.88272
Tarsals	6	2.957-3.711	3.334	0.533159	0.377	15.99156
Length of middle leg						
Femur	6	2.109-2.943	2.526	0.589727	0.417	23.34628
Tibia	6	2.324-2.827	2.5755	0.355675	0.2515	13.80993
Tarsals	6	2.988-3.943	3.4655	0.675287	0.4775	19.48599
Length of hind leg						
Femur	6	2.091-2.939	2.515	0.599627	0.424	23.84201
Tibia	6	2.156-2.933	2.5445	0.549422	0.3885	21.59253
Tarsals	6	3.597-4.667	4.132	0.756604	0.535	18.31085

N =Number of samples; O.R= Observed range; \bar{X} = Mean; SD =Standard deviation; SE =Standard error; CV =Coefficient of variability

3.4.5 *An. fluviatilis*

Full body length: The length of *Anopheles fluviatilis* body ranges from 3.997-4.786mm and it has a mean value of 4.3915mm whereas the standard deviation, standard error, and coefficient of variance have values 0.557907, 0.3945 and 12.70425 respectively.

Length of proboscis: length of proboscis varied from 1.674-1.989mm with a mean value of 1.8315mm and SD, SE, and CV values 0.222739, 0.1575 and 12.16154 respectively.

Length of palpi: length of palpi varied from 1.483-1.889mm with a mean value of 1.686mm and 0.287085, 0.203 and 17.0276 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.264-1.776mm with mean value of 1.52mm and SD, SE and CV have the values 0.362039, 0.256 and 23.81833 respectively.

Length of wings: length of the wings varied from 3.229-3.989mm with 3.609mm mean value where SD, SE and CV have the values 0.537401, 0.38 and 14.89058 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.967-2.098mm and the mean value is 2.0325mm where the values of SD, SE and CV were 0.092631, 0.0655 and 4.55749 respectively.

The observed range in the length of tibia was 1.823-1.997mm with 1.91mm mean value where SD, SE and CV had the values 0.123037, 0.087 and 6.441706 respectively.

The observed range in the length of tarsals was 2.79-3.0242mm with 2.907mm mean value where SD, SE and CV had the values 0.165463, 0.117 and 5.691881 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.014-2.453mm and the mean value is 2.2335mm where the values of SD, SE and CV were 0.31042, 0.2195 and 13.89836 respectively.

The observed range in the length of tibia was 1.927-2.343mm with 2.135mm mean value where SD, SE and CV had the values 0.294156, 0.208 and 13.77782 respectively.

The observed range in the length of tarsals was 2.987-3.156mm with 3.0715mm mean value where SD, SE and CV had 0.119501, 0.0845 and 3.890641 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.103-2.456mm and the mean value is 2.2795mm where the values of SD, SE and CV were 0.249609, 0.1765 and 10.95015 respectively.

The observed range in the length of tibia was 2.153-2.354mm with 2.2535mm mean value where SD, SE and CV had 0.142128, 0.1005 and 6.30701 values respectively. The observed range in the length of tarsals was 3.356-4.098mm with 3.727mm mean value where SD, SE and CV had 0.524673, 0.371 and 14.07763 values respectively (Table 3.7).

Table 3.7: Morphometric measurements of *An. fluviatilis*

Parameters	N	O.R	\bar{X}	SD	SE	CV%
Full body length	6	3.997-4.786	4.3915	0.557907	0.3945	12.70425
Length of proboscis	6	1.674-1.989	1.8315	0.222739	0.1575	12.16154
Length of palpi	6	1.483-1.889	1.686	0.287085	0.203	17.0276
Length of antennae	6	1.264-1.776	1.52	0.362039	0.256	23.81833
Length of wings	6	3.229-3.989	3.609	0.537401	0.38	14.89058
Length of foreleg						
Femur	6	1.967-2.098	2.0325	0.092631	0.0655	4.55749
Tibia	6	1.823-1.997	1.91	0.123037	0.087	6.441706
Tarsals	6	2.79-3.024	2.907	0.165463	0.117	5.691881
Length of middle leg						
Femur	6	2.014-2.453	2.2335	0.31042	0.2195	13.89836
Tibia	6	1.927-2.343	2.135	0.294156	0.208	13.77782
Tarsals	6	2.987-3.156	3.0715	0.119501	0.0845	3.890641
Length of hind leg						
Femur	6	2.103-2.456	2.2795	0.249609	0.1765	10.95015
Tibia	6	2.153-2.354	2.2535	0.142128	0.1005	6.30701
Tarsals	6	3.356-4.098	3.727	0.524673	0.371	14.07763

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.6 *An. tessellatus*

Full body length: The length of *Anopheles tessellatus* body ranges from 3.584-4.098mm and it has a mean value of 3.841mm whereas the standard deviation, standard error, and coefficient of variance have 0.363453, 0.257 and 9.462455 values respectively.

Length of proboscis: length of proboscis varied from 1.585-2.007mm with a mean value of 1.796mm and SD, SE, and CV values 0.298399, 0.211 and 16.61465 respectively.

Length of palpi: length of palpi varied from 1.603-2.109mm with a mean value of 1.856mm and 0.357796, 0.253 and 19.2778 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.289-1.789mm with mean value of 1.539mm and SD, SE and CV have the values 0.353553, 0.25 and 22.97293 respectively.

Length of wings: length of the wings varied from 3.382-3.587mm with 3.4845mm mean value where SD, SE and CV have the values 0.144957, 0.1025 and 4.160049 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.006-2.187mm and the mean value is 2.09735mm where the values of SD, SE and CV were 0.129188, 0.09135 and 6.159602 respectively.

The observed range in the length of tibia was 1.953-2.001mm with mean value 1.977mm where SD, SE and CV had the values 0.033941, 0.024 and 1.716799 respectively.

The observed range in the length of tarsals was 2.252-2.765mm with 2.5085mm mean value where SD, SE and CV had the values 0.362746, 0.2565 and 14.46066 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.052-2.187mm and the mean value is 2.1195mm where the values of SD, SE and CV were 0.095459, 0.0675 and 4.503865 respectively.

The observed range in the length of tibia was 1.986-1.998mm with 1.992mm mean value where SD, SE and CV had the values 0.008485, 0.006 and 0.425968 respectively.

The observed range in the length of tarsals was 3.005-3.345mm with 3.175mm mean value where SD, SE and CV had 0.240416, 0.17 and 7.572167 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.081-2.554mm and the mean value is 2.3175mm where the values of SD, SE and CV were 0.334462, 0.2365 and 14.432 respectively.

The observed range in the length of tibia was 1.998-2.445mm with 2.2215mm mean value where SD, SE and CV had 0.316077, 0.2235 and 14.22808 values respectively. The observed range in the length of tarsals was 3.928-4.543mm with 4.2355mm mean value where SD, SE and CV had values 0.434871, 0.3075 and 10.26728 respectively (Table 3.8).

Table 3.8: Morphometric measurements of *An. tessellatus*

Parameters	N	O.R	\bar{X}	SD	SE	CV
Full body length	6	3.584-4.098	3.841	0.363453	0.257	9.462455
Length of proboscis	6	1.585-2.007	1.796	0.298399	0.211	16.61465
Length of palpi	6	1.603-2.109	1.856	0.357796	0.253	19.2778
Length of antennae	6	1.289-1.789	1.539	0.353553	0.25	22.97293
Length of wings	6	3.382-3.587	3.4845	0.144957	0.1025	4.160049
Length of foreleg						
Femur	6	2.006-2.187	2.09735	0.129188	0.09135	6.159602
Tibia	6	1.953-2.001	1.977	0.033941	0.024	1.716799
Tarsals	6	2.252-2.765	2.5085	0.362746	0.2565	14.46066
Length of middle leg						
Femur	6	2.052-2.187	2.1195	0.095459	0.0675	4.503865
Tibia	6	1.986-1.998	1.992	0.008485	0.006	0.425968
Tarsals	6	3.005-3.345	3.175	0.240416	0.17	7.572167
Length of hind leg						
Femur	6	2.081-2.554	2.3175	0.334462	0.2365	14.432
Tibia	6	1.998-2.445	2.2215	0.316077	0.2235	14.22808
Tarsals	6	3.928-4.543	4.2355	0.434871	0.3075	10.26728

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.7 *An. subpictus*

Full body length: The length of *Anopheles subpictus* body ranges from 3.276-4.989mm and it has a mean value of 4.1325mm whereas the standard deviation, standard error, and coefficient of variance have 1.211274, 0.8565 and 29.31092 values respectively.

Length of proboscis: length of proboscis varied from 1.521-2.879mm with a mean value of 2.2mm and SD, SE, and CV values 0.960251, 0.679 and 43.64777 respectively.

Length of palpi: length of palpi varied from 1.749-2.997mm with a mean value of 2.373mm and 0.882469, 0.624 and 37.18792 values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.117-2.054mm with 1.5855mm mean value of and SD, SE and CV have the values 0.662559, 0.4685 and 41.78865 respectively.

Length of wings: length of the wings varied from 2.978-4.323mm with 3.6505mm mean value where SD, SE and CV have the values 0.951059, 0.6725 and 26.05283 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.883-1.999mm and the mean value is 1.941mm where the values of SD, SE and CV were 0.082024, 0.058 and 4.225883 respectively.

The observed range in the length of tibia was 1.754-1.981mm with 1.8675mm mean value where SD, SE and CV had the values 0.160513, 0.1135 and 8.595086 respectively.

The observed range in the length of tarsals was 2.887-3.176mm with 3.0315mm mean value where SD, SE and CV had the values 0.204354, 0.1445 and 6.741015 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.967-1.998mm and the mean value is 1.9825mm where the values of SD, SE and CV were 0.02192, 0.0155 and 1.10569 respectively.

The observed range in the length of tibia was 1.823-1.989mm with 1.906mm mean value where SD, SE and CV had the values 0.11738, 0.083 and 6.158433 respectively.

The observed range in the length of tarsals was 2.525-3.243mm with 2.884mm mean value where SD, SE and CV had values 0.507703, 0.359 and 17.60411 respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.012-2.237mm and the mean value is 2.1245mm where the values of SD, SE and CV were 0.159099, 0.1125 and 7.488775 respectively.

The observed range in the length of tibia was 1.913-2.234mm with 2.0735mm mean value where SD, SE and CV had 0.226981, 0.1605 and 10.94677 values respectively. The observed range in the length of tarsals was 2.989-3.987mm with mean value 3.488mm where SD, SE and CV had 0.705693, 0.499 and 20.23201 values respectively (Table 3.9).

Table 3.9: Morphometric measurements of *An. subpictus*

Parameters	N	O.R	\bar{X}	SD	SE	CV
Full body length	6	3.276-4.989	4.1325	1.211274	0.8565	29.31092
Length of proboscis	6	1.521-2.879	2.2	0.960251	0.679	43.64777
Length of palpi	6	1.749-2.997	2.373	0.882469	0.624	37.18792
Length of antennae	6	1.117-2.054	1.5855	0.662559	0.4685	41.78865
Length of wings	6	2.978-4.323	3.6505	0.951059	0.6725	26.05283
Length of foreleg						
Femur	6	1.883-1.999	1.941	0.082024	0.058	4.225883
Tibia	6	1.754-1.981	1.8675	0.160513	0.1135	8.595086
Tarsals	6	2.887-3.176	3.0315	0.204354	0.1445	6.741015
Length of middle leg						
Femur	6	1.967-1.998	1.9825	0.02192	0.0155	1.10569
Tibia	6	1.823-1.989	1.906	0.11738	0.083	6.158433
Tarsals	6	2.525-3.243	2.884	0.507703	0.359	17.60411
Length of hind leg						
Femur	6	2.012-2.237	2.1245	0.159099	0.1125	7.488775
Tibia	6	1.913-2.234	2.0735	0.226981	0.1605	10.94677
Tarsals	6	2.989-3.987	3.488	0.705693	0.499	20.23201

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.8 *An. aconitus*

Full body length: The length of *Anopheles aconitus* body ranges from 3.987-4.665mm and it has a mean value of 4.326mm whereas the standard deviation, standard error, and coefficient of variance have 0.479418, 0.339 and 11.08226 values respectively.

Length of proboscis: length of proboscis varied from 1.895-1.994mm with a mean value of 1.9445mm and SD, SE, and CV values 0.070004, 0.0495 and 3.600081 respectively.

Length of palpi: length of palpi varied from 1.805-1.998mm with a mean value of 1.9015mm and 0.136472, 0.0965 and 7.17705 values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.517-1.879mm with mean value of 1.698mm and SD, SE and CV have the values 0.255973, 0.255973 and 15.07495 respectively.

Length of wings: length of the wings varied from 2.988-3.456mm with 3.222mm mean value where SD, SE and CV have the values 0.330926, 0.234 and 10.27082 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.785-1.967mm and the mean value is 1.876mm where the values of SD, SE and CV were 0.128693, 0.091 and 6.859991 respectively.

The observed range in the length of tibia was 1.812-1.976mm with 1.894mm mean value where SD, SE and CV had 0.115966, 0.082 and 6.122783 values respectively.

The observed range in the length of tarsals was 2.883-3.543mm with 3.213mm mean value where SD, SE and CV had 0.46669, 0.33 and 14.52507 values respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.853-1.997mm and the mean value is 1.925mm where the values of SD, SE and CV were 0.101823, 0.072 and 5.289526 respectively.

The observed range in the length of tibia was 1.934-2.009mm with 1.9715mm mean value where SD, SE and CV had the values 0.053033, 0.0375 and 2.689983 respectively.

The observed range in the length of tarsals was 2.794-3.216mm with 3.005mm mean value where SD, SE and CV had 0.298399, 0.211 and 9.930085 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.883-1.908mm and the mean value is 1.8955mm where the values of SD, SE and CV were 0.017678, 0.0125 and 0.932612 respectively.

The observed range in the length of tibia was 1.903-1.956mm with 1.9295mm mean value where SD, SE and CV had 0.037477, 0.0265 and 1.942299 values respectively. The observed range in the length of tarsals was 3.002-3.987mm with 3.4945mm mean value where SD, SE and CV had 0.6965, 0.4925 and 19.93133 values respectively (Table 3.10).

Table 3.10: Morphometric measurements of *An. aconitus*

Parameters	N	O.R	\bar{X}	SD	SE	CV%
Full body length	6	3.987-4.665	4.326	0.479418	0.339	11.08226
Length of proboscis	6	1.895-1.994	1.9445	0.070004	0.0495	3.600081
Length of palpi	6	1.805-1.998	1.9015	0.136472	0.0965	7.17705
Length of antennae	6	1.517-1.879	1.698	0.255973	0.181	15.07495
Length of wings	6	2.988-3.456	3.222	0.330926	0.234	10.27082
Length of foreleg						
Femur	6	1.785-1.967	1.876	0.128693	0.091	6.859991
Tibia	6	1.812-1.976	1.894	0.115966	0.082	6.122783
Tarsals	6	2.883-3.543	3.213	0.46669	0.33	14.52507
Length of middle leg						
Femur	6	1.853-1.997	1.925	0.101823	0.072	5.289526
Tibia	6	1.934-2.009	1.9715	0.053033	0.0375	2.689983
Tarsals	6	2.794-3.216	3.005	0.298399	0.211	9.930085
Length of hind leg						
Femur	6	1.883-1.908	1.8955	0.017678	0.0125	0.932612
Tibia	6	1.903-1.956	1.9295	0.037477	0.0265	1.942299
Tarsals	6	3.002-3.987	3.4945	0.6965	0.4925	19.93133

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.9 *Cx. quinquefasciatus*

Full body length: The length of *Culex quinquefasciatus* body ranges from 3.217-4.231mm and it has a mean value of 3.724mm whereas the standard deviation, standard error, and coefficient of variance have 0.717006, 0.507 and 19.25366 values respectively.

Length of proboscis: length of proboscis varied from 2.042-2.764mm with a mean value of 2.403mm and SD, SE, and CV values 0.510531, 0.361 and 21.24557 respectively.

Length of palpi: length of palpi varied from 0.443-0.654mm with a mean value of 0.5485mm and 0.1492, 0.1055 and 27.20137 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.267-1.587mm with 1.427mm mean value of and SD, SE and CV have the values 0.226274, 0.16 and 15.85663 respectively.

Length of wings: length of the wings varied from 2.491-2.698mm with 2.5945mm mean value where SD, SE and CV have the values 0.146371, 0.1035 and 5.641592 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.113-2.378mm and the mean value is 2.2455mm where the values of SD, SE and CV were 0.187383, 0.1325 and 8.344836 respectively.

The observed range in the length of tibia was 1.956-2.245mm with 2.1005mm mean value where SD, SE and CV had the values 0.204354, 0.1445 and 9.72882 respectively.

The observed range in the length of tarsals was 2.355-2.967mm with 2.661mm mean value where SD, SE and CV had the values 0.432749, 0.306 and 16.26266 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.063-2.445mm and the mean value is 2.254mm where the values of SD, SE and CV were 0.270115, 0.191 and 11.9838 respectively.

The observed range in the length of tibia was 2.003-2.343mm with 2.173mm mean value where SD, SE and CV had 0.240416, 0.17 and 11.0638 values respectively.

The observed range in the length of tarsals was 2.697-3.021mm with mean value 2.859mm where SD, SE and CV had 0.229103, 0.162 and 8.013382 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.978-2.453mm and the mean value is 2.2155mm where the values of SD, SE and CV were 0.335876, 0.2375 and 15.16027 respectively.

The observed range in the length of tibia was 2.255-2.509mm with 2.382mm mean value where SD, SE and CV had 0.179605, 0.127 and 7.540097 values respectively. The observed range in the length of tarsals was 2.989-3.798mm with mean value 3.3935mm where SD, SE and CV had 0.572049, 0.4045 and 16.85721 values respectively (Table 3.11).

Table 3.11: Morphometric measurements of *Cx. quinquefasciatus*

Parameters	N	O.R	\bar{X}	SD	SE	CV%	\bar{X}	
Full body length	6	3.217-4.231	3.724	0.717006	0.507	19.25366	3.96	Limna et al, 2003
Length of proboscis	6	2.042-2.764	2.403	0.510531	0.361	21.24557	-	
Length of palpi	6	0.443-0.654	0.5485	0.1492	0.1055	27.20137	-	
Length of antennae	6	1.267-1.587	1.427	0.226274	0.16	15.85663	-	
Length of wings	6	2.491-2.698	2.5945	0.146371	0.1035	5.641592	-	
Length of foreleg								
Femur	6	2.113-2.378	2.2455	0.187383	0.1325	8.344836	-	
Tibia	6	1.956-2.245	2.1005	0.204354	0.1445	9.72882	-	
Tarsals	6	2.355-2.967	2.661	0.432749	0.306	16.26266	-	
Length of middle leg								
Femur	6	2.063-2.445	2.254	0.270115	0.191	11.9838	-	
Tibia	6	2.003-2.343	2.173	0.240416	0.17	11.0638	-	
Tarsals	6	2.697-3.021	2.859	0.229103	0.162	8.013382	-	
Length of hind leg								
Femur	6	1.978-2.453	2.2155	0.335876	0.2375	15.16027	-	
Tibia	6	2.255-2.509	2.382	0.179605	0.127	7.540097	-	
Tarsals	6	2.989-3.798	3.3935	0.572049	0.4045	16.85721	-	

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.10 *Cx. tritaeniorhynchus*

Full body length: The length of *Culex tritaeniorhynchus* body ranges from 3.108-5.596mm and it has a mean value of 4.352mm whereas the standard deviation, standard error, and coefficient of variance have 1.759282, 1.244 and 40.42467 values respectively.

Length of proboscis: length of proboscis varied from 1.812-3.732mm with a mean value of 2.772mm and SD, SE, and CV values 1.357645, 0.96 and 48.97709 respectively.

Length of palpi: length of palpi varied from 0.478-1.981mm with a mean value of 1.2295mm and 1.062781, 0.7515 and 86.44014 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.267-3.276mm with mean value of 2.2715mm and SD, SE and CV have the values 1.420578, 1.0045 and 62.53918 respectively.

Length of wings: length of the wings varied from 2.578-4.589mm with mean value 3.5835mm where SD, SE and CV have the values 1.421992, 1.0055 and 39.68164 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.006-2.433mm and the mean value is 2.2195mm where the values of SD, SE and CV were 0.301935, 0.2135 and 13.60372 respectively.

The observed range in the length of tibia was 1.876-2.098mm with 1.987mm mean value where SD, SE and CV had the values 0.156978, 0.111 and 7.900237 respectively.

The observed range in the length of tarsals was 2.651-2.978mm with 2.8145mm mean value where SD, SE and CV had the values 0.231224, 0.1635 and 8.215453 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.186-2.445mm and the mean value is 2.3155mm where the values of SD, SE and CV were 0.183141, 0.1295 and 7.909335 respectively.

The observed range in the length of tibia was 1.85-2.397mm with 2.1235mm mean value where SD, SE and CV had the values 0.386787, 0.2735 and 18.21462 respectively.

The observed range in the length of tarsals was 2.842-3.568mm with mean value 3.205mm where SD, SE and CV had 0.51336, 0.363 and 16.01746 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.109-2.354mm and the mean value is 2.2315mm where the values of SD, SE and CV were 0.173241, 0.1225 and 7.76344 respectively.

The observed range in the length of tibia was 2.381-2.443mm with 2.412mm mean value where SD, SE and CV had 0.043841, 0.031 and 1.817604 values respectively. The observed range in the length of tarsals was 2.889-3.456mm with 3.1725mm mean value where SD, SE and CV had 0.40093, 0.2835 and 12.63765 values respectively (Table 3.12).

Table 3.12: Morphometric measurements of *Cx. tritaeniorhynchus*

Parameters	N	O.R	\bar{X}	SD	SE	CV%
Full body length	6	3.108-5.596	4.352	1.759282	1.244	40.42467
Length of proboscis	6	1.812-3.732	2.772	1.357645	0.96	48.97709
Length of palpi	6	0.478-1.981	1.2295	1.062781	0.7515	86.44014
Length of antennae	6	1.267-3.276	2.2715	1.420578	1.0045	62.53918
Length of wings	6	2.578-4.589	3.5835	1.421992	1.0055	39.68164
Length of foreleg						
Femur	6	2.006-2.433	2.2195	0.301935	0.2135	13.60372
Tibia	6	1.876-2.098	1.987	0.156978	0.111	7.900237
Tarsals	6	2.651-2.978	2.8145	0.231224	0.1635	8.215453
Length of middle leg						
Femur	6	2.186-2.445	2.3155	0.183141	0.1295	7.909335
Tibia	6	1.85-2.397	2.1235	0.386787	0.2735	18.21462
Tarsals	6	2.842-3.568	3.205	0.51336	0.363	16.01746
Length of hind leg						
Femur	6	2.109-2.354	2.2315	0.173241	0.1225	7.76344
Tibia	6	2.381-2.443	2.412	0.043841	0.031	1.817604
Tarsals	6	2.889-3.456	3.1725	0.40093	0.2835	12.63765

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.11 *Cx. bitaeniorhynchus*

Full body length: The length of *Culex bitaeniorhynchus* body ranges from 3.587-4.898mm and it has a mean value of 4.2425mm whereas the standard deviation, standard error, and coefficient of variance have 0.927017, 0.6555 and 21.85072 values respectively.

Length of proboscis: length of proboscis varied from 1.642-2.309mm with a mean value of 1.9755mm and SD, SE, and CV values 0.47164, 0.3335 and 23.87447 respectively.

Length of palpi: length of palpi varied from 0.243-1.432mm with a mean value of 0.8375mm and 0.84075, 0.5945 and 100.3881 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.398-2.154mm with mean value of 1.776mm and SD, SE and CV have the values 0.534573, 0.378 and 30.09982 respectively.

Length of wings: length of the wings varied from 2.458-3.981mm with 3.2195mm mean value where SD, SE and CV have the values 1.076924, 0.7615 and 33.45003 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.161-2.489mm and the mean value is 2.325mm where the values of SD, SE and CV were 0.231931, 0.164 and 9.975528 respectively.

The observed range in the length of tibia was 2.287-2.345mm with 2.316mm mean value where SD, SE and CV had the values 0.041012, 0.029 and 1.77082 respectively.

The observed range in the length of tarsals was 2.582-2.987mm with 2.7845mm mean value where SD, SE and CV had the values 0.286378, 0.2025 and 10.28473 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.204-2.454mm and the mean value is 2.329mm where the values of SD, SE and CV were 0.176777, 0.125 and 7.59024 respectively.

The observed range in the length of tibia was 2.238-2.345mm with 2.2915mm mean value where SD, SE and CV had the values 0.07566, 0.0535 and 3.301786 respectively.

The observed range in the length of tarsals was 3.288-3.455mm with 3.3715mm mean value where SD, SE and CV had 0.118087, 0.0835 and 3.502501 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.129-2.267mm and the mean value is 2.198mm where the values of SD, SE and CV were 0.097581, 0.069 and 4.439524 respectively.

The observed range in the length of tibia was 2.298-2.546mm with 2.422mm mean value where SD, SE and CV had 0.175362, 0.124 and 7.2404 values respectively. The observed range in the length of tarsals was 3.615-3.907mm with 3.761mm mean value where SD, SE and CV had 0.206475, 0.146 and 5.489901 values respectively (Table 3.13).

Table 13: Morphometric measurements of *Cx. bitaeniorhynchus*

Parameters	N	O.R	\bar{X}	SD	SE	CV%
Full body length	6	3.587-4.898	4.2425	0.927017	0.6555	21.85072
Length of proboscis	6	1.642-2.309	1.9755	0.47164	0.3335	23.87447
Length of palpi	6	0.243-1.432	0.8375	0.84075	0.5945	100.3881
Length of antennae	6	1.398-2.154	1.776	0.534573	0.378	30.09982
Length of wings	6	2.458-3.981	3.2195	1.076924	0.7615	33.45003
Length of foreleg						
Femur	6	2.161-2.489	2.325	0.231931	0.164	9.975528
Tibia	6	2.287-2.345	2.316	0.041012	0.029	1.77082
Tarsals	6	2.582-2.987	2.7845	0.286378	0.2025	10.28473
Length of middle leg						
Femur	6	2.204-2.454	2.329	0.176777	0.125	7.59024
Tibia	6	2.238-2.345	2.2915	0.07566	0.0535	3.301786
Tarsals	6	3.288-3.455	3.3715	0.118087	0.0835	3.502501
Length of hind leg						
Femur	6	2.129-2.267	2.198	0.097581	0.069	4.439524
Tibia	6	2.298-2.546	2.422	0.175362	0.124	7.2404
Tarsals	6	3.615-3.907	3.761	0.206475	0.146	5.489901

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.12 *Cx. gelidus*

Full body length: The length of *Culex gelidus* body ranges from 3.418-4.908mm and it has a mean value of 4.163mm whereas the standard deviation, standard error, and coefficient of variance have 1.053589, 0.745 and 25.30841 values respectively.

Length of proboscis: length of proboscis varied from 1.984-2.876mm with a mean value of 2.43mm and SD, SE, and CV values 0.630739, 0.446 and 25.95635 respectively.

Length of palpi: length of palpi varied from 0.476-1.098mm with a mean value of 0.787mm and 0.43982, 0.311 and 55.88569 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.655-2.845mm with mean value of 2.25mm and SD, SE and CV have the values 0.841457, 0.595 and 37.39809 respectively.

Length of wings: length of the wings varied from 2.429-3.324mm with 2.8765mm mean value where SD, SE and CV have the values 0.632861, 0.4475 and 22.00106 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.878-2.092mm and the mean value is 1.985mm where the values of SD, SE and CV were 0.151321, 0.107 and 7.623217 respectively.

The observed range in the length of tibia was 2.098-2.115mm with 2.1065mm mean value where SD, SE and CV had the values 0.012021, 0.0085 and 0.570653 respectively.

The observed range in the length of tarsals was 2.873-3.109mm with 2.991mm mean value where SD, SE and CV had the values 0.166877, 0.118 and 5.579311 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.953-2.428mm and the mean value is 2.1905mm where the values of SD, SE and CV were 0.335876, 0.2375 and 15.33329 respectively.

The observed range in the length of tibia was 1.987-2.343mm with 2.165mm mean value where SD, SE and CV had the values 0.25173, 0.178 and 11.62725 respectively.

The observed range in the length of tarsals was 2.993-3.542mm with 3.2675mm mean value where SD, SE and CV had 0.388202, 0.2745 and 11.88069 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.083-2.421mm and the mean value is 2.252mm where the values of SD, SE and CV were 0.239002, 0.169 and 10.61288 respectively.

The observed range in the length of tibia was 2.119-2.349mm with 2.234mm mean value where SD, SE and CV had 0.162635, 0.115 and 7.279971 values respectively. The observed range in the length of tarsals was 3.356-3.945mm with 3.6505mm mean value where SD, SE and CV had 0.416486, 0.2945 and 11.40901 values respectively (Table 3.14).

Table 3.14: Morphometric measurements of *Cx. gelidus*

Parameters	N	O.R	\bar{X}	SD	SE	CV
Full body length	6	3.418-4.908	4.163	1.053589	0.745	25.30841
Length of proboscis	6	1.984-2.876	2.43	0.630739	0.446	25.95635
Length of palpi	6	0.476-1.098	0.787	0.43982	0.311	55.88569
Length of antennae	6	1.655-2.845	2.25	0.841457	0.595	37.39809
Length of wings	6	2.429-3.324	2.8765	0.632861	0.4475	22.00106
Length of foreleg						
Femur	6	1.878-2.092	1.985	0.151321	0.107	7.623217
Tibia	6	2.098-2.115	2.1065	0.012021	0.0085	0.570653
Tarsals	6	2.873-3.109	2.991	0.166877	0.118	5.579311
Length of middle leg						
Femur	6	1.953-2.428	2.1905	0.335876	0.2375	15.33329
Tibia	6	1.987-2.343	2.165	0.25173	0.178	11.62725
Tarsals	6	2.993-3.542	3.2675	0.388202	0.2745	11.88069
Length of hind leg						
Femur	6	2.083-2.421	2.252	0.239002	0.169	10.61288
Tibia	6	2.119-2.349	2.234	0.162635	0.115	7.279971
Tarsals	6	3.356-3.945	3.6505	0.416486	0.2945	11.40901

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.13 *Cx. fuscocephala*

Full body length: The length of *Culex fuscocephala* body ranges from 3.798-4.597mm and it has a mean value of 4.1975mm whereas the standard deviation, standard error, and coefficient of variance have 0.564978, 0.3995 and 13.45988 values respectively.

Length of proboscis: length of proboscis varied from 2.013-2.786mm with a mean value of 2.3995mm and SD, SE, and CV values 0.546594, 0.3865 and 22.77948 respectively.

Length of palpi: length of palpi varied from 0.389-0.982mm with a mean value of 0.6855mm and 0.419314, 0.2965 and 61.16912 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.599-2.698mm with 2.1485mm mean value of and SD, SE and CV have the values 0.77711, 0.5495 and 36.1699 respectively.

Length of wings: length of the wings varied from 3.512-3.994mm with 3.753mm mean value where SD, SE and CV have the values 0.340825, 0.241 and 9.081414 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.797-1.988mm and the mean value is 1.8925mm where the values of SD, SE and CV were 0.135057, 0.0955 and 7.136454 respectively.

The observed range in the length of tibia was 1.854-1.998mm with 1.926mm mean value where SD, SE and CV had the values 0.101823, 0.072 and 5.28678 respectively.

The observed range in the length of tarsals was 2.987-3.567mm with 3.277mm mean value where SD, SE and CV had the values 0.410122, 0.29 and 12.51516 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.809-1.968mm and the mean value is 1.8885mm where the values of SD, SE and CV were 0.11243, 0.0795 and 5.953401 respectively.

The observed range in the length of tibia was 1.922-1.999mm with 1.9605mm mean value where SD, SE and CV had the values 0.054447, 0.0385 and 2.777211 respectively.

The observed range in the length of tarsals was 2.983-3.678mm with 3.3305mm mean value where SD, SE and CV had 0.491439, 0.3475 and 14.75572 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.866-2.086mm and the mean value is 1.976mm where the values of SD, SE and CV were 0.155563, 0.11 and 7.872646 respectively.

The observed range in the length of tibia was 1.887-2.011mm with mean value 1.949mm where SD, SE and CV had 0.087681, 0.062 and 4.498781 values respectively. The observed range in the length of tarsals was 3.089-3.984mm with 3.5365mm mean value where SD, SE and CV had values 0.632861, 0.4475 and 17.89511 respectively (Table 3.15).

Table 3.14: Morphometric measurements of *Cx. fuscocephala*

Parameters	N	O.R	\bar{X}	SD	SE	CV%
Full body length	6	3.798-4.597	4.1975	0.564978	0.3995	13.45988
Length of proboscis	6	2.013-2.786	2.3995	0.546594	0.3865	22.77948
Length of palpi	6	0.389-0.982	0.6855	0.419314	0.2965	61.16912
Length of antennae	6	1.599-2.698	2.1485	0.77711	0.5495	36.1699
Length of wings	6	3.512-3.994	3.753	0.340825	0.241	9.081414
Length of foreleg						
Femur	6	1.797-1.988	1.8925	0.135057	0.0955	7.136454
Tibia	6	1.854-1.998	1.926	0.101823	0.072	5.28678
Tarsals	6	2.987-3.567	3.277	0.410122	0.29	12.51516
Length of middle leg						
Femur	6	1.809-1.968	1.8885	0.11243	0.0795	5.953401
Tibia	6	1.922-1.999	1.9605	0.054447	0.0385	2.777211
Tarsals	6	2.983-3.678	3.3305	0.491439	0.3475	14.75572
Length of hind leg						
Femur	6	1.866-2.086	1.976	0.155563	0.11	7.872646
Tibia	6	1.887-2.011	1.949	0.087681	0.062	4.498781
Tarsals	6	3.089-3.984	3.5365	0.632861	0.4475	17.89511

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD =standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.14 *Cx. vishnui*

Full body length: The length of *Culex vishnui* body ranges from 3.918-5.967mm and it has a mean value of 4.9425mm whereas the standard deviation, standard error, and coefficient of variance have 1.448862, 1.0245 and 29.31435 values respectively.

Length of proboscis: length of proboscis varied from 1.632-2.098mm with a mean value of 1.865mm and SD, SE, and CV values 0.329512, 0.233 and 17.66819 respectively.

Length of palpi: length of palpi varied from 0.473-1.584mm with a mean value of 1.0285mm and 0.785596, 0.5555 and 76.38266 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.655-2.342mm with 1.9985mm mean value of and SD, SE and CV have the values 0.485782, 0.3435 and 24.30735 respectively.

Length of wings: length of the wings varied from 2.739-4.685mm with 3.712mm mean value where SD, SE and CV have the values 1.37603, 0.973 and 37.06977 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.977-2.234mm and the mean value is 2.1055mm where the values of SD, SE and CV were 0.181726, 0.1285 and 8.631035 respectively.

The observed range in the length of tibia was 2.017-2.342mm with 2.1795mm mean value where SD, SE and CV had the values 0.22981, 0.1625 and 10.54415 respectively.

The observed range in the length of tarsals was 3.168-3.678mm with 3.423mm mean value where SD, SE and CV had the values 0.360624, 0.255 and 10.53533 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.032-2.456mm and the mean value is 2.244mm where the values of SD, SE and CV were 0.299813, 0.212 and 13.36066 respectively.

The observed range in the length of tibia was 2.112-2.577mm with 2.3445mm mean value where SD, SE and CV had the values 0.328805, 0.2325 and 14.02451 respectively.

The observed range in the length of tarsals was 3.235-3.768mm with 3.5015mm mean value where SD, SE and CV had 0.376888, 0.2665 and 10.76361 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.067-2.497mm and the mean value is 2.282mm where the values of SD, SE and CV were 0.304056, 0.215 and 13.3241 respectively.

The observed range in the length of tibia was 2.178-2.589mm with 2.3835mm mean value where SD, SE and CV had 0.290621, 0.2055 and 12.19303 values respectively. The observed range in the length of tarsals was 3.929-4.563mm with 4.246mm mean value where SD, SE and CV had values 0.448306, 0.317 and 10.55831 respectively (Table 3.16).

Table 15: Morphometric measurements of *Cx. vishnui*

Parameters	N	O.R	\bar{X}	SD	SE	CV%
Full body length	6	3.918-5.967	4.9425	1.448862	1.0245	29.31435
Length of proboscis	6	1.632-2.098	1.865	0.329512	0.233	17.66819
Length of palpi	6	0.473-1.584	1.0285	0.785596	0.5555	76.38266
Length of antennae	6	1.655-2.342	1.9985	0.485782	0.3435	24.30735
Length of wings	6	2.739-4.685	3.712	1.37603	0.973	37.06977
Length of foreleg						
Femur	6	1.977-2.234	2.1055	0.181726	0.1285	8.631035
Tibia	6	2.017-2.342	2.1795	0.22981	0.1625	10.54415
Tarsals	6	3.168-3.678	3.423	0.360624	0.255	10.53533
Length of middle leg						
Femur	6	2.032-2.456	2.244	0.299813	0.212	13.36066
Tibia	6	2.112-2.577	2.3445	0.328805	0.2325	14.02451
Tarsals	6	3.235-3.768	3.5015	0.376888	0.2665	10.76361
Length of hind leg						
Femur	6	2.067-2.497	2.282	0.304056	0.215	13.3241
Tibia	6	2.178-2.589	2.3835	0.290621	0.2055	12.19303
Tarsals	6	3.929-4.563	4.246	0.448306	0.317	10.55831

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.15 *Cx. pseudovishnui*

Full body length: The length of *Culex pseudovishnui* body ranges from 3.981-5.109mm and it has a mean value of 4.545mm whereas the standard deviation, standard error, and coefficient of variance have 0.797616, 0.564 and 17.54932 values respectively.

Length of proboscis: length of proboscis varied from 1.965-2.341mm with a mean value of 2.153mm and SD, SE, and CV values 0.265872, 0.188 and 12.34892 respectively.

Length of palpi: length of palpi varied from 0.526-1.111mm with a mean value of 0.8185mm and 0.413657, 0.2925 and 50.53848 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.599-2.356mm with 1.9775mm mean value of and SD, SE and CV have the values 0.53528, 0.3785 and 27.06851 respectively.

Length of wings: length of the wings varied from 3.284-4.846mm with 4.065mm mean value where SD, SE and CV have the values 1.104501, 0.781 and 27.17099 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.925-2.098mm and the mean value is 2.0115mm where the values of SD, SE and CV were 0.122329, 0.0865 and 6.081505 respectively.

The observed range in the length of tibia was 2.059-2.301mm with 2.18mm mean value where SD, SE and CV had the values 0.17112, 0.121 and 7.849534 respectively.

The observed range in the length of tarsals was 2.94-3.098mm with 3.019mm mean value where SD, SE and CV had the values 0.111723, 0.079 and 3.700658 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.987-2.145mm and the mean value is 2.066mm where the values of SD, SE and CV were 0.111723, 0.079 and 5.40769 respectively.

The observed range in the length of tibia was 1.995-2.325mm with 2.16mm mean value where SD, SE and CV had the values 0.233345, 0.165 and 10.80302 respectively.

The observed range in the length of tarsals was 3.009-3.765mm with 3.387mm mean value where SD, SE and CV had 0.534573, 0.378 and 15.78307 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.883-2.245mm and the mean value is 2.064mm where the values of SD, SE and CV were 0.255973, 0.181 and 12.40178 respectively.

The observed range in the length of tibia was 2.057-2.367mm with 2.212mm mean value where SD, SE and CV had 0.219203, 0.155 and 9.909724 values respectively. The observed range in the length of tarsals was 3.598-4.906mm with 4.252mm mean value where SD, SE and CV had 0.924896, 0.654 and 21.75201 values respectively (Table 3.17).

Table 3.16: Morphometric measurements of *Cx. pseudovishnui*

Parameters	N	O.R	\bar{X}	SD	SE	CV%
Full body length	6	3.981-5.109	4.545	0.797616	0.564	17.54932
Length of proboscis	6	1.965-2.341	2.153	0.265872	0.188	12.34892
Length of palpi	6	0.526-1.111	0.8185	0.413657	0.2925	50.53848
Length of antennae	6	1.599-2.356	1.9775	0.53528	0.3785	27.06851
Length of wings	6	3.284-4.846	4.065	1.104501	0.781	27.17099
Length of foreleg						
Femur	6	1.925-2.098	2.0115	0.122329	0.0865	6.081505
Tibia	6	2.059-2.301	2.18	0.17112	0.121	7.849534
Tarsals	6	2.94-3.098	3.019	0.111723	0.079	3.700658
Length of middle leg						
Femur	6	1.987-2.145	2.066	0.111723	0.079	5.40769
Tibia	6	1.995-2.325	2.16	0.233345	0.165	10.80302
Tarsals	6	3.009-3.765	3.387	0.534573	0.378	15.78307
Length of hind leg						
Femur	6	1.883-2.245	2.064	0.255973	0.181	12.40178
Tibia	6	2.057-2.367	2.212	0.219203	0.155	9.909724
Tarsals	6	3.598-4.906	4.252	0.924896	0.654	21.75201

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.16 *Cx. whitmorei*

Full body length: The length of *Culex whitmorei* body ranges from 4.787-5.923mm and it has a mean value of 5.355mm whereas the standard deviation, standard error, and coefficient of variance have 0.803273, 0.568 and 15.00044 values respectively.

Length of proboscis: length of proboscis varied from 2.02-2.87mm with a mean value of 2.445mm and SD, SE, and CV values 0.601041, 0.425 and 24.58244 respectively.

Length of palpi: length of palpi varied from 0.509-1.098mm with a mean value of 0.8035mm and 0.416486, 0.2945 and 51.83396 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.811-2.678mm with 2.2445mm mean value and SD, SE and CV have the values 0.613062, 0.4335 and 27.31395 respectively.

Length of wings: length of the wings varied from 3.504-4.564mm with 4.034mm mean value where SD, SE and CV have the values 0.749533, 0.53 and 18.5804 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.245-2.983mm and the mean value is 2.614mm where the values of SD, SE and CV were 0.521845, 0.369 and 19.96346 respectively.

The observed range in the length of tibia was 2.324-2.997mm with mean value 2.6605mm where SD, SE and CV had the values 0.475883, 0.3365 and 17.88697 respectively.

The observed range in the length of tarsals was 3.029-4.176mm with 3.6025mm mean value where SD, SE and CV had the values 0.811051, 0.5735 and 22.51357 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.283-2.543mm and the mean value is 2.413mm where the values of SD, SE and CV were 0.183848, 0.13 and 7.619054 respectively.

The observed range in the length of tibia was 2.366-2.567mm with 2.4665mm mean value where SD, SE and CV had the values 0.142128, 0.1005 and 5.762354 respectively.

The observed range in the length of tarsals was 3.423-4.541mm with 3.982mm mean value where SD, SE and CV had 0.790545, 0.559 and 19.85297 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 2.303-2.676mm and the mean value is 2.4895mm where the values of SD, SE and CV were 0.263751, 0.1865 and 10.59453 respectively.

The observed range in the length of tibia was 2.329-2.762mm with 2.5455mm mean value where SD, SE and CV had 0.306177, 0.2165 and 12.02818 values respectively. The observed range in the length of tarsals was 3.987-4.876mm with 4.4315mm mean value where SD, SE and CV had 0.628618, 0.4445 and 14.18522 values respectively (Table 3.18).

Table 3.17: Morphometric measurements of *Cx. whitmorei*

Parameters	N	O.R	\bar{X}	SD	SE	CV%
Full body length	6	4.787-5.923	5.355	0.803273	0.568	15.00044
Length of proboscis	6	2.02-2.87	2.445	0.601041	0.425	24.58244
Length of palpi	6	0.509-1.098	0.8035	0.416486	0.2945	51.83396
Length of antennae	6	1.811-2.678	2.2445	0.613062	0.4335	27.31395
Length of wings	6	3.504-4.564	4.034	0.749533	0.53	18.5804
Length of foreleg						
Femur	6	2.245-2.983	2.614	0.521845	0.369	19.96346
Tibia	6	2.324-2.997	2.6605	0.475883	0.3365	17.88697
Tarsals	6	3.029-4.176	3.6025	0.811051	0.5735	22.51357
Length of middle leg						
Femur	6	2.283-2.543	2.413	0.183848	0.13	7.619054
Tibia	6	2.366-2.567	2.4665	0.142128	0.1005	5.762354
Tarsals	6	3.423-4.541	3.982	0.790545	0.559	19.85297
Length of hind leg						
Femur	6	2.303-2.676	2.4895	0.263751	0.1865	10.59453
Tibia	6	2.329-2.762	2.5455	0.306177	0.2165	12.02818
Tarsals	6	3.987-4.876	4.4315	0.628618	0.4445	14.18522

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.17 *Ar. obturbans*

Full body length: The length of *Armigeres obturbans* body ranges from 3.997-5.982mm and it has a mean value of 4.9895mm whereas the standard deviation, standard error, and coefficient of variance have values 1.403607, 0.9925 and 28.13121 respectively.

Length of proboscis: length of proboscis varied from 2.143-3.967mm with a mean value of 3.055mm and SD, SE, and CV values 1.289763, 0.912 and 42.21809 respectively.

Length of palpi: length of palpi varied from 0.597-2.023mm with a mean value of 1.31mm and 1.008334, 0.713 and 76.97208 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.967-3.456mm with mean value of 2.7115mm and SD, SE and CV have the values 1.052882, 0.7445 and 38.83024 respectively.

Length of wings: length of the wings varied from 2.924-4.876mm with mean value 3.9mm where SD, SE and CV have the values 1.380272, 0.976 and 35.3916 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.324-2.765mm and the mean value is 2.0445mm where the values of SD, SE and CV were 1.018941, 0.7205 and 49.83814 respectively.

The observed range in the length of tibia was 1.543-2.672mm with 2.1075mm mean value where SD, SE and CV had the values 0.798324, 0.5645 and 37.88012 respectively.

The observed range in the length of tarsals was 2.776-3.687mm with 3.2315mm mean value where SD, SE and CV had the values 0.644174, 0.4555 and 19.93422 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.398-2.876mm and the mean value is 2.137mm where the values of SD, SE and CV were 1.045104, 0.739 and 48.90519 respectively.

The observed range in the length of tibia was 1.467-2.978mm with 2.2225mm mean value where SD, SE and CV had the values 1.068438, 0.7555 and 48.07372 respectively.

The observed range in the length of tarsals was 2.986-3.953mm with 3.4695mm mean value where SD, SE and CV had 0.683772, 0.4835 and 19.70809 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.509-2.789mm and the mean value is 2.149mm where the values of SD, SE and CV were 0.905097, 0.64 and 42.11711 respectively.

The observed range in the length of tibia was 1.675-2.886mm with mean value 2.2805mm where SD, SE and CV had 0.856306, 0.6055 and 37.54906 values respectively. The observed range in the length of tarsals was 2.998-4.097mm with 3.5475mm mean value where SD, SE and CV had 0.77711, 0.5495 and 21.90586 values respectively (Table 3.19).

Table 3.18: Morphometric measurements of *Ar. obturbans*

Parameters	N	O.R	\bar{X}	SD	SE	CV%
Full body length	6	3.997-5.982	4.9895	1.403607	0.9925	28.13121
Length of proboscis	6	2.143-3.967	3.055	1.289763	0.912	42.21809
Length of palpi	6	0.597-2.023	1.31	1.008334	0.713	76.97208
Length of antennae	6	1.967-3.456	2.7115	1.052882	0.7445	38.83024
Length of wings	6	2.924-4.876	3.9	1.380272	0.976	35.3916
Length of foreleg						
Femur	6	1.324-2.765	2.0445	1.018941	0.7205	49.83814
Tibia	6	1.543-2.672	2.1075	0.798324	0.5645	37.88012
Tarsals	6	2.776-3.687	3.2315	0.644174	0.4555	19.93422
Length of middle leg						
Femur	6	1.398-2.876	2.137	1.045104	0.739	48.90519
Tibia	6	1.467-2.978	2.2225	1.068438	0.7555	48.07372
Tarsals	6	2.986-3.953	3.4695	0.683772	0.4835	19.70809
Length of hind leg						
Femur	6	1.509-2.789	2.149	0.905097	0.64	42.11711
Tibia	6	1.675-2.886	2.2805	0.856306	0.6055	37.54906
Tarsals	6	2.998-4.097	3.5475	0.77711	0.5495	21.90586

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

3.4.18 *Ar. kuchingensis*

Full body length: The length of *Armigeres kuchingensis* body ranges from 3.651-4.987mm and it has a mean value of 4.319mm whereas the standard deviation, standard error, and coefficient of variance have 0.944695, 0.668 and 21.873 values respectively.

Length of proboscis: length of proboscis varied from 1.988-2.693mm with a mean value of 2.3405mm and SD, SE, and CV values 0.49851, 0.3525 and 21.29931 respectively.

Length of palpi: length of palpi varied from 0.325-0.987mm with a mean value of 0.656mm and 0.468105, 0.331 and 71.35742 as values of SD, SE, and CV respectively.

Length of antennae: length of antennae ranged from 1.974-2.987mm with mean value of 2.4805mm and SD, SE and CV have the values 0.716299, 0.5065 and 28.87721 respectively.

Length of wings: length of the wings varied from 2.896-4.098mm with 3.497mm mean value where SD, SE and CV have the values 0.849942, 0.601 and 24.3049 respectively.

Length of foreleg: length of the different segments of the leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.746-1.996mm and the mean value is 1.871mm where the values of SD, SE and CV were 0.176777, 0.125 and 9.448247 respectively.

The observed range in the length of tibia was 1.893-2.012mm with 1.9525mm mean value where SD, SE and CV had the values 0.084146, 0.0595 and 4.309639 respectively.

The observed range in the length of tarsals was 2.987-3.215mm with 3.101mm mean value where SD, SE and CV had the values 0.16122, 0.114 and 5.198979 respectively.

Length of middle leg: length of the different segments of the middle leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.721-1.937mm and the mean value is 1.829mm where the values of SD, SE and CV were 0.152735, 0.108 and 8.350742 respectively.

The observed range in the length of tibia was 1.821-1.998mm with mean value 1.9095mm where SD, SE and CV had the values 0.125158, 0.0885 and 6.554485 respectively.

The observed range in the length of tarsals was 2.888-3.356mm with 3.122mm mean value where SD, SE and CV had 0.330926, 0.234 and 10.59981 values respectively.

Length of hind leg: length of the different segments of the hind leg such as femur, tibia and tarsals were observed. The observed range in length of the femur was 1.808-1.997mm and the mean value is 1.9025mm where the values of SD, SE and CV were 0.133643, 0.0945 and 7.024609 respectively.

The observed range in the length of tibia was 1.973-2.121mm with mean value 2.047mm where SD, SE and CV had 0.104652, 0.074 and 5.112448 values respectively.

The observed range in the length of tarsals was 3.667-4.098mm with 3.8825mm mean value where SD, SE and CV had 0.304763, 0.2155 and 7.849659 values respectively (Table 3.20).

Table 3.19: Morphometric measurements of *Ar. kuchingensis*

Parameters	N	O.R	\bar{X}	SD	SE	CV
Full body length	6	3.651-4.987	4.319	0.944695	0.668	21.873
Length of proboscis	6	1.988-2.693	2.3405	0.49851	0.3525	21.29931
Length of palpi	6	0.325-0.987	0.656	0.468105	0.331	71.35742
Length of antennae	6	1.974-2.987	2.4805	0.716299	0.5065	28.87721
Length of wings	6	2.896-4.098	3.497	0.849942	0.601	24.3049
Length of foreleg						
Femur	6	1.746-1.996	1.871	0.176777	0.125	9.448247
Tibia	6	1.893-2.012	1.9525	0.084146	0.0595	4.309639
Tarsals	6	2.987-3.215	3.101	0.16122	0.114	5.198979
Length of middle leg						
Femur	6	1.721-1.937	1.829	0.152735	0.108	8.350742
Tibia	6	1.821-1.998	1.9095	0.125158	0.0885	6.554485
Tarsals	6	2.888-3.356	3.122	0.330926	0.234	10.59981
Length of hind leg						
Femur	6	1.808-1.997	1.9025	0.133643	0.0945	7.024609
Tibia	6	1.973-2.121	2.047	0.104652	0.074	5.112448
Tarsals	6	3.667-4.098	3.8825	0.304763	0.2155	7.849659

N=Number of samples; O.R=Observed range; \bar{X} =Mean; SD=Standard deviation; SE=Standard error; CV=Coefficient of variability

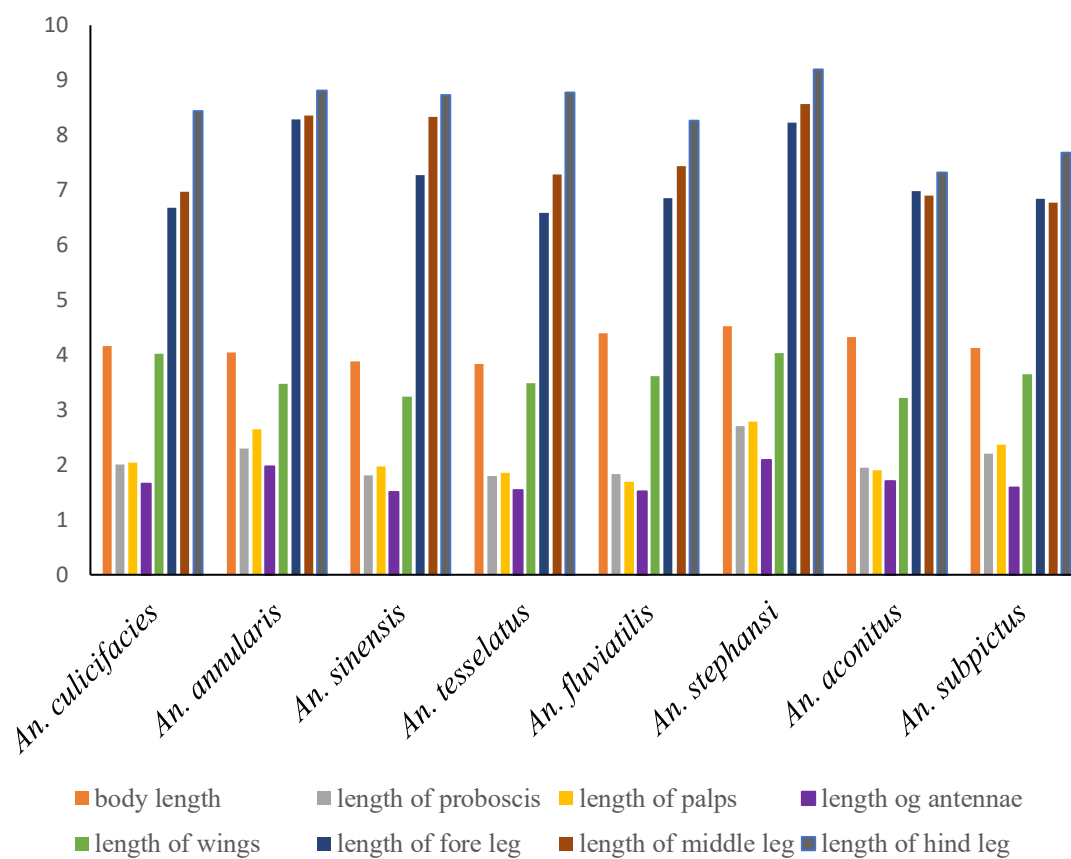


Figure 3.19: Comparison of measurements of body size of *Anopheles* species

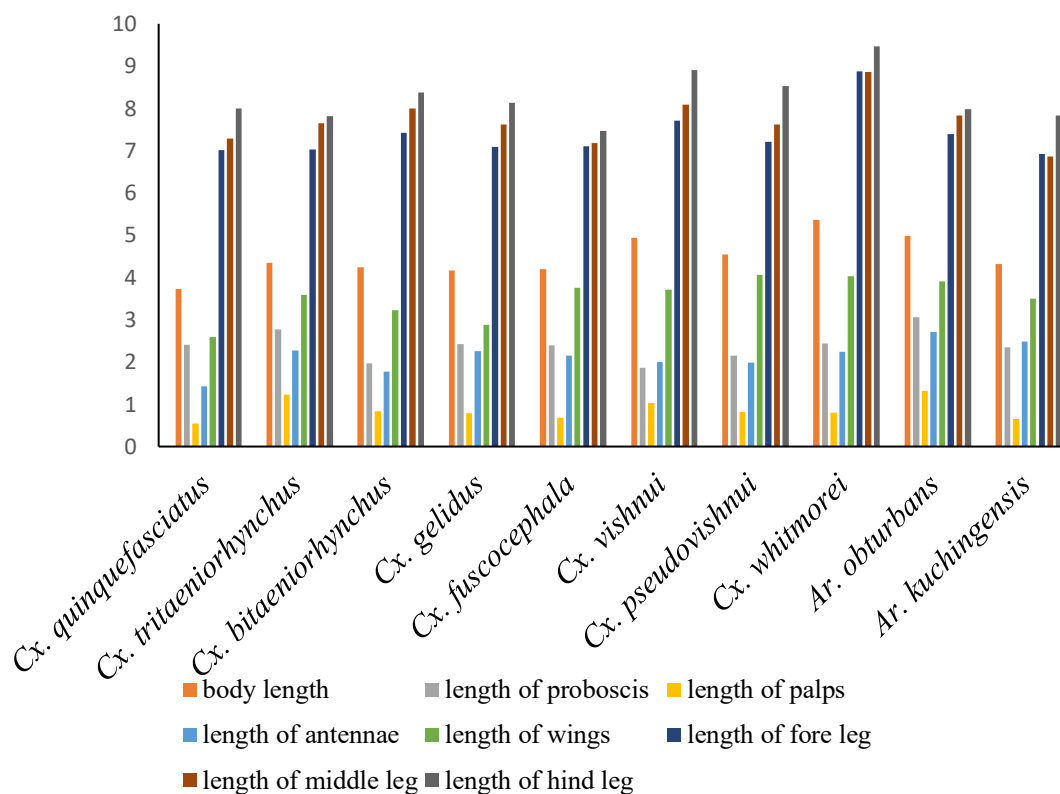


Figure 3.20: Comparison of measurements of body size of *Culex* and *Armigeres* species

Table 3.20: Mosquito fauna of District Bannu

Species	<i>An. annularis</i>	<i>An. sinensis</i>	<i>An. stephansi</i>	<i>Cx. quinquefasciatus</i>	<i>Cx. tritaneorhynchus</i>	Total number	
Male	6	12	7	9	13	47	
Female	15	12	23	22	28	100	
% age	Male	4.08	8.16	4.76	6.122	8.84	147
	Female	10.20	8.16	15.65	14.97	19.05	

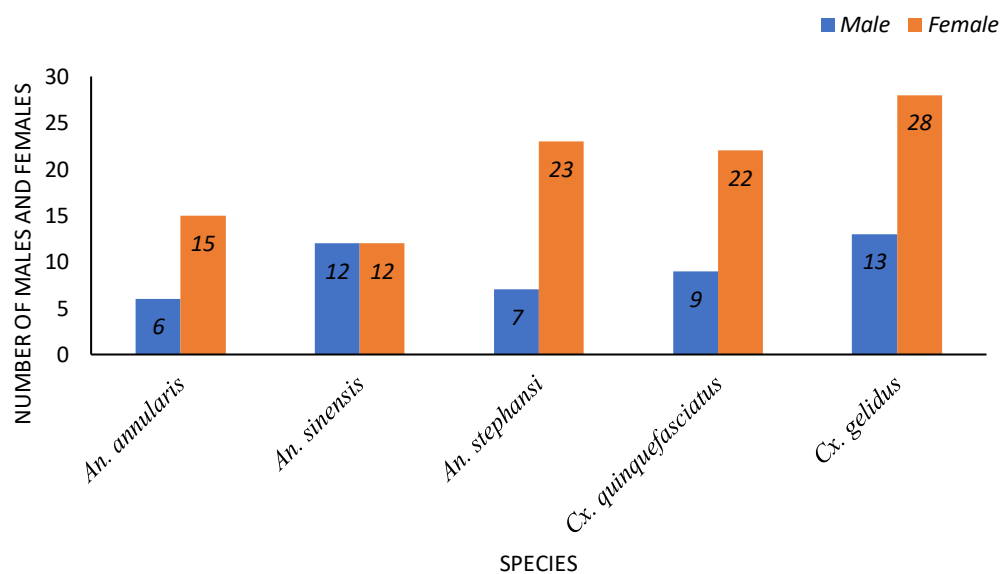
**Figure 3.21:** Representation of species and number of male and female mosquitoes collected from Bannu.

Table 3.21: Mosquito fauna of District Karak

Species	<i>An. annularis</i>	<i>An. aconitus</i>	<i>Cx. quinquefasciatus</i>	<i>Cx. tritaneorhynchus</i>	Total number	
Male	5	3	8	12	28	
Female	13	9	27	23	72	
%age	Male	5	3	8	12	100
	Female	13	9	27	23	

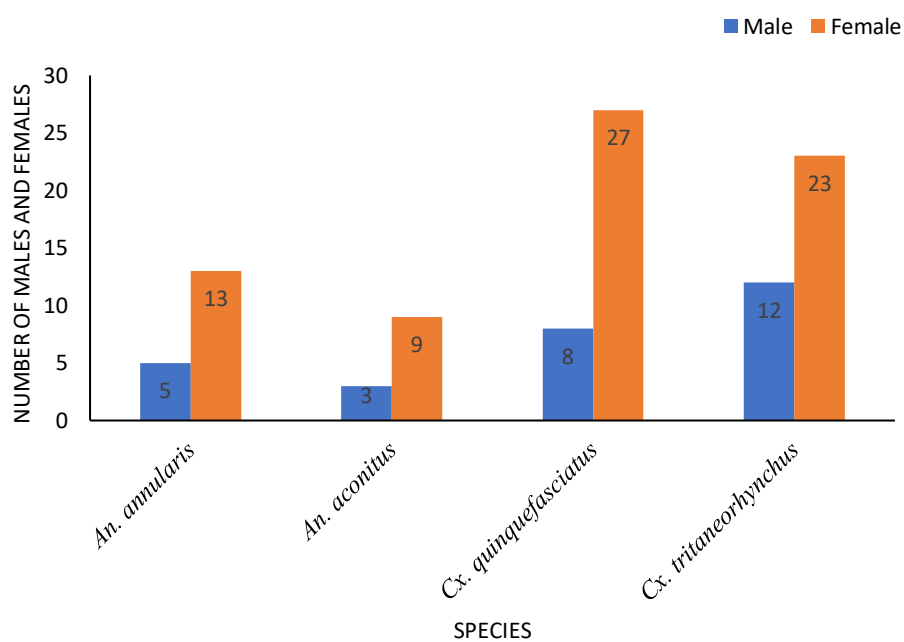
**Figure 3.22:** Representation of species and number of male and female mosquitoes collected from Karak.

Table 3.22: Mosquito fauna of District Mardan

Species		<i>An. culicifacies</i>	<i>Cx. quinquefasciatus</i>	<i>Cx. tritaneorhynchus</i>	<i>Cx. fuscocephala</i>	<i>Cx. vishnui</i>	Total number
Male		9	4	5	2	10	30
Female		18	23	21	14	26	102
% age	Male	6.82	3.03	3.79	1.52	7.57	132
	Female	13.63	17.42	15.91	10.61	19.70	

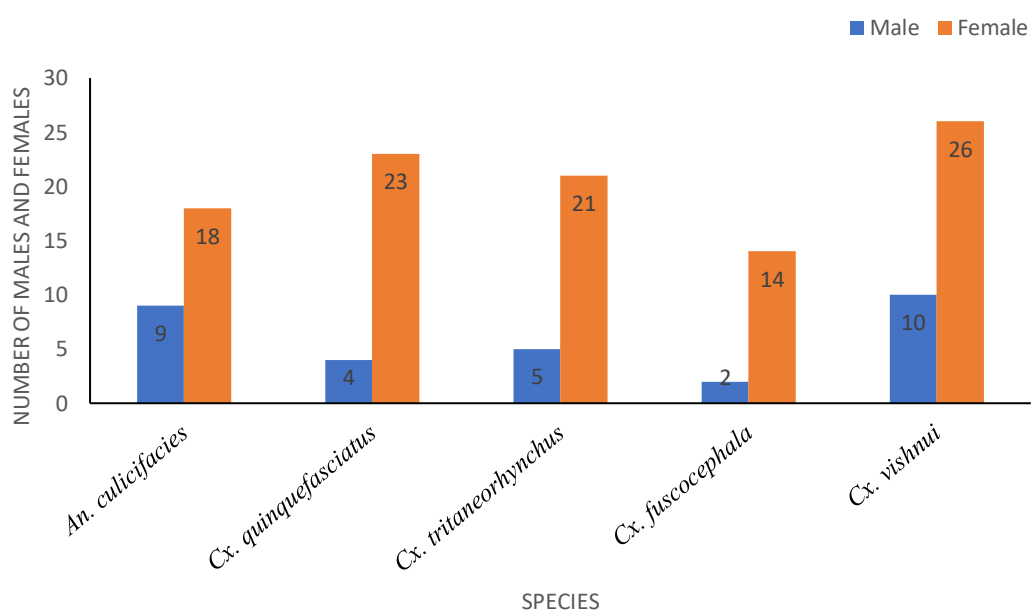
**Figure 3.23:** Representation of species and number of male and female mosquitoes collected from Mardan.

Table 3.23: Mosquito fauna of District Lower Dir

Species	<i>An. annularis</i>	<i>An. fluviatilis</i>	<i>Cx. quinquefasciatus</i>	<i>Cx. vishnui</i>	<i>Cx. pseudovishnui</i>	Total number	
Male	3	4	11	15	4	37	
Female	15	7	24	10	6	62	
%age	Male	3.03	4.04	11.11	15.15	4.04	99
	Female	15.15	7.07	24.24	10.10	6.06	

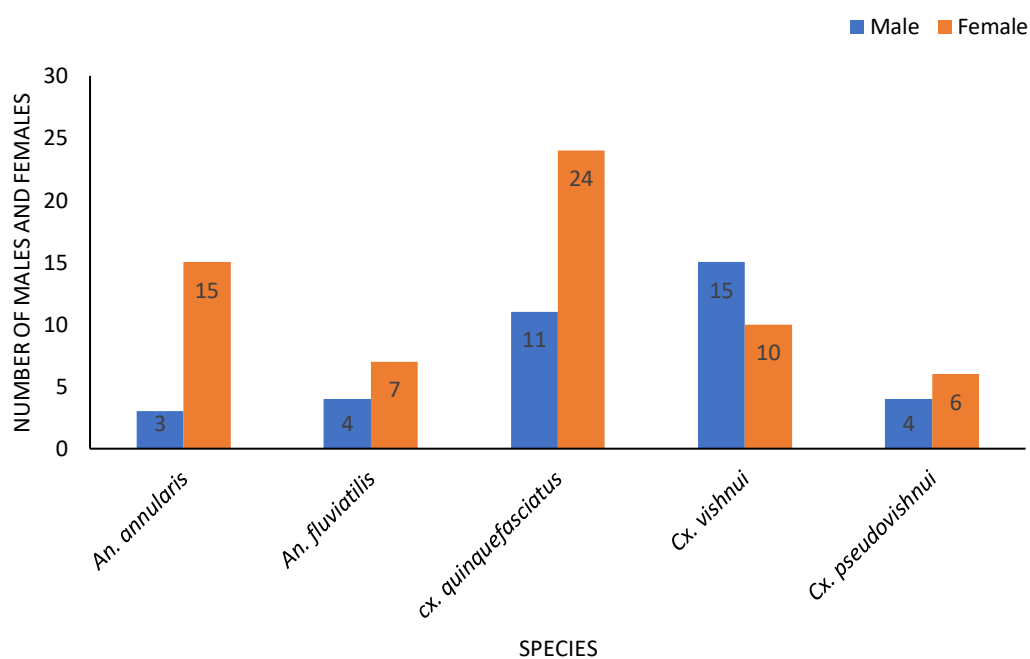
**Figure 3.24:** Representation of species and number of male and female mosquitoes collected from Lower Dir

Table 3.24: Mosquito fauna of District Upper Dir

Species		<i>An. stephensi</i>	<i>An. fluviatilis</i>	<i>An. subpictus</i>	<i>Cx. quinquefasciatus</i>	<i>Cx. fuscocephala</i>	<i>Cx. gelidus</i>	Total number
Male		11	4	8	2	7	7	39
Female		27	9	17	12	13	19	97
% age	Male	8.09	2.94	5.88	1.47	5.15	5.15	136
	Female	19.85	6.62	12.5	8.82	9.55	13.97	

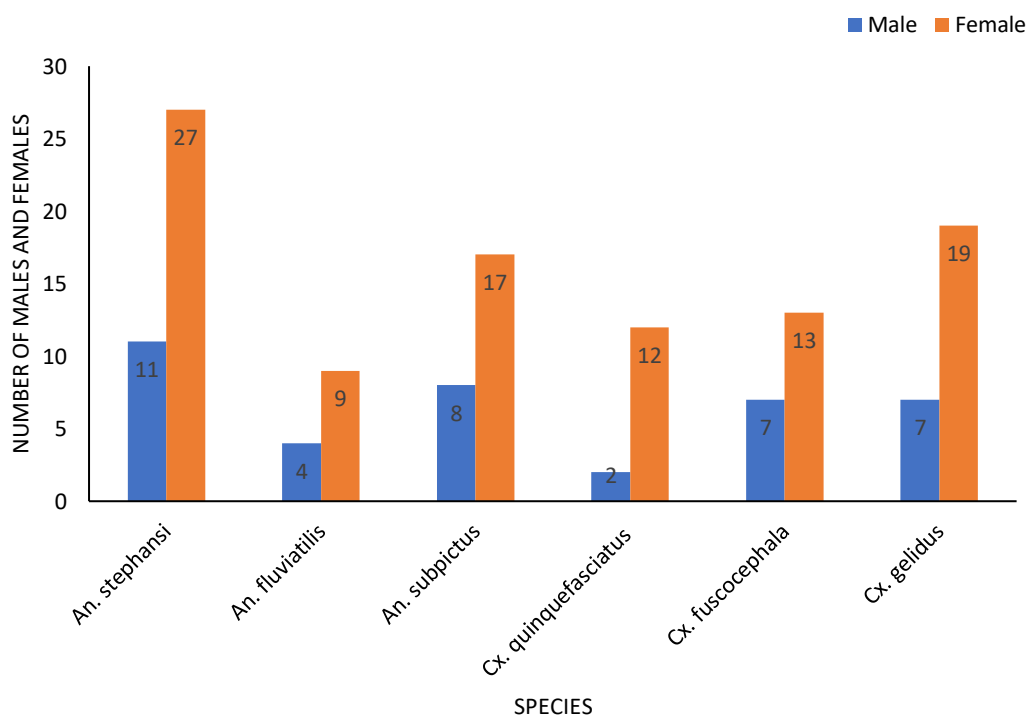
**Figure 3.25:** Representation of species and number of male and female mosquitoes collected from Upper Dir.

Table 3.25: Mosquito fauna of District Swat

Species	<i>An. culicifacies</i>	<i>An. stephansi</i>	<i>Cx. gelidus</i>	<i>Cx. pseudovishnui</i>	<i>Ar. obturbans</i>	Total number	
Male	2	13	6	9	5	35	
Female	14	25	9	5	16	69	
%age	Male	1.92	12.5	5.77	8.65	4.81	104
	Female	13.46	24.04	8.65	4.81	15.38	

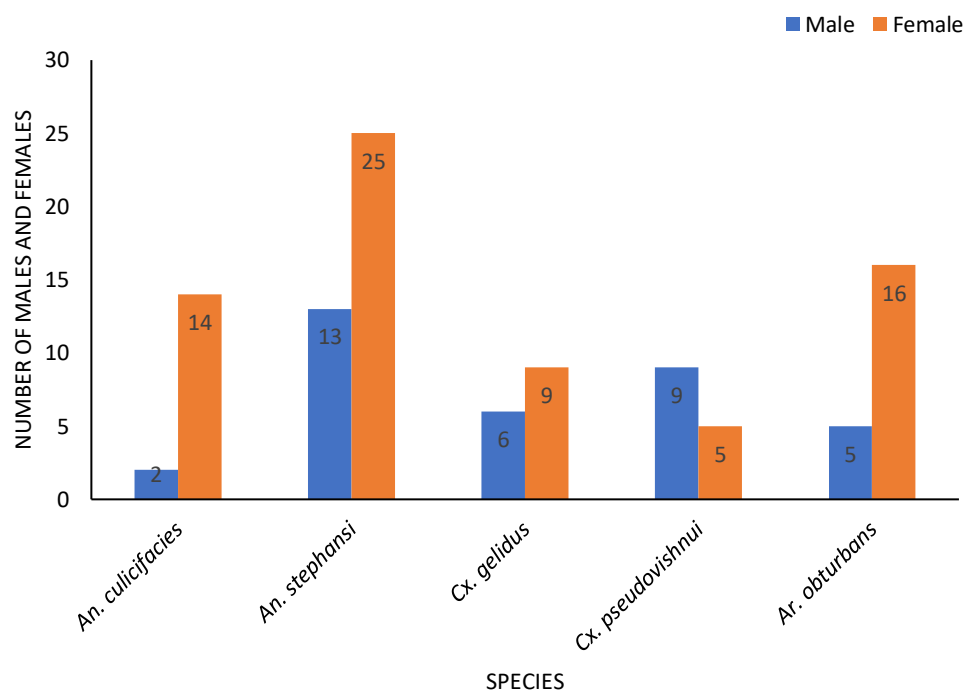
**Figure 3.26:** Representation of species and number of male and female mosquitoes collected from Swat.

Table 3.26: Mosquito fauna of District Swabi

Species		<i>An. tessellatus</i>	<i>An. subpictus</i>	<i>Cx. tritaneorhynchus</i>	<i>Cx. bitaneorhynchus</i>	<i>Cx. vishnui</i>	Total number
Male		0	7	16	3	5	31
Female		5	14	22	12	13	66
%age	Male	0	7.21	16.49	3.09	5.15	97
	Female	5.15	14.43	22.68	12.37	13.40	

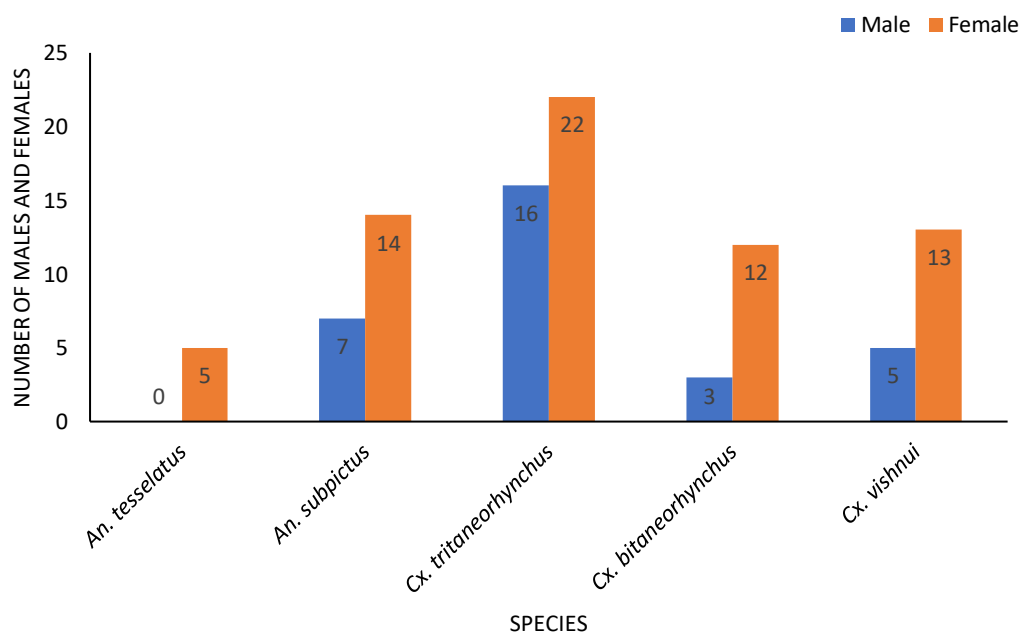
**Figure 3.27:** Representation of species and number of male and female mosquitoes collected from Swabi.

Table 3.27: Mosquito fauna of District Lakki Marwat.

Species	<i>An. culicifacies</i>	<i>An. sinensis</i>	<i>Cx. whitmori</i>	<i>Ar. obturbans</i>	<i>Ar. kuchingansis</i>	Total number	
Male	8	6	2	7	9	32	
Female	14	23	9	13	16	75	
%age	Male	7.47	5.61	1.87	6.54	8.41	107
	Female	13.08	21.5	8.41	12.15	14.95	

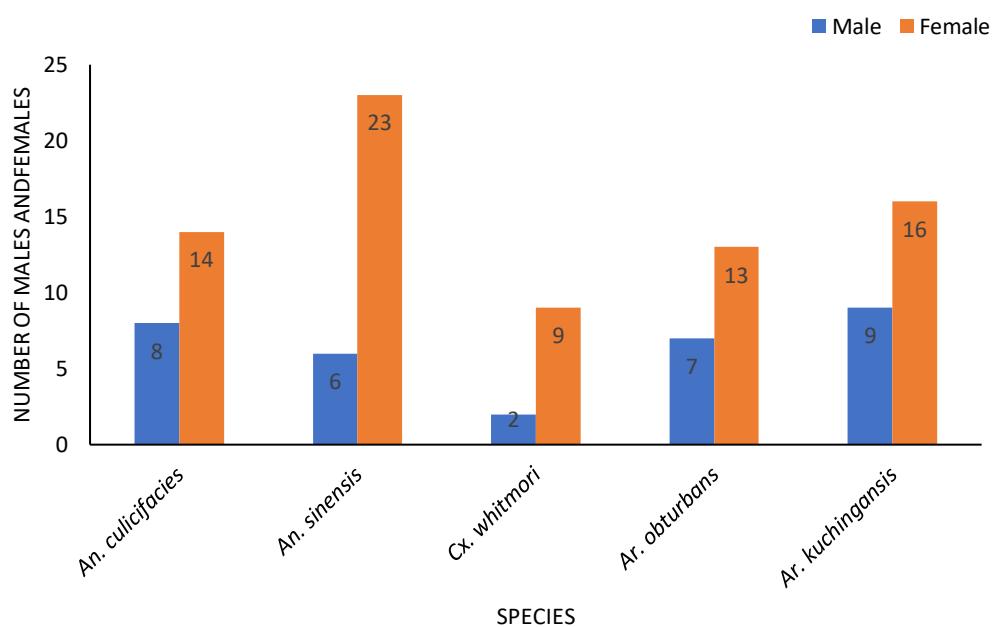
**Figure 3.28:** Representation of species and number of male and female mosquitoes collected from Lakki Marwat.

Table 3.28: Mosquito fauna of District Peshawar

Species	<i>An. stephansi</i>	<i>An. tessellatus</i>	<i>Cx. quenquifasciatus</i>	<i>Cx. tritaneorhynchus</i>	Total number	
Male	13	9	15	7	44	
Female	17	12	23	18	70	
%age	Male	11.40	7.89	13.16	6.14	114
	Female	14.91	10.53	20.18	15.79	

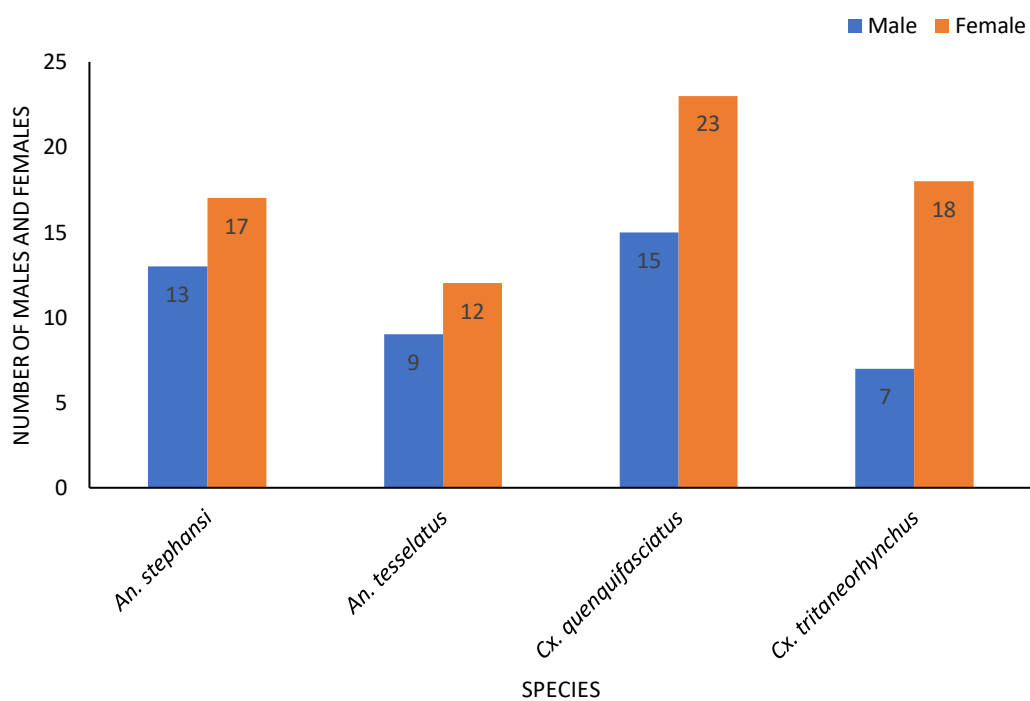
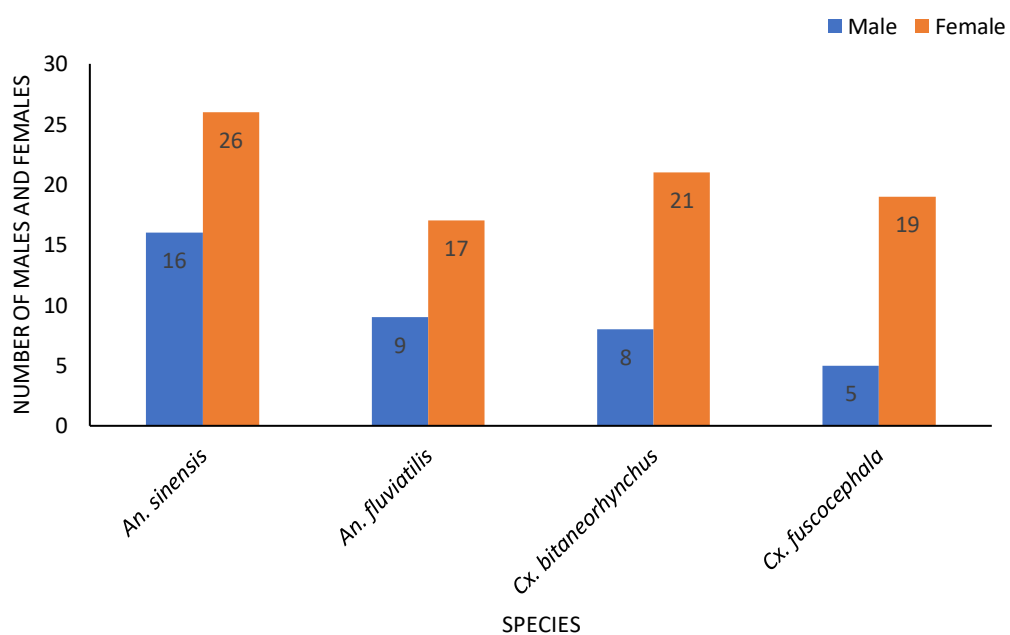
**Figure 3.29:** Representation of species and number of male and female mosquitoes collected from Peshawar.

Table 3.29: Mosquito fauna of District Waziristan

Species		<i>An. sinensis</i>	<i>An. fluviatilis</i>	<i>Cx. bitaneorhynchus</i>	<i>Cx. fuscocephala</i>	Total number
Male		16	9	8	5	38
Female		26	17	21	19	83
%age	Male	13.22	7.44	6.61	4.13	121
	Female	21.49	14.05	17.36	15.70	

**Figure 3.30:** Representation of species and number of male and female mosquitoes collected from Waziristan

Relative abundance and distribution status of recovered mosquito species

In terms of relative abundance 3 species were dominant, 10 subdominant and 5 satellite species whereas in terms of distribution status 9 species were sporadic, 7 infrequent, 1 frequent and 1 moderate species.

The highest number of mosquitoes was 200 and they belong to *Cx. quinquefasciatus* with the relative abundance 16.93% followed by *Cx. tritaeniorhynchus* with relative abundance 14.23% and *An. stephansi* having relative abundance 11.52%. The rest of the species represent relatively less number and *Cx. pseudovishnui* represents the lowest relative abundance 0.84%.

Table 3.30: Relative abundance, status and distribution class of mosquitoes collected from 10 districts of KPK.

Species	Abundance	Relative abundance	Relative abundance status	Distribution status
<i>An. annularis</i>	57	4.826418	Subdominant	Infrequent
<i>An. aconitus</i>	12	1.016088	Satellite	Sporadic
<i>An. sinensis</i>	95	8.04403	Subdominant	Infrequent
<i>An. stephansi</i>	136	11.51566	Dominant	Infrequent
<i>An. culicifacies</i>	65	5.50381	Subdominant	Infrequent
<i>An. tessellatus</i>	27	2.286198	Satellite	Sporadic
<i>An. fluviatilis</i>	50	4.2337	Subdominant	Infrequent
<i>An. subpictus</i>	46	3.895004	Subdominant	Sporadic
<i>Cx. quinquefasciatus</i>	200	16.9348	Dominant	Frequent
<i>Cx. tritaeniorhynchus</i>	168	14.22523	Dominant	Moderate
<i>Cx. bitaeniorhynchus</i>	44	3.725656	Subdominant	Sporadic
<i>Cx. gelidus</i>	41	3.471634	Subdominant	Sporadic
<i>Cx. vishnui</i>	93	7.874682	Subdominant	Infrequent
<i>Cx. pseudovishnui</i>	10	0.84674	Satellite	Sporadic
<i>Cx. fuscocephala</i>	60	5.08044	Subdominant	Infrequent
<i>Cx. whitmorei</i>	11	0.931414	Satellite	Sporadic
<i>Ar. obturbans</i>	41	3.471634	Subdominant	Sporadic
<i>Ar. kuchingensis</i>	25	2.11685	Satellite	Sporadic

DISCUSSION

Mosquitoes belong to family Culicidae, suborder Nematocera and order Diptera (Paksa *et al.*, 2019). There are about 3,500 known species of mosquitoes worldwide having an immense number of vectors causing vector borne diseases. Mosquitoes are generally cosmopolitan in distribution except Antarctica (the permanently frozen zones) (Bibi, 2019). Species of mosquito varies in different geographical zones of the globe. 31% of the known species are present in Neotropical region followed by 30% in Oriental region, 22% in Afrotropical region and 22% in Australasian regions (Foley *et al.*, 2007). The Pakistan, because of its geographical locations and ecology is a hotspot for mosquitoes, the vectors involved in transmission of deadly diseases like malaria, dengue fever, yellow fever etc (Ashfaq *et al.*, 2014).

Morphological identification has been customarily used for depiction of the species and for separation of problematic species. With the progression of technology some of the characters used customarily in scientific classification and systematics have been discovered to be polymorphic bringing about identification of cryptic species complexes. Subsequently the cytogenetic and molecular description of such traditional and problematic species have brought about revision of the systematics and phylogeny of anophelines (Chhilar, 2014; Harbach *et al.*, 2005). However, the precise species identification is important for understanding of the vectors associated with the transmission of diseases and providing the gateway for the researchers to improve strategies for their control (Lorenz *et al.*, 2012).

252 species of *Culex* and 43 *Anopheles* mosquito species had been recognized in subcontinent of India that include 34 *Anopheles* species and 66 *Culex* in Pakistan (Khan *et al.*, 2015). Ali and Rasheed recorded 9 species of mosquitoes from Peshawar that belong to 2 genera *Anopheles* and *Culex* (Ali and Rasheed, 2009). Fifteen species were reported from Swat that belong to 5 genera viz *Anopheles*, *Aedes*, *Culex*, *Armigeres* and *Culiseta* (Usman *et al.*, 2017). Ali *et al* reported 15 species from District Malakand, Subdivision Swat Ranizai (Ali *et al.*, 2013). In addition to these, 16 more species were reported from Swat (Ilahi and Suleman, 2013). 9 *Culicine* and 4 *Anopheles* species of mosquitoes have been recorded from Murree hills (Qasim *et al.*, 2014). 29 mosquito species have been recorded from the Lahore (Aslamkhan and Salman, 1996). 30 mosquito species were reported from Changa Manga Lahore (Suleman *et al.*, 1977).

From 1934-1971, one *Anopheles* species and 3 species of *Culex* were added in mosquito fauna of Pakistan (Khan, 1971).

In the present study stereomicroscope was used in order to identify various mosquito species. Different parameters were used to make appropriate identification of the species. On the basis of following parameters morphometric analysis was carried out; full body length, length of proboscis, length of palp, length of wings, length of fore leg, length of mid leg, and length of hind leg. Morphometric measurements of the body parts of *An.culicifacies* are given in (Table 3.3), that of *An. annularis* in (Table 3.4), *An. sinensis* in (Table 3.5), *An. stephensi* in (Table 3.6), *An. fluviatilis* in (Table 3.7), *An. tessellatus* in (Table 3.8), *An. subpictus* in (Table 3.9), *An. aconitus* in (Table 3.10), *Cx. quinquefasciatus* in (Table 3.11), *Cx. tritaeniorhynchus* in (Table 3.12), *Cx. bitaeniorhynchus* in (Table 3.13), *Cx. gelidus* in (Table 3.14), *Cx. fuscocephala* in (Table 3.15), *Cx. vishnui* in (Table 3.16), *Cx. pseudovishnui* in (Table 3.17), *Cx. whitmorei* in (Table 3.18), *Ar. obturbans* in (Table 3.19) and *Ar. kuchingensis* in (Table 3.20).

A total of eighteen mosquito species were collected from ten districts of Khyber Pakhtunkhwa, Pakistan. Duration of the study was 4 months i.e. from June to September 2020. All the identified mosquito species were properly organized into a systematic position. The species of mosquitoes collected and identified belongs to class Insecta; order Diptera; family Culicidae; and three genera *Anopheles*, *Culex* and *Armigeres*; eighteen species respectively. The eight species belongs to the genus *Anopheles* i.e. *An. culicifacies*, *An. sinensis*, *An. annularis*, *An. stephensi*, *An. tessellatus*, *An. fluviatilis*, *An. subpictus* and *An. aconitus*, eight species of *Culex* i.e. *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, *Cx. bitaeniorhynchus*, *Cx. fuscocephala*, *Cx. vishnui*, *Cx. pseudovishnui*, *Cx. gelidus* and *Cx. whitmorei*, and two species of *Armigeres* i.e. *Ar. obturbans* and *Ar. kuchingensis*.

The total specimens collected from District Bannu were 147, out of these 14.3% were *An. annularis*, 16.3% *An. sinensis*, 20.4% *An. stephensi*, 21.1% *Cx. quinquefasciatus* and 27.9% *Cx. tritaeniorhynchus*. However, total specimens collected from District Karak were 100. Out of these 18% were *An. annularis*, 12% *An. aconitus*, 35% *Cx. quinquefasciatus* and 35% *Cx. tritaeniorhynchus*. From District Mardan, total of 132 specimens were collected having 20.4% *An. culicifacies*, 20.5% *Cx. quinquefasciatus*, 19.7% *Cx. tritaeniorhynchus*, 12.1% *Cx. fuscocephala* and

27.3% *Cx. vishnui*. Similarly, from District Lower Dir 99 specimens were collected containing 18.2% *An. annularis*, 11.1% *An. fluviatilis*, 35.4% *Cx. quinquefasciatus*, 25.3% *Cx. vishnui* and 10.1% *Cx. pseudovishnui*. 136 specimens were gathered from District Upper Dir that contains 27.9% *An. stephensi*, 9.6% *An. fluviatilis*, 18.4% *An. subpictus*, 10.3% *Cx. quinquefasciatus*, 14.7% *Cx. fuscocephala* and 19.1% *Cx. gelidus*.

From District Swat 104 specimens were collected that holds 15.4% *An. culicifacies*, 36.5% *An. stephensi*, 14.4% *Cx. gelidus*, 13.5% *Cx. pseudovishnui* and 20.2% *Ar. obturbans*. Similarly, 97 specimens collected from Swabi contains 5.2% *An. tessellatus*, 21.6% *An. subpictus*, 39.2% *Cx. tritaeniorhynchus*, 15.5% *Cx. bitaeniorhynchus* and 18.6% *Cx. vishnui*. Likewise, 107 specimens gathered from Lakki Marwat has 20.6% *An. culicifacies*, 27.1% *An. sinensis*, 10.3% *Cx. whitmorei*, 18.7% *Ar. obturbans* and 23.4% *Ar. kuchingensis*. Also, from Peshawar 114 specimens were collected having 26.3% *An. stephensi*, 18.4% *An. tessellatus*, 33.3% *Cx. quinquefasciatus* and 21.9% *Cx. tritaeniorhynchus*. Lastly, 121 specimens were collected from Waziristan District containing 34.7% *An. sinensis*, 21.49% *An. fluviatilis*, 24% *Cx. bitaeniorhynchus* and 19.8% *Cx. fuscocephala*.

The study conducted in district Peshawar shows that taxonomic identification discovered 11 species of mosquitoes that belongs to four genera *Anopheles*, *Culex*, *Armigeres* and *Aedes*. Genus *Anopheles* was represented by *An. culicifacies*, *An. subpictus*, *An. maculatus*, and *An. stephensi*, Genus *Culex* by *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus* and *Cx. vishnui*, Genus *Aedes* by *Ae. Unilineatus*, *Ae. Albopictus* and *Ae. Walbus* and Genus *Armigeres* by *Ar. subalbatus*. Maximum frequency was detected for *Ae albopictus* preceded by *Cx tritaeniorhynchus*, *Cx. quinquefasciatus* and so on (Wajiha *et al.*, 2017).

Another study on the determination of species composition of mosquitoes present in Palosai stream, Peshawar represents nine species belonging to 2 genera i.e. *Anopheles* and *Culex* were discovered viz., *An. culicifacies*, *An. stephensi*, *An. fluviatilis*, *An. nigerrimus*, *An. subpictus*, *An. maculatus*, *Culex pipiens quinquefasciatus*, *Cx. vishnui*, and *Cx. tritaeniorhynchus*. *Culex* was the dominant specie representing the maximum number where *Anopheles* have the few individuals (Ali and Rasheed, 2009). Similarly, studies conducted by Khan *et al* recorded 21 species in district Buner and 15 species in Swat Ranizai. The present study represents 4 species

belonging to 2 genera *Anopheles* and *Culex*. 2 species of Genus *Anopheles* i.e. *An. stephansi* and *An. tessellatus*, and 2 species of Genus *Culex* i.e. *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus*.

Likewise, the five species were recorded from the District Swabi in the latest study. 2 species belongs to the genus *Anopheles* that were *An. tessellatus* and *An. subpictus* and 3 species of genus *Culex* were *Cx. tritaeniorhynchus*, *Cx. bitaeniorhynchus* and *Cx. vishnui*. Similarly from Mardan District total of 5 species were recorded that belongs to 2 genera and the species were *An. culicifacies*, *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, *Cx. fuscocephala* and *Cx. vishnui*. These studies are in accordance with the previous studies (Wajiha et al, 2017; Ali and Rasheed, 2009) and some species are overlapping in these areas that illustrates some common climatic and ecological factors due to which common species are present in these regions.

A study was conducted on Swat Ranizai Sub Division of Malakand and fifteen mosquito species were recorded that belong to five genera i.e. *Anopheles*, *Aedes*, *Culex*, *Armigeres* and *Culiseta*. The species were *An. Stephensi* Liston (6.22%), *An. Fluviatilis* James (0.39%), *An. Maculates* Theobald (1.34%), *An. Culicifacies* Giles (0.32%), *An. subpictus* Grassi (0.17%), *An. lindesayi* Giles (0.02%), *Ae. vittatus* Bigot (3.93%), *Cx. quinquefasciatus* Say (79.43%), *Cx. tritaeniorhynchus* Giles (4.43%), *Cx. tritaeniorhynchus* Giles (0.59%), *Cx. theileri* Theobald (2.14%), *Cx. mimeticus* Noe (2.14%), *Cx. Vishnui* Theo bald (0.22%), *Ar. subalbatus* Coquillett (0.04%) and *Cu. longiareolata* Macquart (0.59%). *Cx. quinquefasciatus* (79.4%) and *An. stephensi* (6.2%) were the dominant and constant species, regarding relative abundance and distribution recorded in most of the months and from the majority of the habitats (Usman et al., 2017). In the recent study, six species of three genera *Anopheles*, *Culex* and *Armigeres* were recorded i.e. *An. culicifacies*, *An. stephansi*, *Cx. gelidus*, *Cx. pseudovishnui* and *Ar. obturbans*. *Armigeres obturbans* was recorded for the first time from Swat.

Another research study was conducted in Upper Dir in 2014 to determine the species composition, seasonal variation of mosquito fauna and their relative abundance. The mosquito species recorded were *Culex quinquefasciatus*, *Culex theileri*, *Culex mimeticus*, *Anopheles maculates*, *Anopheles annularis*, *Anopheles stephensi*, *Aedes shortii* *Aedes albopictus*, and *Culiseta longiareolata* respectively (Khan et al. 2015). In

the present study conducted on District Upper Dir, the species recorded were *An. stephansi*, *An. fluviatilis*, *An. subpictus*, *Cx. quinquefasciatus*, *Cx. fuscocephala* and *Cx. gelidus*. Similarly, the recent study from District Lower Dir represents 5 species belonging to 2 genera i.e. *Anopheles* and *Culex*. The species were *An. annularis*, *An. fluviatilis*, *Cx. quinquefasciatus*, *Cx. vishnui* and *Cx. pseudovishnui*.

In the study conducted on Amin Khel, District Karak, five species belonging to three genera were recorded. 2 species of Genus *Anopheles* were *An. annularis* and *An. maculates*, 2 species of Genus *Culex* were *Cx. quinquefasciatus* and *Cx. theileri* and a single specie of Genus *Aedes* i.e. *Ae. albopictus* (Usman *et al.*, 2017) In the recent study conducted on District Karak, five species of two genera were recorded. 2 species of Genus *Anopheles* were *An. annularis* and *An. aconitus*, and 2 species of Genus *Culex* were *Cx. quinquefasciatus*, and *Cx. tritaeniorhynchus*.

From District Lakki Marwat, 5 species belonging to 3 genera were recovered in the recent study. The species were *An. culicifacies*, *An. sinensis*, *Cx. whitmorei*, *Ar. obturbans* and *Ar. kuchingensis*. Correspondingly, 5 species of two genera were recorded from District Bannu. The species were *An. annularis*, *An. sinensis*, *An. stephensi*, *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus*. Also, the recent study conducted in District Waziristan represents 4 species belonging to 2 genera and the species were *An. sinensis*, *An. fluviatilis*, *Cx. bitaeniorhynchus* and *Cx. fuscocephala*. The results of both the previous and latest study revealed that due to some similar environmental conditions, some common species are present in these study areas. Further, no published data is accessible for the mosquito fauna of District Bannu, Lakki Marwat, Waziristan, Swabi, Lower Dir and Mardan. The current research is first of its kind to examine species.

The relative abundance and distribution status was observed in the current research. Among these 18 species, three were dominant; *Cx. quinquefasciatus* (16.93%) was the dominant specie followed by *Cx. tritaeniorhynchus* (14.23%) and *An. stephensi* (11.52%), ten subdominant; *An. sinensis* (8.04%), *An. culicifacies* (5.50%), *An. annularis* (4.81%), *An. fluviatilis* (4.23%), *An. subpictus* (3.89%), *Cx. vishnui* (7.87%), *Cx. fuscocephala* (5.08%), *Cx. bitaeniorhynchus* (3.73%), *Cx. gelidus* (3.47%) and *Ar. obturbans* (3.47%), and the five species were satellite; *An. aconitus* (1.01%), *An. tessellatus* (2.28%), *Cx. pseudovishnui* (0.84%), *Cx. whitmorei* (0.93%) and *Ar.*

kuchingensis (2.12%). In terms of Distribution, one specie was frequent, one moderate, six infrequent and ten species were sporadic.

In conclusion, the mosquito fauna of the study areas of Khyber Pakhtunkhwa, Pakistan is characterized by *Anopheles*, *Culex* and *Armigeres* species where, *Culex* and *Anopheles* are more abundant than *Armigeres*. From the findings of this study and former studies it can be concluded that a worldwide climatic shift along widespread development is persuading the distribution as well as the diversity of mosquito fauna of Khyber Pakhtunkhwa. Therefore, there is always a possible risk of the occurrence of mosquito borne diseases. Also, there is no available data on the geographical distribution of mosquito fauna in some Districts and Provinces of Pakistan. The result of this study requires more entomological surveys of mosquitoes using diverse sampling methods to designate their resting, feeding behaviors and role in transmission of diseases. Further, molecular based techniques should be used for the identification of mosquito fauna of Khyber Pakhtunkhwa, Pakistan.

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