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# GEOGRAPHICAL DISTRIBUTION OF MOSQUITOES IN PAKISTAN

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**Abstract**

*Although mosquitoes are vectors of many diseases, the biodiversity of mosquitoes is poorly studied in Pakistan. This study was conducted to determine the recent trends in diversity and distribution of mosquito species. For this purpose, total of 14,013 specimens were collected from 14 districts of Pakistan during 2018-19. Both immature and adult mosquitoes were collected by knockdown, aspirator, and sweep net from various habitats including ponds, farmhouses, animal sheds, residential areas, gutters, etc. Various taxonomic keys were used to identify them upto species level. Relative abundance and distribution of mosquitoes were calculated. A total of 29 species were identified during the study, which belongs to five genera i.e. Culex, Anopheles, Aedes, Mansonia, and Armigeres. Moreover, the Culex species were found to be the most abundant and constant genus across Pakistan among the collected mosquitoes, which were followed by Anopheles, and Aedes, respectively. Mansonia and Armigeres have very low diversity in Pakistan. Although, no new species were detected but this study will provide information about the current status of biodiversity, distribution and abundance of mosquitoes in Pakistan. The pattern of distribution of mosquito species could be used to predict mosquito-borne infectious diseases in Pakistan.*

**Keywords:** *Abundance, Distribution, Geographical, Mosquitoes, Pakistan*

## INTRODUCTION

Many arthropods act as vectors of diseases. Among them, mosquitoes are the most important as they are notoriously responsible for causing greater misery to mankind (1). Mosquitoes serve to transmit protozoans, helminths, and viruses. On the other hand, they also cause discomfort, insomnia, frustration, and blood loss in the host. Millions of individuals acquired mosquito-borne diseases such as yellow fever, dengue, and malaria each year (2). World Health Organization estimated that there were between 50 and 200 million dengue infections and roughly 20,000 fatalities worldwide in 2015. Over 225 million people worldwide suffer malaria every year, and 800,000 people die; of these, 85% are children under the age of five. Various human diseases have been reported to be transmitted by species from the genera *Culex*, *Anopheles*, *Armigeres*, and *Aedes* that act as disease vectors (3). Genus *Culex* is reported as the vector of Japanese encephalitis, and filariasis, while mosquitoes of genus *Armigeres* are responsible for the transmission of helminthic infections like lymphatic filariasis and dog heartworm (4). Malaria and dengue are caused by different species of *Anopheles* and *Aedes* mosquitoes. *Anopheles* contains more than 400 species of which 40 species can transmit malaria to humans (5). Malaria is among the most devastating vector-borne diseases caused by parasites (*Plasmodium spp*.). The spread of these diseases is influenced by changing meteorological factors, as well as economic, political and social conditions. In many cases the impact of these non-climatic factors is greater than that of climatic reasons (6). Due to the abundance, biodiversity, vector capability, and recurrent infections, mosquitoes are the most studied group of insects (7).

To control all mosquito-transmitted diseases in an area, it is necessary to focus on the vector to map and keep track of the mosquitoes' geographic dispersion (8, 9). For this purpose, accurate species identifications are needed to reduce the waste of limited resources on controlling those species that are not the vectors of pathogens or more resources investing in naturally resistant species and particular control methods. Different species of mosquitoes (even within a genus) vary widely in their ability to transmit

disease, resistance mechanisms against vector control strategies, their resting and feeding behaviors, and their habitats (10). In these circumstances, accurate species-level information is required to target relevant species present in a given area by applying proper vector control measures (11). The aim of the study is to determine the distribution, diversity and abundance of the mosquitoes in different districts of Pakistan to have insights about most prevalent species found in each area, which could potentially contribute to the occurrence of any kind of outbreak in near future.

# MATERIALS AND METHODS

## STUDY AREA

Mosquitoes were collected from various districts of Punjab, Sindh, Baluchistan, and Khyber Pakhtunkhwa provinces of Pakistan. A total of 14 districts were surveyed to study the distribution and diversity of mosquitoes. Among these, 6 districts belong to Punjab, 4 districts to Sindh, two districts to Khyber Pakhtunkhwa, and one district to Baluchistan (Fig. 1).

## COLLECTION OF ADULT MOSQUITOES

The adult mosquitoes were collected from human dwellings and animal sheds during swarming, and resting conditions. Mosquitoes were collected by using mouth aspirators, sweep nets, and knock-down methods. A mouth aspirator is used to capture adult mosquitoes resting on walls indoors and outdoors. The indoor collection was done by the knockdown method. For the knockdown of adult mosquitoes, commercial Pyrethroid spray or coils of the Mortein brand were used. The collection was done by simply spraying thoroughly inside closed rooms. Large white sheets were laid on the floor to cover all surfaces in each room before spraying. After 10-15 minutes, all immobilized mosquitoes were collected carefully with forceps. Mosquitoes were then placed in Petri dishes containing moist filter paper and then placed in a plastic cooler. For outdoor collections, sites were identified where mosquitoes swarm and congregate. Collections were carried out by sweep nets when mosquitoes exhibited swarming behaviors.

## COLLECTION OF MOSQUITO LARVAE

Larvae and pupae were also collected from randomly selected larval habitats present at each site. Natural (e.g. ponds, puddles, sewerage water and garbage) and artificial (e.g. old discarded tyres) breeding sites were considered (12, 13). The larval collection was done by using a standard dipper (400ml) with a one-meter handle. They were transported to the Institute of Zoology, the University of Punjab, Lahore, in plastic containers. While waiting for the emergence of adults all larvae and pupae were kept at room temperature in plastic containers covered with a net (14, 15). Water (300- 500 ml) collected with larvae contains an adequate amount of food for larvae so no artificial food was given. A small hole was made in the net to collect adult mosquitoes and kept close by a cotton swab. Each container was labelled properly, with locality, date of collection, and collector name, counted, and recorded.

## MORPHOLOGICAL IDENTIFICATIONS

Adult mosquitoes were transferred to a lethal chamber and killed by using 90% ethanol fumes (16). All the collected mosquitoes were identified up to the species level by using a stereomicroscope. The mosquitoes which were damaged or have broken body parts were not included in the study (17). For identification, various morphological keys were followed such as “The fauna of British India, including Ceylon and Burma” by Christophers (18); Barraud (19); Edwards (20); Gillies and De Meillon (21); Jupp, McIntosh (22); Harbach (23) etc. In addition, available dichotomous keys and original species descriptions were compiled through literature freely available on the WRBU website (www.wrbu.org) (16). All identified mosquitoes were individually transferred to labeled 1.5 ml tubes. Each tube was pierced with a mounted needle (to allow moisture escape) and placed in plastic bags already containing silica gel.

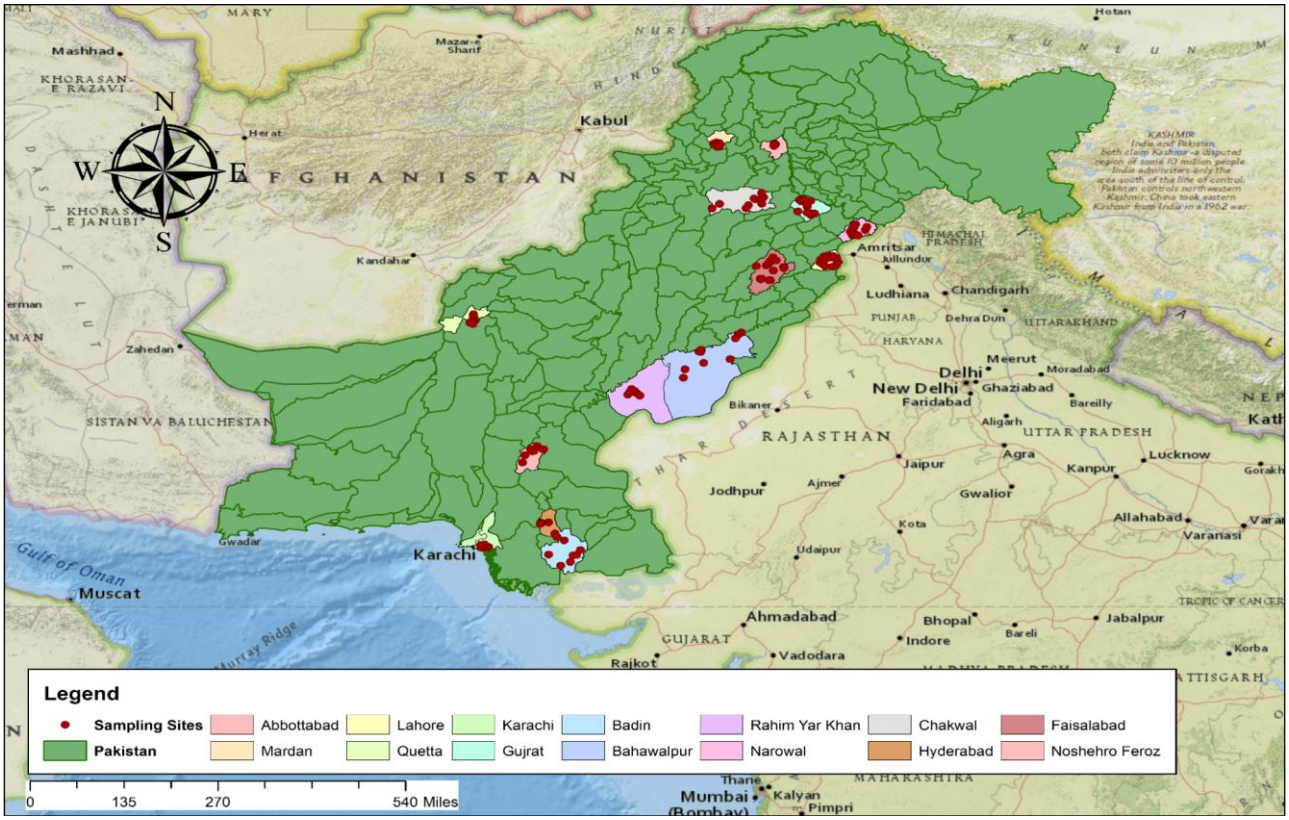


**Fig. 1.** Mosquito collection sites from different districts of Pakistan

## DATA ANALYSIS

### *DISTRIBUTION OF MOSQUITOES*

All the collected mosquitoes were analyzed by relative abundance (RA) and distribution (C). These were calculated following the formulas as described by Ali, Khan (24); Rydzanicz and Lonc (25); and Sengil, Akkaya (26). To calculate relative abundance (RA), the following formula was used:

$$RA = \frac{l}{L} \times 100$$

(Where, l= number of specimens of a species collected; L = Total number of specimens collected)

The results of RA values were interpreted as described by Trojan (27) as follows: RA > 5% = Dominant species, RA < 5% = Sub-dominant, and RA < 1% = Satellite.

The following formula was used to calculate distribution;

$$C = \frac{n}{N} \times 100$$

(Where, n = number of sites where a particular species was found; N = Total number of sites)

The values of distribution (C) were interpreted as described by (28): Sporadic species if C = 0-20%; Infrequent species if C = 20.1-40%; Moderate species if C = 40.1-60%; Frequent species if C = 60.1-80%; and Constant species if C = 80.1-100%.

# RESULTS

## MOSQUITO DIVERSITY IN PAKISTAN

A total of 14,013 mosquito specimens were collected from 14 districts of Pakistan (Fig. 2). These specimens belong to 29 species and 5 genera of mosquitoes viz. *Culex*, *Aedes*, *Anopheles*, *Armigeres*, and *Mansonia.*

From district Lahore, a total of 1629 mosquitoes were collected from 13 sites. They belonged to 13 species and 4 genera. Of which *Cx. quinquefasciatus* was the most dominant species. *Mansonia uniformis* was collected in low numbers. In terms of distribution status, *M. uniformis* and *An. nigerrimus* were sporadic, while *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus* were constant species in district Lahore. *An. stephensi, An. subpictus,* and *An. albopictus* were dominant and frequent in distribution. *Cx. theleri, An. annularis, Cx. sitiens,*

and *An. pulcherimus* were dominant and infrequent. *Ae. aegypti*, and *Cx. vagans* were found to be sub-dominant and infrequent (Table I).

From district Gujrat, total 1966 mosquitoes were collected from 11 sites. They belonged to 14 species and 4 genera of which Cx. quinquefasciatus and Ae. albopictus were the most dominant species, followed by Ae. cogilli, Cx. tritaeniorhynchus, Cx. bitaeniorhynchus, Cx. vishnui, and An. peditaeniatus. While An. stephensi, Ae. aegypti, An. annularis, Cx. fuscocephala, An. nigerrimus and Armigeres obturbans were found to be sub-dominant. Armigeres subalbatus was the only species which was satellite in Gujrat. Cx. quinquefasciatus, Ae. albopictus Ae. cogilli, and Cx. tritaeniorhynchus were distributed throughout the district (constant in distribution). Cx. bitaeniorhynchus, Cx. vishnui, and An. peditaeniatus were frequent in distribution, while An. stephensi, Ae. aegypti, An. annularis, and Cx. fuscocephala were moderately distributed.

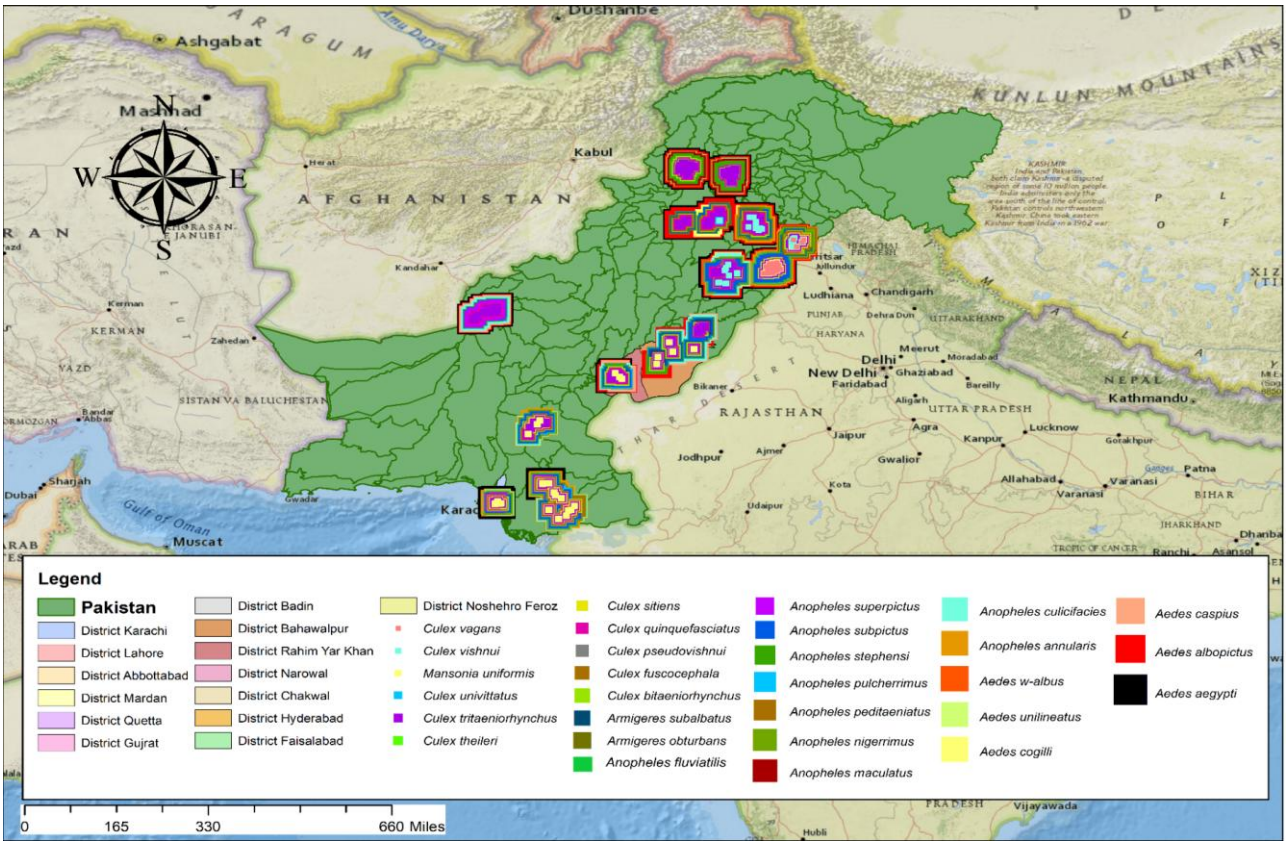


**Fig. 2**. Distribution of mosquito species in different districts of Pakistan

**Table I.** Relative abundance and distribution of mosquito species in district Lahore, Pakistan

| Sr. No. | Species | No. of specimens | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. quinquefasciatus* | 376 | 23.08 | Dominant | 92.31 | Constant |
| 2 | *Cx. tritaeniorhynchus* | 339 | 20.81 | Dominant | 84.62 | Constant |
| 3 | *An. stephensi* | 143 | 8.78 | Dominant | 53.85 | Frequent |
| 4 | *An. subpictus* | 109 | 6.69 | Dominant | 46.15 | Frequent |
| 5 | *Ae. albopictus* | 106 | 6.51 | Dominant | 46.15 | Frequent |
| 6 | *Cx. theleri* | 104 | 6.38 | Dominant | 38.46 | Infrequent |
| 7 | *An. annularis* | 102 | 6.26 | Dominant | 38.46 | Infrequent |
| 8 | *Cx. sitiens* | 87 | 5.34 | Dominant | 38.46 | Infrequent |
| 9 | *An. pulcherimus* | 82 | 5.03 | Dominant | 30.77 | Infrequent |
| 10 | *Ae. aegypti* | 78 | 4.79 | Sub-dominant | 30.77 | Infrequent |
| 11 | *Cx. vagans* | 62 | 3.81 | Sub-dominant | 23.08 | Infrequent |
| 12 | *An. nigerrimus* | 24 | 1.47 | Sub-dominant | 15.38 | Sporadic |
| 13 | *M. uniformis* | 17 | 1.04 | Sub-dominant | 15.38 | Sporadic |
| | **Total** | **1629** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

*An. nigerrimus* was infrequently distributed in Gujrat. Both species of *Armigeres* i.e. *Armigeres obturbans* and *Armigeres subalbatus* were found to be sporadic (Table II).

A total of 799 mosquitoes were collected from district Chakwal. They were identified as 12 species and 4 genera of mosquitoes. Among them *Cx. quinquefasciatus* was found to be the most dominant and constantly distributed in the Chakwal. *An. stephensi, Cx. tritaeniorhynchus, Cx. bitaeniorhynchus,* and *Cx. fuscocephala* were dominant species and frequently distributed in the area. *Ae. albopictus* and *Ae. aegypti* were also dominant but they were moderately distributed in Chakwal. *Ar. obturbans, Ae. cogilli,* and *Ar. subalbatus* were found to be sub-dominant and infrequently distributed species. *Cx. univittatus,* and *Cx. vishnui* were satellite species and sporadic in distribution (Table III).

From Narowal, 1354 mosquitoes were collected that belong to 19 species and 5 genera. Of these *Cx. quinquefasciatus, Cx. tritaeniorhynchus, An. nigerrimus,* and *Cx. bitaeniorhynchus* were dominant and constantly distributed species in Narowal. *An. stephensi, Cx. fuscocephala, An. annularis, Ae. albopictus,* and *An. maculatus* were also dominant species in the study area but they were frequently distributed. *Cx. vishnui* was the only species which was sub-dominant and frequently distributed in Narowal. *Ar. obturbans, Cx. sitiens, An. culicifacies, Cx. theileri,* and *Cx. pseudovishnui* were sub-dominant and moderately distributed species in district Narowal. *Ae. w-albus, Cx. vagans, Ma. uniformis,* and *An. subpictus* were sub-dominant and infrequently distributed species (Table IV).

**Table II.** Relative abundance and distribution of mosquito species in district Gujrat, Pakistan

| Sr. No. | Species | No. of specimens | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. quinquefasciatus* | 391 | 19.89 | Dominant | 100.00 | Constant |
| 2 | *Ae. albopictus* | 344 | 17.50 | Dominant | 100.00 | Constant |
| 3 | *Ae. cogilli* | 260 | 13.22 | Dominant | 81.82 | Constant |
| 4 | *Cx. tritaeniorhynchus* | 252 | 12.82 | Dominant | 81.82 | Constant |
| 5 | *Cx. bitaeniorhynchus* | 164 | 8.34 | Dominant | 72.73 | Frequent |
| 6 | *Cx. vishnui* | 126 | 6.41 | Dominant | 72.73 | Frequent |
| 7 | *An. peditaeniatus* | 100 | 5.09 | Dominant | 63.64 | Frequent |
| 8 | *An. stephensi* | 93 | 4.73 | Sub-dominant | 54.55 | Moderate |
| 9 | *Ae. aegypti* | 59 | 3.00 | Sub-dominant | 45.45 | Moderate |
| 10 | *An. annularis* | 53 | 2.70 | Sub-dominant | 45.45 | Moderate |
| 11 | *Cx. fuscocephala* | 48 | 2.44 | Sub-dominant | 45.45 | Moderate |
| 12 | *An. nigerrimus* | 42 | 2.14 | Sub-dominant | 36.36 | Infrequent |
| 13 | *Armigeres obturbans* | 20 | 1.02 | Sub-dominant | 18.18 | Sporadic |
| 14 | *Armigeres subalbatus* | 14 | 0.71 | Satellite | 18.18 | Sporadic |
| | **Total** | **1966** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

**Table III.** Relative abundance and distribution of mosquito species in district Chakwal, Pakistan

| Sr. No. | Species | No. of specimens | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. quinquefasciatus* | 202 | 25.28 | Dominant | 87.50 | Constant |
| 2 | *An. stephensi* | 119 | 14.89 | Dominant | 75.00 | Frequent |
| 3 | *Cx. tritaeniorhynchus* | 104 | 13.02 | Dominant | 75.00 | Frequent |
| 4 | *Cx. bitaeniorhynchus* | 94 | 11.76 | Dominant | 62.50 | Frequent |
| 5 | *Cx. fuscocephala* | 85 | 10.64 | Dominant | 62.50 | Frequent |
| 6 | *Ae. albopictus* | 68 | 8.51 | Dominant | 50.00 | Moderate |
| 7 | *Ae. aegypti* | 44 | 5.51 | Dominant | 50.00 | Moderate |
| 8 | *Ar. obturbans* | 33 | 4.13 | Sub-dominant | 37.50 | Infrequent |
| 9 | *Ae. cogilli* | 25 | 3.13 | Sub-dominant | 37.50 | Infrequent |
| 10 | *Ar. subalbatus* | 17 | 2.13 | Sub-dominant | 37.50 | Infrequent |
| 11 | *Cx. univittatus* | 5 | 0.63 | Satellite | 12.50 | Sporadic |
| 12 | *Cx. vishnui* | 3 | 0.38 | Satellite | 12.50 | Sporadic |

| | | |
|---|---|---|
| **Total** | **799** | |

*Abbreviations: RA=Relative Abundance; C=Distribution

**Table IV.** Relative abundance and distribution of mosquito species in district Narowal, Pakistan

| Sr. No. | Species | No. of specimens | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. quinquefasciatus* | 188 | 13.88 | Dominant | 100.00 | Constant |
| 2 | *Cx. tritaeniorhynchus* | 132 | 9.75 | Dominant | 100.00 | Constant |
| 3 | *An. nigerrimus* | 124 | 9.16 | Dominant | 88.89 | Constant |
| 4 | *Cx. bitaeniorhynchus* | 109 | 8.05 | Dominant | 88.89 | Constant |
| 5 | *An. stephensi* | 97 | 7.16 | Dominant | 77.78 | Frequent |
| 6 | *Cx. fuscocephala* | 92 | 6.79 | Dominant | 77.78 | Frequent |
| 7 | *An. annularis* | 89 | 6.57 | Dominant | 77.78 | Frequent |
| 8 | *Ae. albopictus* | 79 | 5.83 | Dominant | 77.78 | Frequent |
| 9 | *An. maculatus* | 74 | 5.47 | Dominant | 66.67 | Frequent |
| 10 | *Cx. vishnui* | 64 | 4.73 | Sub-dominant | 66.67 | Frequent |
| 11 | *Ar. obturbans* | 58 | 4.28 | Sub-dominant | 55.56 | Moderate |
| 12 | *Cx. sitiens* | 46 | 3.40 | Sub-dominant | 55.56 | Moderate |
| 13 | *An. culicifacies* | 43 | 3.18 | Sub-dominant | 55.56 | Moderate |
| 14 | *Cx. theileri* | 41 | 3.03 | Sub-dominant | 55.56 | Moderate |
| 15 | *Cx. pseudovishnui* | 31 | 2.29 | Sub-dominant | 44.44 | Moderate |
| 16 | *Ae. w-albus* | 28 | 2.07 | Sub-dominant | 33.33 | Infrequent |
| 17 | *Cx. vagans* | 25 | 1.85 | Sub-dominant | 33.33 | Infrequent |
| 18 | *Ma. uniformis* | 17 | 1.26 | Sub-dominant | 22.22 | Infrequent |
| 19 | *An. subpictus* | 17 | 1.26 | Sub-dominant | 22.22 | Infrequent |
| | **Total** | **1354** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

Total 1030 specimens were collected from Faisalabad. They were identified as 16 species and 3 genera. *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus* were found to be dominant and constant species in Faisalabad. *Ae. albopictus, An. stephensi, Ae. cogilli, An. culicifacies, Cx. theileri,* and *Ae. aegypti* were dominant and frequently distributed species in Faisalabad. *Cx. pseudovishnui, Cx. vishnui,* and *An. peditaeniatus* were dominant and moderately distributed species. The only sub-dominant and moderately distributed species was *An. pulcherrimus*. *An. annularis, An. nigerrimus* were sub-dominant species which were infrequently distributed in Faisalabad. *Ae. unilineatus* was sub-dominant and sporadic in distribution. *Ae. w-albus* was satellite and sporadic (Table V).

From district Bahawalpur, 905 mosquitoes were collected. They belonged to 13 species and 5 genera. *Cx. quinquefasciatus, Cx. bitaeniorhynchus, Cx. tritaeniorhynchus,* and *An. culicifacies* were dominant and frequently distributed species in Bahawalpur. *An. peditaeniatus, An. stephensi, Cx. theileri, and An. pulcherrimus* were dominant and moderately distributed species. *Ae. albopictus, Ar. subalbatus, Ae. caspius, Ma. uniformis,* and *An. subpictus* were found to be sub-dominant and infrequently distributed species in Bahawalpur (Table VI).

Total 559 mosquito samples were collected from Rahim Yar Khan. They belonged to 13 species and 5 genera. Among these, Cx. quinquefasciatus and Cx. tritaeniorhynchus were dominant and constant in distribution. Cx. bitaeniorhynchus, An. peditaeniatus, An. culicifacies, An. stephensi, An. pulcherrimus, and Ae. albopictus were also dominant species but these were frequently distributed in Rahim Yar Khan. Ae. aegypti was found to be a sub-dominant and frequently distributed species. Ar. subalbatus, and An. subpictus were sub-dominant and moderately distributed species in the study area. Ma. uniformis was sub-dominant and infrequently distributed species. Whereas, Ae. caspius was found to be satellite and infrequently distributed species in Rahim Yar Khan (Table VII).

**Table V.** Relative abundance and distribution of mosquito species in district Faisalabad, Pakistan

| Sr. No. | Species | No. of specimens | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. quinquefasciatus* | 156 | 15.15 | Dominant | 89.47 | Constant |
| 2 | *Cx. tritaeniorhynchus* | 109 | 10.58 | Dominant | 84.21 | Constant |
| 3 | *Ae. albopictus* | 99 | 9.61 | Dominant | 78.95 | Frequent |
| 4 | *An. stephensi* | 92 | 8.93 | Dominant | 78.95 | Frequent |
| 5 | *Ae. cogilli* | 87 | 8.45 | Dominant | 73.68 | Frequent |
| 6 | *An. culicifacies* | 64 | 6.21 | Dominant | 68.42 | Frequent |
| 7 | *Cx. theileri* | 63 | 6.12 | Dominant | 68.42 | Frequent |
| 8 | *Ae. aegypti* | 61 | 5.92 | Dominant | 63.16 | Frequent |
| 9 | *Cx. pseudovishnui* | 58 | 5.63 | Dominant | 57.89 | Moderate |
| 10 | *Cx. vishnui* | 56 | 5.44 | Dominant | 57.89 | Moderate |
| 11 | *An. peditaeniatus* | 53 | 5.15 | Dominant | 52.63 | Moderate |
| 12 | *An. pulcherrimus* | 49 | 4.76 | Sub-dominant | 42.11 | Moderate |
| 13 | *An. annularis* | 36 | 3.50 | Sub-dominant | 31.58 | Infrequent |
| 14 | *An. nigerrimus* | 23 | 2.23 | Sub-dominant | 21.05 | Infrequent |
| 15 | *Ae. unilineatus* | 17 | 1.65 | Sub-dominant | 15.79 | Sporadic |
| 16 | *Ae. w-albus* | 7 | 0.68 | Satellite | 10.53 | Sporadic |
| | **Total** | **1030** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

**Table VI.** Relative abundance and distribution of mosquito species in district Bahawalpur, Pakistan

| Sr. No. | Species | No. of specimens | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. quinquefasciatus* | 124 | 13.70 | Dominant | 77.78 | Frequent |
| 2 | *Cx. bitaeniorhynchus* | 118 | 13.04 | Dominant | 77.78 | Frequent |
| 3 | *Cx. tritaeniorhynchus* | 104 | 11.49 | Dominant | 66.67 | Frequent |
| 4 | *An. culicifacies* | 101 | 11.16 | Dominant | 66.67 | Frequent |
| 5 | *An. peditaeniatus* | 93 | 10.28 | Dominant | 55.56 | Moderate |
| 6 | *An. stephensi* | 91 | 10.06 | Dominant | 44.44 | Moderate |
| 7 | *Cx. theileri* | 79 | 8.73 | Dominant | 44.44 | Moderate |
| 8 | *An. pulcherrimus* | 78 | 8.62 | Dominant | 44.44 | Moderate |
| 9 | *Ae. albopictus* | 39 | 4.31 | Sub-dominant | 33.33 | Infrequent |
| 10 | *Ar. subalbatus* | 25 | 2.76 | Sub-dominant | 33.33 | Infrequent |
| 11 | *Ae. caspius* | 21 | 2.32 | Sub-dominant | 33.33 | Infrequent |
| 12 | *Ma. uniformis* | 16 | 1.77 | Sub-dominant | 22.22 | Infrequent |
| 13 | *An. subpictus* | 16 | 1.77 | Sub-dominant | 22.22 | Infrequent |
| | **Total** | **905** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

From Quetta, 10 mosquito species belonging to 3 genera were collected. *Cx. tritaeniorhynchus,* and *Cx. quinquefasciatus* were dominant and constantly distributed species in Quetta. *An. stephensi, An. culicifacies, An. subpictus,* and *An. pulcherrimus* were dominant and frequently distributed species in the study area. Whereas, *Ae albopictus* and *An. superpictus* were dominant and moderately distributed species in Quetta. *Ae aegypti* and *Ae caspius* were sub-dominant and infrequently distributed species in the study area (Table VIII).

From Mardan, 1149 specimens were collected. They were identified as 13 species and 3 genera. *Cx. quinquefasciatus* and *Cx tritaeniorhynchus* were dominant and constantly distributed species. *Cx pseudovishnui, Cx. bitaeniorhynchus,* and *An. stephensi* were dominant and frequently distributed species. *Cx. theileri, An. maculates,* and *An. annularis* were found to be dominant and moderately distributed species in the study area. *An. culicifacies, Ae. albopictus, Ae. aegypti,* and *Ae. cogilli* were sub-dominant and infrequently distributed species in Mardan. Whereas, *An. fluviatilis* was sub-dominant and sporadic in distribution (Table IX). From district Abbottabad, 569 mosquitoes were collected. They belonged to 8 species and 3 genera. All the species were found to be dominant in the study area except *Ae. aegypti,* which was sub-dominant.

According to distribution status, *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, and *An. stephensi* were constantly distributed. Whereas, *Cx. theileri*, *An. annularis*, and *An. culicifacies* were frequently distributed species. *Ae. albopictus* was moderately distributed and *Ae. aegypti* was an infrequently distributed species in Abbottabad (Table X).

**Table VII.** Relative abundance and distribution of mosquito species in district Rahim Yar Khan, Pakistan

| Sr. No. | Species | No. of specimens | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. quinquefasciatus* | 115 | 20.57 | Dominant | 100.00 | Constant |
| 2 | *Cx. tritaeniorhynchus* | 73 | 13.06 | Dominant | 100.00 | Constant |
| 3 | *Cx. bitaeniorhynchus* | 59 | 10.55 | Dominant | 75.00 | Frequent |
| 4 | *An. peditaeniatus* | 59 | 10.55 | Dominant | 75.00 | Frequent |
| 5 | *An. culicifacies* | 58 | 10.38 | Dominant | 75.00 | Frequent |
| 6 | *An. stephensi* | 56 | 10.02 | Dominant | 75.00 | Frequent |
| 7 | *An. pulcherrimus* | 42 | 7.51 | Dominant | 75.00 | Frequent |
| 8 | *Ae. albopictus* | 35 | 6.26 | Dominant | 75.00 | Frequent |
| 9 | *Ae. aegypti* | 24 | 4.29 | Sub-dominant | 75.00 | Frequent |
| 10 | *Ar. subalbatus* | 17 | 3.04 | Sub-dominant | 50.00 | Moderate |
| 11 | *An. subpictus* | 8 | 1.43 | Sub-dominant | 50.00 | Moderate |
| 12 | *Ma. uniformis* | 8 | 1.43 | Sub-dominant | 25.00 | Infrequent |
| 13 | *Ae. caspius* | 5 | 0.89 | Satellite | 25.00 | Infrequent |
| | **Total** | **559** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

**Table VIII.** Relative abundance and distribution of mosquito species in district Quetta, Pakistan

| Sr. No. | Species | No. of specimen | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. tritaeniorhynchus* | 196 | 20.48 | Dominant | 100.00 | Constant |
| 2 | *Cx. quinquefasciatus* | 182 | 19.02 | Dominant | 100.00 | Constant |
| 3 | *An. Stephensi* | 114 | 11.91 | Dominant | 75.00 | Frequent |
| 4 | *An. Culicifacies* | 94 | 9.82 | Dominant | 62.50 | Frequent |
| 5 | *An. Subpictus* | 88 | 9.20 | Dominant | 62.50 | Frequent |
| 6 | *An. pulcherrimus* | 81 | 8.46 | Dominant | 62.50 | Frequent |
| 7 | *Ae albopictus* | 69 | 7.21 | Dominant | 50.00 | Moderate |
| 8 | *An. Superpictus* | 63 | 6.58 | Dominant | 50.00 | Moderate |
| 9 | *Ae aegypti* | 43 | 4.49 | Sub-dominant | 37.50 | Infrequent |
| 10 | *Ae caspius* | 27 | 2.82 | Sub-dominant | 37.50 | Infrequent |
| | **Total** | **957** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

**Table IX.** Relative abundance and distribution of mosquito species in district Mardan, Pakistan

| Sr. No. | Species | No. of specimen | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. quinquefasciatus* | 179 | 15.58 | Dominant | 100.00 | Constant |
| 2 | *Cx tritaeniorhynchus* | 166 | 14.45 | Dominant | 90.00 | Constant |
| 3 | *Cx pseudovishnui* | 138 | 12.01 | Dominant | 80.00 | Frequent |
| 4 | *Cx. bitaeniorhynchus* | 115 | 10.01 | Dominant | 70.00 | Frequent |
| 5 | *An. stephensi* | 103 | 8.96 | Dominant | 70.00 | Frequent |
| 6 | *Cx. theileri* | 90 | 7.83 | Dominant | 60.00 | Moderate |
| 7 | *An. maculates* | 82 | 7.14 | Dominant | 60.00 | Moderate |
| 8 | *An. annularis* | 76 | 6.61 | Dominant | 60.00 | Moderate |
| 9 | *An. culicifacies* | 56 | 4.87 | Sub-dominant | 40.00 | Infrequent |
| 10 | *Ae. albopictus* | 47 | 4.09 | Sub-dominant | 40.00 | Infrequent |
| 11 | *Ae. aegypti* | 37 | 3.22 | Sub-dominant | 30.00 | Infrequent |

| | | | | | | |
|---|---|---|---|---|---|---|
| 12 | *Ae. cogilli* | 31 | 2.70 | Sub-dominant | 30.00 | Infrequent |
| 13 | *An. fluviatilis* | 29 | 2.52 | Sub-dominant | 20.00 | Sporadic |
| | **Total** | **1149** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

**Table X.** Relative abundance and distribution of mosquito species in district Abbottabad, Pakistan

| Sr. No. | Species | No. of sample | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. quinquefasciatus* | 122 | 21.44 | Dominant | 100.00 | Constant |
| 2 | *Cx. tritaeniorhynchus* | 108 | 18.98 | Dominant | 100.00 | Constant |
| 3 | *An. stephensi* | 79 | 13.88 | Dominant | 85.71 | Constant |
| 4 | *Cx. theileri* | 75 | 13.18 | Dominant | 71.43 | Frequent |
| 5 | *An. annularis* | 61 | 10.72 | Dominant | 71.43 | Frequent |
| 6 | *An. culicifacies* | 54 | 9.49 | Dominant | 71.43 | Frequent |
| 7 | *Ae. albopictus* | 48 | 8.44 | Dominant | 42.86 | Moderate |
| 8 | *Ae. aegypti* | 22 | 3.87 | Sub-dominant | 28.57 | Infrequent |
| | **Total** | **569** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

From Karachi, 16 species and 4 genera of mosquitoes were found during this study. The dominant species of Karachi were *Cx. tritaeniorhynchus, Cx quinquefasciatus, An. subpictus, An. stephensi, An. pulcherrimus, Cx. bitaeniorhynchus, An. culicifacies, An. annularis, Cx. pseudovishnui,* and *Ae. unilineatus*. Whereas, *Ae. aegypti, Cx. fuscocephala, An. nigerrimus, An. peditaeniatus, Ma. uniformis,* and *An. superpictus* were found to be sub-dominant species in Karachi. Moreover, *Cx. tritaeniorhynchus, Cx quinquefasciatus,* and *An. subpictus* were constant species, whereas, *An. stephensi, An. pulcherrimus,* and *Cx. bitaeniorhynchus* were frequently distributed species. Moderately distributed species were *An. culicifacies, An. annularis, Cx. pseudovishnui, Ae. unilineatus, Ae. aegypti, Cx. fuscocephala, An. nigerrimus,* and *An. peditaeniatus*. *Ma. uniformis* and *An. superpictus* were infrequently distributed species in Karachi (Table XI).

A total of 922 specimens were collected from district Badin. They were identified as 14 species and 4 genera of mosquitoes. Data shows that *Cx. tritaeniorhynchus, Cx. quinquefasciatus, An. subpictus, An. peditaeniatus, Cx. bitaeniorhynchus,* and *An. pulcherrimus* were dominant species in Badin. Whereas, *Ma. uniformis, An. culicifacies, An. annularis, Cx. fuscocephala, An. stephensi, Cx. pseudovishnui, An. nigerrimus,* and *Ae. aegypti* were found to be sub-dominant. Among these species, *Cx. tritaeniorhynchus,* and *Cx. quinquefasciatus* were found to be constantly distributed. *An. subpictus, An. peditaeniatus, Cx. bitaeniorhynchus, An. pulcherrimus* and *Ma. uniformis* were frequently distributed in the area. *An. culicifacies, An. annularis, Cx. fuscocephala, An. stephensi,* and *Cx. pseudovishnui* were moderately distributed. *An. nigerrimus* was infrequent in distribution and *Ae. aegypti* was found to be sporadic (Table XII).

**Table XI.** Relative abundance and distribution of mosquito species in district Karachi, Pakistan

| Sr. No. | Species | No. of specimen | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. tritaeniorhynchus* | 122 | 14.90 | Dominant | 100.00 | Constant |
| 2 | *Cx quinquefasciatus* | 89 | 10.87 | Dominant | 85.71 | Constant |
| 3 | *An. subpictus* | 83 | 10.13 | Dominant | 85.71 | Constant |
| 4 | *An. stephensi* | 69 | 8.42 | Dominant | 71.43 | Frequent |
| 5 | *An. pulcherrimus* | 53 | 6.47 | Dominant | 71.43 | Frequent |
| 6 | *Cx. bitaeniorhynchus* | 52 | 6.35 | Dominant | 71.43 | Frequent |
| 7 | *An. culicifacies* | 50 | 6.11 | Dominant | 57.14 | *Moderate* |
| 8 | *An. annularis* | 49 | 5.98 | Dominant | 57.14 | *Moderate* |
| 9 | *Cx. pseudovishnui* | 42 | 5.13 | Dominant | 57.14 | *Moderate* |
| 10 | *Ae. unilineatus* | 41 | 5.01 | Dominant | 57.14 | *Moderate* |
| 11 | *Ae. aegypti* | 39 | 4.76 | Sub-dominant | 42.86 | *Moderate* |
| 12 | *Cx. fuscocephala* | 34 | 4.15 | Sub-dominant | 42.86 | *Moderate* |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | *An. nigerrimus* | 31 | 3.79 | Sub-dominant | 42.86 | *Moderate* |
| 14 | *An. peditaeniatus* | 26 | 3.17 | Sub-dominant | 42.86 | *Moderate* |
| 15 | *Ma. uniformis* | 24 | 2.93 | Sub-dominant | 28.57 | *Infrequent* |
| 16 | *An. superpictus* | 15 | 1.83 | Sub-dominant | 28.57 | *Infrequent* |
| | **Total** | **819** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

**Table XII.** Relative abundance and distribution of mosquito species in district Badin, Pakistan

| Sr. No. | Species | No. of specimen | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. tritaeniorhynchus* | 175 | 18.98 | Dominant | 100.00 | Constant |
| 2 | *Cx. quinquefasciatus* | 129 | 13.99 | Dominant | 88.89 | Constant |
| 3 | *An. subpictus* | 94 | 10.20 | Dominant | 77.78 | Frequent |
| 4 | *An. peditaeniatus* | 87 | 9.44 | Dominant | 77.78 | Frequent |
| 5 | *Cx. bitaeniorhynchus* | 73 | 7.92 | Dominant | 77.78 | Frequent |
| 6 | *An. pulcherrimus* | 65 | 7.05 | Dominant | 66.67 | Frequent |
| 7 | *Ma. uniformis* | 46 | 4.99 | Sub-dominant | 66.67 | Frequent |
| 8 | *An. culicifacies* | 44 | 4.77 | Sub-dominant | 55.56 | Moderate |
| 9 | *An. annularis* | 44 | 4.77 | Sub-dominant | 44.44 | Moderate |
| 10 | *Cx. fuscocephala* | 42 | 4.56 | Sub-dominant | 44.44 | Moderate |
| 11 | *An. stephensi* | 42 | 4.56 | Sub-dominant | 44.44 | Moderate |
| 12 | *Cx. pseudovishnui* | 36 | 3.90 | Sub-dominant | 44.44 | Moderate |
| 13 | *An. nigerrimus* | 34 | 3.69 | Sub-dominant | 33.33 | Infrequent |
| 14 | *Ae. aegypti* | 11 | 1.19 | Sub-dominant | 11.11 | Sporadic |
| | **Total** | **922** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

In this study, 13 species and 3 genera of mosquitoes were collected from Naushahro Feroze. Of which *Cx. tritaeniorhynchus, An. subpictus, Cx. quinquefasciatus, Cx. bitaeniorhynchus, An. annularis, Cx. fuscocephala, An. stephensi,* and *An. pulcherrimus* were found to be the dominant species. Whereas, *An. culicifacies, An. nigerrimus, Cx. pseudovishnui, An. peditaeniatus, and Ma. uniformis* were sub-dominant species in the area. Moreover, *Cx. tritaeniorhynchus,* and *An. subpictus* were constant in distribution, while *Cx. quinquefasciatus, Cx. bitaeniorhynchus, An. annularis,* and *Cx. fuscocephala* were frequently distributed species. *An. stephensi, An. pulcherrimus,* and *An. culicifacies* were moderately distributed. *An. nigerrimus, Cx. pseudovishnui, An. peditaeniatus, and Ma. uniformis* were infrequently distributed species in the Naushahro Feroze (Table XIII).

A total of 14 species and 4 genera of mosquitoes were collected from the district of Hyderabad. The dominant species were *Cx. tritaeniorhynchus, Cx. quinquefasciatus, Ae. unilineatus, An. subpictus, Cx. fuscocephala, Cx. pseudovishnui, Cx. bitaeniorhynchus, An. pulcherrimus, An. nigerrimus,* whereas *An. stephensi, An. annularis, Ae. aegypti, Ma. uniformis,* and *An. superpictus* were sub-dominant species of the Hyderabad. *Cx. tritaeniorhynchus,* and *Cx. quinquefasciatus* were constantly distributed, while *Ae. unilineatus, An. subpictus, Cx. fuscocephala, Cx. pseudovishnui, Cx. bitaeniorhynchus,* and *An. pulcherrimus* were frequently distributed species in Hyderabad. *An. nigerrimus, An. stephensi, An. annularis,* and *Ae. aegypti* were found to be moderately distributed species. Moreover, *Ma. uniformis,* and *An. superpictus* were infrequent in distribution in Hyderabad (Table XIV).

**Table XIII.** Relative abundance and distribution of mosquito species in district Naushahro Feroze, Pakistan

| Sr. No. | Species | No. of specimen | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. tritaeniorhynchus* | 135 | 18.32 | Dominant | 90.00 | Constant |
| 2 | *An. subpictus* | 99 | 13.43 | Dominant | 90.00 | Constant |
| 3 | *Cx. quinquefasciatus* | 97 | 13.16 | Dominant | 80.00 | Frequent |
| 4 | *Cx. bitaeniorhynchus* | 74 | 10.04 | Dominant | 80.00 | Frequent |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | *An. annularis* | 56 | 7.60 | Dominant | 70.00 | Frequent |
| 6 | *Cx. fuscocephala* | 48 | 6.51 | Dominant | 70.00 | Frequent |
| 7 | *An. stephensi* | 46 | 6.24 | Dominant | 60.00 | Moderate |
| 8 | *An. pulcherrimus* | 41 | 5.56 | Dominant | 60.00 | Moderate |
| 9 | *An. culicifacies* | 32 | 4.34 | Sub-dominant | 50.00 | Moderate |
| 10 | *An. nigerrimus* | 32 | 4.34 | Sub-dominant | 40.00 | Infrequent |
| 11 | *Cx. pseudovishnui* | 31 | 4.21 | Sub-dominant | 40.00 | Infrequent |
| 12 | *An. peditaeniatus* | 30 | 4.07 | Sub-dominant | 40.00 | Infrequent |
| 13 | *Ma. uniformis* | 16 | 2.17 | Sub-dominant | 30.00 | Infrequent |
| | **Total** | **737** | | | | |

*Abbreviations: RA=Relative Abundance; C=Distribution

**Table XIV.** Relative abundance and distribution of mosquito species in district Hyderabad, Pakistan

| Sr. No. | Species | No. of specimen | RA* | Status | C* | Status |
|---|---|---|---|---|---|---|
| 1 | *Cx. tritaeniorhynchus* | 126 | 20.39 | Dominant | 100.00 | Constant |
| 2 | *Cx. quinquefasciatus* | 87 | 14.08 | Dominant | 83.33 | Constant |
| 3 | *Ae. unilineatus* | 57 | 9.22 | Dominant | 66.67 | Frequent |
| 4 | *An. subpictus* | 56 | 9.06 | Dominant | 66.67 | Frequent |
| 5 | *Cx. fuscocephala* | 42 | 6.80 | Dominant | 66.67 | Frequent |
| 6 | *Cx. pseudovishnui* | 37 | 5.99 | Dominant | 66.67 | Frequent |
| 7 | *Cx. bitaeniorhynchus* | 33 | 5.34 | Dominant | 66.67 | Frequent |
| 8 | *An. pulcherrimus* | 31 | 5.02 | Dominant | 66.67 | Frequent |
| 9 | *An. nigerrimus* | 31 | 5.02 | Dominant | 50.00 | Moderate |
| 10 | *An. stephensi* | 30 | 4.85 | Sub-dominant | 50.00 | Moderate |
| 11 | *An. annularis* | 30 | 4.85 | Sub-dominant | 50.00 | Moderate |
| 12 | *Ae. aegypti* | 27 | 4.37 | Sub-dominant | 50.00 | Moderate |
| 13 | *Ma. uniformis* | 21 | 3.40 | Sub-dominant | 33.33 | Infrequent |
| 14 | *An. superpictus* | 10 | 1.62 | Sub-dominant | 33.33 | Infrequent |
| | **Total** | **618** | | | | |

# DISCUSSION

The present survey was carried out to examine the different mosquito species and their distribution pattern in Pakistan. The occurrence of mosquito species in different areas reflects both the habitat preferences of the mosquitoes as well as the ability of the mosquitoes to survive in various environmental conditions (29). Most mosquito species prefer high temperatures and humidity (30).

Khan, Maibach (31) reports total 104 species of mosquitoes from Pakistan and Bangladesh in the species checklist. Since then no detailed work has been done so far. Many researchers repeatedly reported the same species in different areas of Pakistan. For instance, from Murree four Anophelinae and ten Culicinae species have been reported, including *An. stephensi, An. theobaldi, An. maculatus, An. fluviatilis, Ae. albopictus, Ae. aegypti, Culex quinquefasciatus, Cx. nilgiricus, Cx. fuscitarsis, Cx. vagans Cx. raptor, Ar. obturbans* and *Culiseta longiareolata* (Qasim, Naeem (32). From the University of Peshawar six mosquito species including *Ae. albopictus, Ae. unilineatus, Ae. w-albus, Ar. subalbatus, Cx. quinquefasciatus* and *An. stephensi* have been reported until now (Naz and Shabnam (33). From Swat 21 mosquito species reported up till now including *Cx. quinquefasciatus, An. maculatus, Cx. pseudovishnui, An. annularis, An. stephensi, Cx. bitaeniorhynchus, An. splendidus* and *Cx. theileri* (Ilahi and Suleman (34). From Aminkhel, Karak, and Peshawar a total of five species, including *Cx. quinquefasciatus, Cx. theileri, An. maculatus, An. annularis* and *Ae. albopictus* were reported (Usman, Rehman (35). A total of 11 species, including *Cx. quinquefasciatus, Cx. tritaeniorhynchus, Cx. vishnui, Ae. albopictus, Ae. w-albus, Ae. unilineatus, An. stephensi, An. culicifacies, An. subpictus, An. maculatus* and *Ar. subalbatus* were reported from Peshawar, KPK, Pakistan (36). Recently,

Ashfaq, Hebert (37) did a detailed study in Pakistan on the diversity of mosquitoes by DNA barcoding and they could only be able to document 32 species from Punjab and KPK, Pakistan (37).

The present study showed that three important genera *Anopheles*, *Culex*, and *Aedes* were found throughout the study area. While *Armigeres* and *Mansonia* were found in a few collection sites. In the current study, a total of 29 species of mosquitoes were documented in Pakistan. Of which 10 species of *Culex*, 10 species of *Anopheles*, 06 species of *Aedes*, 2 species of *Armigeres*, and 1 species of *Mansonia* were recovered in this study. Different researchers previously reported all the species however, the current study reported many species in those districts where they were not reported previously. In neighboring countries of Pakistan, scatter studies have been conducted to study the diversity of mosquitoes similarly as in Pakistan. For example, forty-four species belonging to eleven genera were reported from Alappuzha, South India (38). A checklist of mosquito species in Iran includes sixty-four species belonging to seven genera (39). Fourteen species from the *Armigeres* genus were reported from India (40); From Brazil Leal-Santos, Jacobina (41) studied 34 species belonging to 12 genera**.** In the current investigation, the data shows that among five genera, the most abundant and constant genus was *Culex*. *Culex* spp. has a wide range of preferences in their habitats as well as the seasons. *Culex* species were mostly found in stagnant water, seepage pools, field crops, houses, scrapyards, graveyards, and forests. Most of the *Culex* were found in highly humid and vegetative habitats as well as dry and low humid habitats (42).

Anopheline mosquitoes (Culicidae, Anophelinae) are of prime medical importance as human malaria vectors, yet their phylogeny is poorly known (43). In the current study, ten species of *Anopheles* (*An. subpictus, An. stephensi, An. peditaeniatus, An. culicifacies, An. pulcherrimus, An. annularis, An. nigerrimus, An. superpictus, An. fluviatilis,* and *An. maculatus*) were documented from Pakistan. The same species were recovered from Punjab and Sindh except *An. superpictus* that was not found in any district of Punjab during the current study, while it was only found in Karachi and Hyderabad districts of Sindh, Pakistan. Similarly, *An. maculatus* was not identified from Sindh. It was only found in the district of Narowal in Punjab, Pakistan. Moreover, *An. fluviatilis* was only found in district Mardan (KPK) and has not been documented anywhere else during the current study. *Anopheles* mosquitoes were recorded in the surroundings of animals, telling the zoophilic nature of most of them. Most of the *Anopheles* mosquito species were collected from animal sheds, houses and river margins. *Anopheles* species have been reported by many researchers such as Rohani, Zamree (44) from Serian, Sarawak, Malaysia; Soleimani-Ahmadi, Vatandoost (45) from South Iran; Pal and Dutta, 1992 from West Bengal Thatoi, Behera (46); Ilahi and Suleman (34) from Swat, Pakistan; Martinez (47) from South Texas; Fakoorziba and Vijayan (48) from Mysore, India; Manzoor, Shabbir (49) Lahore; Nasir, Ahmed (50) from Kasur and Sheikhupura.

*Ae. albopictus* was found more adaptive in nature than *Ae. aegypti*. Reportedly, *Ae. aegypti* recorded in those habitats having less humidity, vegetation, and human activities during the months with normal humidity levels (34, 51). *Ae. albopictus* reported comparatively in highly humid habitats during the months with high humidity July-October (52). Ashfaq et al (2014) reported that *Ae. albopictus* as the dominant species among other *Aedes* species in Punjab, but they could not detect this species at higher elevation sites (1100 m) in Swat (37). The results of our survey indicated that *Ae. albopictus* was more widely distributed and commoner than *Ae. aegypti* across the Pakistan. Akhtar et al. (2012) found that larvae of *Ae. aegypti* predominated in collections from water pots inside houses in Lahore during 2011 (53). Adult *Ae. aegypti* is unable to survive in the transition zones between the world's tropical and temperate zone, however invasive populations of *Ae. albopictus* can remain alive (54). Additionally, *Ae. albopictus* larval population growth remain unaffected by low nuitrition levels, giving it an edge over *Ae. aegypti* (54, 55). The current dominance of *Ae. albopictus* in Pakistan also supports a trend towards expansion of *Ae. albopictus* and a decline of *Ae. aegypti***.** The results of the current study are also supported this phenomenon as *Ae. albopictus* were collected from all the districts from Punjab, while *Ae. aegypti* was not found in Narowal and Bahawalpur. Moreover, *Ae. aegypti* were less abundant as compared to *Ae. albopictus. Ae. aegypti* was collected from Hyderabad and Karachi. Both these species were also found in KPK, and Balochistan, Pakistan. *Ae. aegypti* has been previously reported from Pakistan (32-34, 37, 56, 57); Bangladesh (58), India

(38, 59, 60), Iran (61), Saudi Arabia (62) and Nepal (63). *Ae. albopictus* was reported from Pakistan (32, 37, 56, 57, 64, 65), India (38, 66), Taiwan (67) and China (68).

*Ae. unilineatus* was collected from Hyderabad, Karachi, and Badin from Sindh. While this species was only found in Faisalabad from Punjab. No specimen of this species was collected from KPK and Balochistan. *Ae. caspius*, *Ae. w-albus*, and *Ae. cogilli* were not identified from Sindh while they were found in Punjab in low numbers. In the present survey, *Ae. cogilli* collected from Gujrat, Faisalabad, Rahim Yar Khan, Bahawalpur, and Chakwal, while absent from Narowal. *Ae. cogilli* was also found in Mardan (KPK). *Ae. cogilli* was not found in Balochistan. *Ae. w-albus* was collected from Narowal and Faisalabad. Similarly, *Ae. caspius* was collected only from Bahawalpur and Rahim Yar Khan. *Ae. caspius* was also collected from Quetta, Balochistan. No specimen of *Ae. w-albus* was collected from KPK and Balochistan. *Armigeres* mosquitoes are the largest, stout-bodied and the most aggressive mosquitoes (69). *Ar. obturbans* was collected from Gujrat, Narowal and Chakwal districts of Punjab, while it was absent from South Punjab (Bahawalpur and Rahim and Khan) and Sindh, KPK, and Balochistan. *Ar. obturbans* was previously reported from Pakistan (32, 64, 65); Taiwan (67); and India (60). In the current study, *Ar. subalbatus* was documented from Gujrat, Chakwal, Bahawalpur, and Rahim Yar Khan. This species was not found in Sindh, KPK, and Balochistan. From the genus *Mansonia,* only one species could be collected in the current study. *Mansonia uniformis* was documented from districts Narowal, Lahore, Bahawalpur, and Rahim Yar Khan from Punjab and interestingly, it was collected from all districts (Karachi, Badin, Hyderabad, and Naushahro Feroze) of Sindh. During this study, no specimen was collected from KPK and Balochistan.

# CONCLUSION

Worldwide, mosquitoes are leading vector for transmission of numerous diseases. In this study, five mosquito genera (i.e. *Culex*, *Anopheles, Aedes, Mansonia*, and *Armigeres*) belonging to 30 species were identified in Pakistan. In order to implement vector control programs more precisely, the abundance and distribution pattern of mosquito species found in the current study in various habitats of Pakistan could be useful. It is recommended that the molecular analysis, particularly DNA barcoding, should be used to determine the genetic diversity and species identification of mosquitoes in order to identify morphologically closely related species more accurately.

## Author Contribution:

SA conducted the experiment, collected data, and wrote manuscript; AB designed and supervised the study; SSS collected data and wrote manuscript; MHL collected data and prepare all illustrations. All authors reviewed the manuscript.

## Conflict of interest:

The authors declare that there is no conflict of interest.

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