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# Altitudinal distribution of mosquitoes in mountainous area of Garhwal region : Part–I

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*Background & objectives* : Mosquito fauna diversity in mountainous areas of Garhwal region was studied during November 2000 to October 2002 to correlate the altitudinal vegetation and distribution of mosquitoes.

*Methods* : Adult mosquitoes and mosquito immatures were collected using WHO methods and identified using standard keys and catalogues. Altitude of mosquito habitat was measured using portable altimeter and also by GPS.

*Results* : Altogether 34 species in five genera — *Aedes, Anopheles, Armigeres, Culex* and *Uranotaenia* were encountered in the present study in the altitude range of 300 to 2000 m. Majority of the mosquitoes were found in between 300 to 900 m altitude except *Culex vagus* and *Anopheles maculatus*, which were found throughout the range.

*Interpretation & conclusion* : The mosquitoes were categorised into six groups based on their altitudinal distribution. The areas at lowest elevation were having the greatest number of species but not the corresponding greater number of specimens in the present study.

**Key words** Altitudinal/elevational distribution – Garhwal region – immature mosquitoes – mosquito fauna

In the mountainous areas of Garhwal region, mosquitoes seriously impact outdoor recreation and livestock agriculture. In spite of their importance as pests of man and animals, the mosquitoes in Garhwal region have not been studied from ecological point of view. Earlier studies in Garhwal region[1–5] are based on the collection of mosquito specimens and an attempt has been made to correlate the studies with the elevation at which the mosquitoes were collected. Still there is no clear-cut information on their distribution across elevation and other ecological factors. In fact, the distribution of various mosquitoes in different geographic settings has been worked out at different places with particular reference to their elevational or vertical distribution[6–13]. Besides above, there are other workers too who have furnished information on the mosquito faunal diversity in Garhwal region[14–16].

Over the last two decades the environmental scenario of Garhwal region of Uttaranchal has totally changed due to growth and development projects including urbanisation, development of water resources, large-scale population movement and newly inhabited areas, etc. Besides this, the irrigation system has also dramatically altered the ecology of the area. The habitats that are available to the survival of mosquitoes differ with elevation and vegetation and, therefore, the mosquito species that are specific for a habitat would be distributed according to elevation/altitude. During dis-

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persal the mosquito often stops and refuels with energy along the flight path, there is a possibility of reappearance/disappearance/appearance of hitherto unknown mosquito forms. With this background it warrants to determine how mosquito species (adults/larvae) are distributed with regard to elevation/altitude in the mountainous areas of Garhwal region and is there any correlation with altitudinal vegetation in existing mosquito diversity.

## Material & Methods

*Study area* : The surveys were carried out between November 2000 to October 2002 from fixed localities of the five districts—Dehradun, Pauri, Tehri, Chamoli and Uttarkashi of Garhwal region having different altitudes ranging from 300 to 2000 m (Fig. 1). In each locality the collection spots were in different directions. Random collection was also done from each and every possible habitat.

*Methodology* : Adult mosquito sampling and immature collection was done as per WHO[17] guidelines. The collected mosquito's specimens were first of all narcotized with petroleum ether and thereafter they were identified using keys and catalogues[18–23].


*Fig. 1:* Map of Garhwal region showing study area at different altitudes

Attempts were made to identify immature mosquitoes using keys of Das *et al* [24]. The immatures were also reared in laboratory for emergence of adults and then they were identified.

Altitude of the mosquito's habitat was measured by using portable altimeter and also by GPS. Information on co-existing biotic community was also recorded at the time of mosquito collection.

## Results

The present study reveals the occurrence of 34 species of mosquitoes belonging to five genera— *Aedes, Anopheles, Armigeres, Culex* and *Uranotaenia* within the altitudinal range of 300 to 2000 m. The distribution of different species was manipulated according to the altitude/elevation (Table 1) and plotted in Fig. 2.

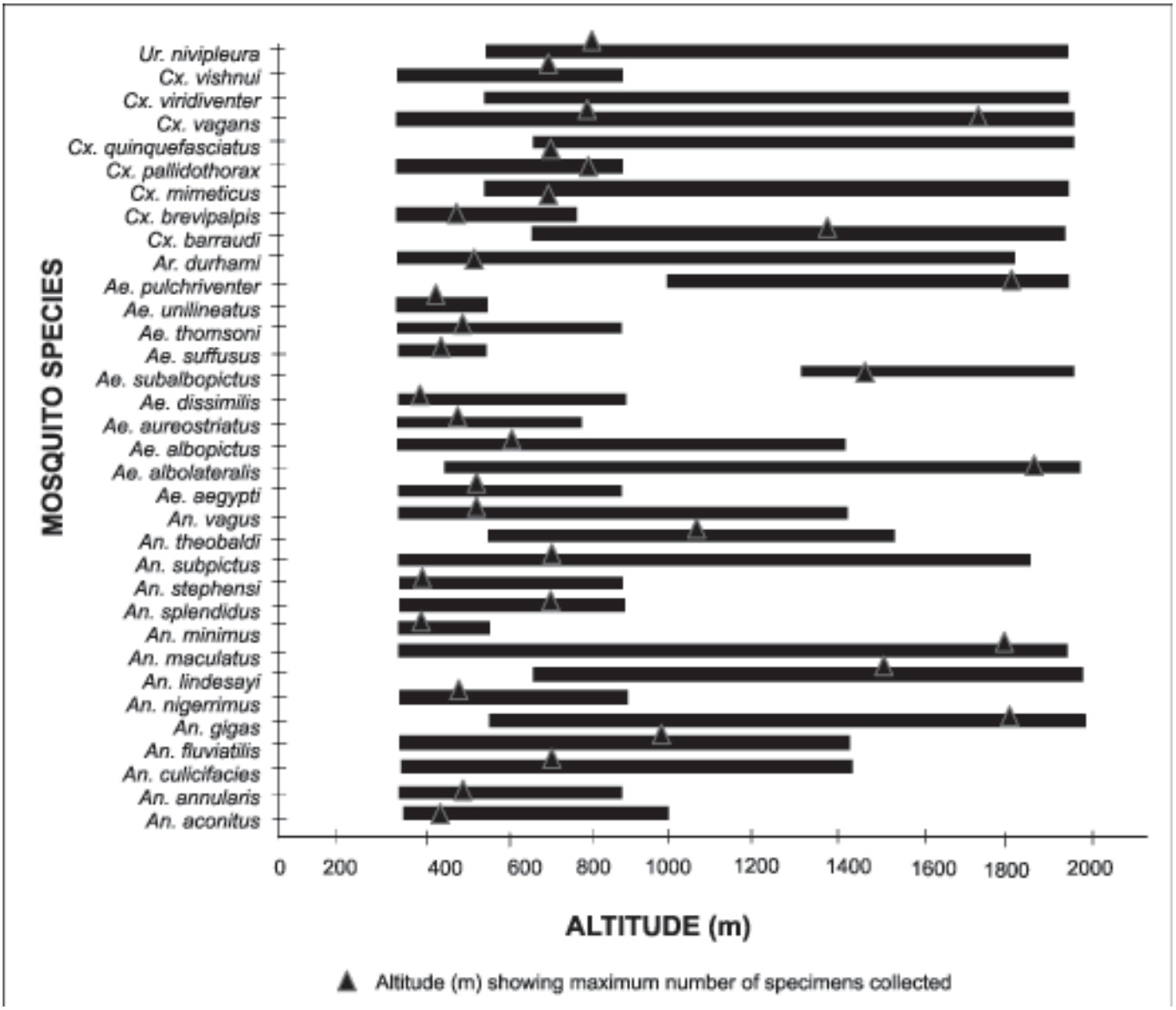


*Fig. 2:* Altitudinal distribution of adult mosquitoes in Garhwal region during November 2000 to October 2002

**Table 1. Altitudinal/elevational distribution of different mosquito species in the Garhwal region as reported by earlier workers and also in the present study**

| Mosquito species | Elevational distribution (m) | | |
|---|---|---|---|
| | Rao *et al* (1973) | Bhat (1975) | Present study |
| **Genus *Aedes* Meigen, 1818** | | | |
| **Subgenus *Christophersiomyia* Barraud, 1923** | | | |
| *Ae. thomsoni* Theobald, 1905 | 340–760 | 370–700 | 300–800 (480) |
| **Subgenus *Finlaya* Theobald, 1903** | | | |
| *Ae. albolateralis* Theobald, 1908 | 450–2280 | 480–1550 | 400–2000 (1870) |
| *Ae. aureostriatus* greenii, Theobald, 1903 | 365–760 | 370–480 | 300–700 (430) |
| *Ae. dissimilis* Leicester, 1908 | – | 480 | 300–800 (340) |
| *Ae. elsiae* Barraud, 1923 | 910 | 1000 | – |
| *Ae. formosensis* Yamada, 1921 | – | 980 | – |
| *Ae. gilli* Barraud, 1924 | 450 | 480 | – |
| *Ae. gubernatoris* Giles, 1901 | 340–460 | 370–480 | – |
| *Ae. oreophilus* Edwards, 1916 | 1830–2590 | – | – |
| *Ae. pseudotaeniatus* Giles, 1901 | 420–3200 | 340–3230 | – |
| *Ae. pulchriventer* Giles, 1901 | 1340–3200 | 980–3230 | 900–2000 (1850) |
| *Ae. shortti* Barraud, 1923 | 1125–3500 | 2200–3530 | – |
| *Ae. simlensis* Edwards, 1922 | 1830 | 1800 | – |
| *Ae. suffusus* Edwards, 1922 | 760 | 460 | 300–500 (460) |
| *Ae. unicinctus* Edwards, 1922 | 1830–2540 | 1800 | – |
| **Subgenus *Stegomyia* Theobald, 1901** | | | |
| *Ae. aegypti* Linnaeus, 1762 | – | – | 300–800 (450) |
| *Ae. albopictus* Skuse, 1894 | 230–1830 | 340–1800 | 300–1300 (550) |
| *Ae. novalbopictus* Barraud, 1931 | 450 | 480 | |
| *Ae. subalbopictus* Barraud, 1931 | 190–8500 | 1550–1800 | 1200–2000 (1350) |
| *Ae. unilineatus* Theobald, 1906 | 450 | 430–480 | 300–500 (470) |
| *Ae. vittatus* Bigot, 1861 | 330–2130 | 340–2150 | – |
| *Ae.w-albus* Theobald, 1905 | 230–1520 | 370–750 | – |
| **Genus *Anopheles* Meigen, 1818** | | | |
| **Subgenus *Anopheles* Meigen, 1818** | | | |
| *An. gigas* Giles, 1901 | 690–1080 | 750–3530 | 500–2000 (1800) |
| *An. lindesayi* Giles, 1900 | 550–2130 | 1400–1800 | 600–2000 (1400) |
| *An. nigerrimus* Giles, 1901 | – | – | 300–800 (450) |
| **Subgenus *Cellia* Theobald, 1902** | | | |
| *An. aconitus* Donitz, 1902 | – | – | 300–900 (370) |
| *An. annularis* Van der Wulp, 1884 | 475 | 480 | 300–800 (480) |
| *An. culicifacies* Giles, 1901 | 230–1130 | 370–650 | 300–1300 (650) |
| *An. fluviatilis* James, 1902 | 760–1070 | 650–1070 | 300–1300 (900) |
| *An. maculatus* Theobald, 1901 | 150–2740 | 650–2100 | 300–2000 (1750) |

*contd...*

**Table 1.** ***(contd.)***

| Mosquito species | Elevational distribution (m) | | |
|---|---|---|---|
| | Rao *et al* (1973) | Bhat (1975) | Present study |
| *An. minimus* Theobald, 1901 | – | – | 300–500 (370) |
| *An. splendidus* Koidzumi, 1920 | 760 | 650 | 300–800 (650) |
| *An. stephensi* Liston, 1901 | 330–460 | 340–480 | 300–800 (380) |
| *An. subpictus* Grassi, 1899 | 230–1910 | 370–1550 | 300–1700 (650) |
| *An. theobaldi* Giles, 1901 | 460–1070 | 800 | 500–1400 (980) |
| *An. vagus* Donitz, 1902 | – | 260 | 300–1300 (470) |
| **Genus *Armigeres* Theobald, 1901** | | | |
| **Subgenus *Armigeres* Theobald, 1901** | | | |
| *Ar. durhami* Edwards, 1917 | – | 370–650 | 300–1800 (480) |
| *Ar. obturbans* Walker, 1860 | 150-450 | – | – |
| **Genus *Culex* Linnaeus, 1758** | | | |
| ***Subgenus Culex* Linnaeus, 1758** | | | |
| *Cx. barraudi* Edwards, 1922 | 690–2440 | 620–2250 | 600–2000 (1250) |
| *Cx. bitaeniorhynchus* Giles, 1901 | 230–1220 | 620–650 | – |
| *Cx. mimeticus* Neo, 1899 | 150–3200 | 650–2300 | 500–2000 (650) |
| *Cx. mimulus* Edwards, 1915 | 760–1380 | 650 | – |
| *Cx. pseudovishnui* Colless, 1957 | 230–1220 | 650 | – |
| *Cx. quinquefasciatus* Say, 1828 | 350–2680 | 340–3200 | 500–2000 (650) |
| *Cx. theileri*, Theobald, 1903 | 550–3050 | 2200–3230 | – |
| *Cx. univittatus* Theobald, 1901 | 450 | 480 | – |
| *Cx. vagans* Weideman, 1828 | 770–3417 | 750–3230 | 300–2000 (1800) |
| *Cx. vishnui* Theobald, 1901 | – | 400 | 300–800 (650) |
| **Subgenus *Culiciomyia* Theobald, 1907** | | | |
| *Cx. bailyi* Barraud, 1934 | 150–2900 | – | – |
| *Cx. pallidothorax* Theobald, 1905 | 150–760 | 600–700 | 300–800 (700) |
| *Cx. shebbearei* Barraud, 1924 | 610–1830 | 460–1800 | – |
| *Cx. viridiventer* Giles, 1901 | 610–1830 | 650–3540 | 500–2000 (700) |
| **Subgenus *Lutzia* Theobald, 1907** | | | |
| *Cx. raptor* Edwards, 1922 | 360–2340 | 370–2400 | – |
| **Subgenus *Neoculex* Dyar, 1905** | | | |
| *Cx. brevipalpis* Giles, 1902 | 450–630 | 430 | 300–700 (430) |
| *Cx. tenuipalpis* Barraud, 1924 | 150–1030 | 1150 | – |
| **Genus *Uranotaenia* Lynch Arribalzaga, 189**1 | | | |
| *Ur. nivipleura* Leicester, 1908 | 150–1830 | 1800 | 500–1800 (700) |

Figures in parentheses indicate the elevation (in metre) at which maximum number of mosquito specimens were collected.

As many as 14 species of *Anopheles* were recovered in the selected sites of Garhwal region. Of these, the following ten species—*Anopheles aconitus, An. annularis, An. culicifacies, An. fluviatilis, An. nigerrimus, An. maculatus, An. splendidus, An. stephensi, An. subpictus* and *An. vagus* were common and widespread within the range of 300 to 800 m. Further, *An. minimus* was the uncommon species showing limitations in its occurrence within 300 to 500 m and that too in some localities of Doon Valley and Kotdwar. Moreover, *An. maculatus* was collected throughout the ranges of altitudes and was numerically the most abundant and wide-spread species among all anophelines recorded from the region. The following three species, namely, *An. gigas, An. lindesayi* and *An. theobaldi* were restricted at 500 m and above.

Among *Aedes* species, *Ae. suffusus* and *Ae. unilineatus* were distributed in lower ranges 300 to 400 m whereas *Ae. aegypti, Ae. aureostriatus, Ae dissimilis* and *Ae. thomsoni* were encountered up to 800 m altitude. *Ae. albopictus* and *Ae. albolateralis* were found to be distributed in wide ranges between 300 to 1300 and 400 to 2000 m respectively. The other two species — *Ae. pulchriventer* and *Ae. subalbopictus* were found above 900 m. Further, *Armigeres durhami* was found common within the range of 300 to 1800 m.

In all, eight species of *Culex* were collected during the study period. Of these, the following three species—*Cx. brevipalpis, Cx. pallidothorax* and *Cx. vishnui* were found in significant numbers in lower altitudes within the range of 300 to 800 m. Other four species *Cx. barraudi, Cx. mimeticus, Cx. quinquefasciatus* and *Cx. viridiventer* were found to be distributed at the elevation from 500 m and above. *Uranotaenia nivipleura,* a very rare species was found within the range of 500 to 1800 m.

On the basis of the results of the present study an attempt has been made with regard to grouping of the species of mosquitoes. The mosquitoes have been categorised into six groups according to their altitudinal distribution (Table 2). Further, the maximum number of species was recorded at the elevation between

**Table 2. Elevational distribution of mosquito species in different groups during November 2000 to October 2002**

| Group I (300–500 m) | Group II (300–800 m) | Group III (300–1300 m) | Group IV (500–1300 m) | Group V (300–2000 m) | Group VI (500–2000 m) |
|---|---|---|---|---|---|
| *An. minimus* | *An. aconitus* | *An. culicifacies* | *An. theobaldi* | *An. maculatus* | *An. gigas* |
| *Ae. suffusus* | *An. annularis* | *An. fluviatilis* | | *Ar. durhami* | *An. lindesayi* |
| *Ae. unilineatus* | *An. nigerrimus* | *An. subpictus* | | *Cx. vagans* | *Ae. albolateralis* |
| | *An. splendidus* | *An. vagus* | | | *Ae. pulchriventer* |
| | *An. stephensi* | *Ae. albopictus* | | | *Ae. subalbopictus* |
| | *Ae. aegypti* | | | | *Cx. barraudi* |
| | *Ae. aureostriatus* | | | | *Cx. mimeticus* |
| | *Ae. dissimilis* | | | | *Cx. quinquefasciatus* |
| | *Ae. thomsoni* | | | | *Cx. viridiventer* |
| | *Cx. brevipalpis* | | | | *Ur. nivipleura* |
| | *Cx. pallidothorax* | | | | |
| | *Cx. vishnui* | | | | |

450 and 550 m. However, the maximum number of specimens of each mosquito species differ from species to species. At the lowest level of elevation—300 m the mosquito species collected were higher than at the level of elevation at 2000 m. The mosquito species under Group IV and VI could not be collected below 500 m elevation. Moreover, the mosquito species as mentioned in Group I could not be collected above 500 m during the study period. Fig. 3 shows the details about the occurrence of immature mosquitoes at different elevational range. Adults of the following species—*An. aconitus, An. minimus, An. theobaldi, Ae. aureostriatus, Ae. suffusus, Ae. unilineatus, Ar. durhami* and *Cx. pallidothorax* were recorded but the immatures could not be collected. Another interesting aspect noted in the present investigation is that the larvae of some mosquito species—*Ae. albolateralis, Cx. mimeticus* and *Cx. quinquefasciatus* were also collected at the low elevation but the adults were obtained from the higher elevation. Streams and seepage pools were the habitats that shared most immatures of anopheline mosquitoes followed by shallow pits, rice fields, tanks, rock holes and riverbeds. In case of *Aedes* and *Culex,* tree holes and seepage pools produced maximum number of immatures. The immatures of *An. maculatus* in association with *Cx. mimeticus* were found in highest number in well sun lighted shallow pits of nearby hill streams and rivers. Most of the collected *Aedes* species were found in association with each other mainly in tree holes.

As far as the altitudinal vegetation is concerned, the western part of Himalaya is extremely rich in plant life. While developing a relationship between mosquito species abundance and the prevailing vegetation across elevation it is gathered that deciduous forest of

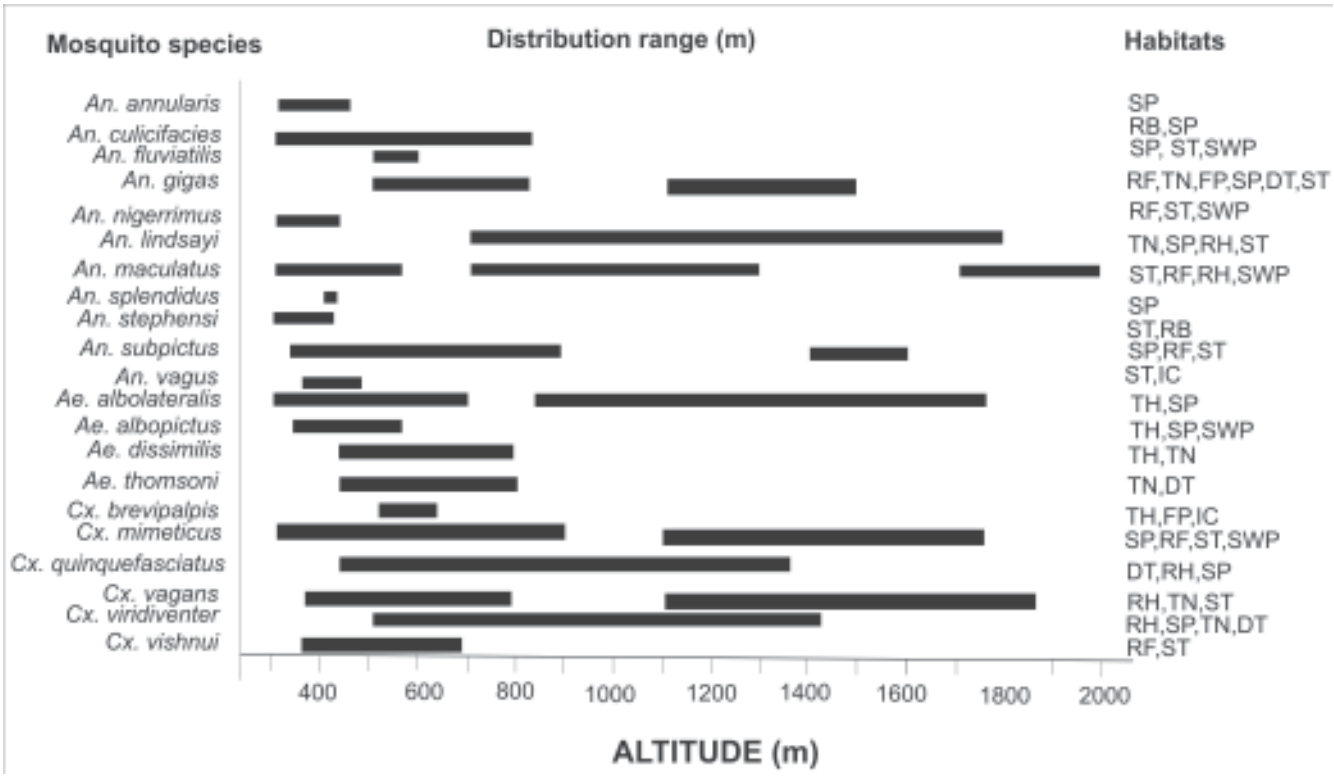


*Fig. 3:* Altitudinal distribution of immatures mosquitoe in Garhwal region during November 2000 to October 2002 (SP — Seepage pools; RB — River beds; RF — Rice fields; TN — Tanks; FP — Forest pools; DT — Ditches; ST — Streams; RH — Rock holes; TH — Tree holes; IC — Intra domestic containers; SWP — Shallow pits)

tropical zone (up to 915 m) provide maximum number of species richness. But the lower elevation of the region—300–500 m shared less species than the higher—501–915 m. However, tropical sub-himalayan region having sub-tropical forest type including pine forest and mixed oak and rhododendron vegetation shares less number of species than the tropical zone. It shares 19 species among a total of 34 species. Further as increasing the altitudinal level, less amount of species were found. The third zone of temperate forest composed of conifers, oak and rhododendron complex provides only 14 species of mosquitoes.

## Discussion

The species included in group—*Anopheles minimus, Aedes suffusus* and *Ae. unilineatus* were found within 300–500 m range. The occurrence of *Ae. unilineatus* within the same altitudinal range has been reported by earlier workers[4,5] but *Ae. suffusus* was recorded[4] at 760 m. Some mosquito species—*An. maculatus, Culex vagans* and *Armigeres durhami* were found to distribute from lowest level to uppermost—300 to 2000 m. More or less similar studies were carried out on the distribution of *An. maculatus* species but in case of *Cx. vagans* there was no record of its distribution below 600 m[4,5].

*Ar. durhami* was found to be distributed from 300 m to upper level but the data is inadequate to support its distribution up to 2000 m. Earlier, its occurrence has been reported up to 1700 m starting from the lowest level[4]. The VI group of mosquitoes which comprises *An. gigas, An. lindesayi, Ae. albolateralis, Cx. mimeticus, Cx. quinquefasciatus* and *Cx. viridiventer* between 500 and 2000 m range, shows their identity about the distribution. However, the distribution of *Cx. quinquefasciatus*/*fatigans* was recorded at 350 m and onwards[4,5].

On comparing the results of present study with those of Rao *et al* [4] and Bhat[5] in (Table 1), it was revealed that there are some species of mosquitoes such as *An. aconitus, An. nigerrimus, An. minimus* and *An. vagus* not reported by earlier workers. Hence, their elevational distribution is being added in the light of earlier studies. The major difference between the findings of earlier workers[4] and our studies is the distribution of *Ae. dissimilis, Ar. durhami* and *Cx. vishnui.* With regard to Bhat's[5] observation and the results of present study, the difference is mainly on the elevational distribution of *An. gigas, An. maculatus, An. splendidus, An. theobaldi, Ae. dissimilis, Ae. suffusus, Cx. brevipalpis, Cx. pallidothorax, Cx. quinquefasciatus*/*fatigans, Cx. vagans* and *Uranotaenia nivipleura.* Further, in the present study the figures in parentheses indicate the elevation at which maximum number of specimens of a particular species of mosquito has been collected (Table 1). This has not been furnished previously [4,5].

In general, there were few species per site with increasing altitude. The areas at lowest elevation produced the greatest number of species but did not produce a corresponding greater number of specimens. A decrease in the number of mosquito species at the higher elevation has already been reported[5,7,8,10]. The larger number of mosquito species collected at lower elevation may be due to increased human disruption in those areas[8]. There is a similarity between the present findings and those already made in respect of number of species which remained relatively constant for the first 800 m from the lowest level followed by a decrease. There are a number of views about the increased diversity at lower altitudes but the possible explanation could be the availability of favourable breeding places and preferred host. Another cause may be related to dispersal of mosquito, since they have to stop while flying to refuel with blood/nectar. Further, the tropical zone ranging between 300 and 900 m has the maximum temperature—27.2–29.4°C during June while the lowest (11.1– 13.3°C) in the month of January[25]. As the optimal range of temperature for the best survival of mosquito is from 22 to 31°C, hence in the present study the diversity is more between 500 and 900 m.

A slight variation in the distribution and abundance of

most of the mosquito species during the study period could be the result of several interacting climatic factors which depend on the severity of the amount and duration of rain in the wet season. As these conditions fluctuate season-to-season and place-to-place, henceforth, restriction in elevational distribution is a result of habitat specificity. Another possible explanation is that the elevation may limit niche availability which results in differential distribution pattern.

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