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## Research Articles

# Reappraisal on anopheline mosquitoes of Garhwal region, Uttarakhand, India

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### Abstract

**Background & objectives:** The study examines occurrence of anopheline mosquitoes in seven districts— Dehradun, Pauri, New Tehri, Hardwar, Rudraprayag, Chamoli and Uttarkashi of Garhwal region in Uttarakhand state, India.

**Methods:** The methodological approach comprised sampling and processing of adult/immature mosquitoes, data compilation, meteorological information and parasitological survey.

**Results:** A total of 87 localities covering 24 tehsils/blocks were surveyed during January 2000 to December 2005 for mosquito sampling. The study encountered 18 species of anophelines including three malaria vectors namely *Anopheles culicifacies*, *An. fluviatilis* and *An. stephensi* collected from Kalsi, Dehradun City, Sahaspur, Hardwar town, Roorkee, New Tehri town and Kotdwar localities. *An. pallidus* has been recorded for the first time from the Garhwal region. All the collected species have been presented with particular reference to their both adult and immature distribution, brief account of bionomics and some ecological notes.

**Interpretation & conclusion:** Out of 18 collected anopheline species, 15 were non-vectors and they were found to create nuisance to the inhabitants. As far as the species distribution was concerned the diversity was more at elevation between 150 and 1000 m above the mean sea level, while the immature of some species were not recovered from those localities where their adults were collected. Certain species of *Anopheles* were climate determined and their distribution was localized while some others were cosmopolitan.

**Key words** *Anopheles* – distribution – Garhwal region – habitats – mosquitoes

### Introduction

Mosquitoes have been known in India from very ancient times. The recognition of anopheline species and naming them scientifically is associated with the discoveries of Ross<sup>1</sup>. As far as the literature on the records of mosquitoes from Garhwal region (Uttarakhand) is concerned, the search revealed that

the faunal resources from this region require indepth study. Further, the information about mosquito species involved in malaria transmission is poor with exceptions from the Doon Valley<sup>2–4</sup>. While going through the earlier work on mosquitoes from Garhwal region<sup>5</sup>, *Nyssorhynchus maculatus* (now *Anopheles maculatus*) was the first record from District Dehradun. Subsequently<sup>6</sup>, a list of nine species

of mosquitoes along with information on their role in malaria transmission was presented from Dehradun district. Later on, a number of workers<sup>7-9</sup> recorded anopheline mosquitoes from Garhwal region. Almost all of them, besides recording mosquito species, also reviewed the taxonomic status of family, subfamily and genera/subgenera. In 1958, Wattal *et al*<sup>10</sup> observations on the mosquitoes from the Doon Valley added more information in the existing knowledge by collecting 25 species of mosquitoes belonging to seven genera. Thereafter, entomological surveys<sup>11,12</sup> of Dehradun valley updated the mosquito fauna. An extensive survey of haematophagous arthropods including 16 species of *Anopheles* from western Himalayas between 1966 and 1970 added more information in the existing knowledge<sup>13</sup>. Bhat<sup>14</sup> reported 10 species of *Anopheles* from different altitudes of the western Himalayan region covering five districts— Dehradun, Chamoli, Uttarkashi, Tehri and Pauri of Garhwal region. After a gap of about 15 years, the Dehradun region was again explored so as to review the results of the previous studies about the mosquitoes<sup>15-16</sup> in the light of changed scenario of the area.

For the last one and a half decades the ecological balance of the Garhwal region is upset due to various developmental activities. This has established innumerable mosquito breeding habitats and almost there is no serious work being undertaken on anopheline mosquitoes. Hence, it is felt desired to record the changed scenario of anopheline fauna and reasons for that change. There are chances of getting new records, besides disappearance and reappearance of certain forms. Indeed, the main objective of this paper is to provide a list of anophelines of Garhwal region in the light of earlier studies and present records.

### Material & Methods

*Study area:* Garhwal region of western Himalayas in Uttarakhand state (India) covering seven districts namely Dehradun, Pauri, New Tehri, Hardwar, Rudrapur, Chamoli and Uttarkashi between

29°26'N to 31°26'N latitude and 77°39'E to 80°03'E longitude across the altitudinal gradients between 150 and 3000 m, has been selected for the present investigation (Fig. 1). The total area of land cover is 32,449 km<sup>2</sup>, represented by different phytogeographic zones, the tropical zone, mainly covered by deciduous forests while sub-tropical zone includes pine forest and mixed oak and rhododendron vegetation. The third zone is of temperate forest, composed of conifers, oak and rhododendrons. Details of the selected area such as longitude, latitude and altitude were computed using the global positioning system (GPS) for accurate location of sampling stations and the areas of interest. A portable altimeter was also used for measuring altitude of the sampling site.

*Methodology:* The methodological approach comprised, site sampling, adult/immature mosquito collection, identification, data compilation, meteorological information and parasitological survey. The mosquitoes were collected from each sampling site by using aspirator and flashlight during the morning and evening hours. Collection of immature mosquitoes was also made on the same day by dipping and netting method as per WHO guidelines<sup>17</sup>. A close search for adult mosquitoes was made in every possible habitat like human dwelling, cattleshed, mixed dwelling and other outdoor resting sites such as bushes, tree holes, rock holes and discarded containers to collect maximum number of specimens. Random collection was also made while surveying fixed localities. In a nutshell, the sampling was done throughout the year. After collection, all mosquito specimens were immobilized with petroleum ether followed by their sorting, firstly genera-wise and thereafter species-wise. Identification was based on adult characters using standard taxonomic keys and catalogues<sup>18-21</sup>. The internal classification of the genus *Anopheles* as well as names of species is after Nagpal & Sharma<sup>21</sup> and Harbach<sup>22</sup>. The immature forms were emerged into adults under laboratory conditions for species identification.

Information on co-existing biotic community and



Fig. 1: Map of Garhwal region showing mosquito sampling sites (S<sub>1</sub> to S<sub>87</sub>)

breeding characters was also recorded at the time of mosquito sampling. Only indoor collected female specimens were dissected to detect infection in the stomach for oocysts and salivary glands for sporozoites using standard techniques<sup>17</sup>. The sporozoites were fixed in normal saline and stained with Leishman stain<sup>23,24</sup>. While compiling the data, the relevant information on the geographic and environmental features was also taken into consideration.

### Results

A total of 18 species of anophelines (*An. gigas* Giles, 1901; *An. lindesayi* Giles, 1900; *An. aconitus* Doenitz, 1902; *An. annularis* Van der Wulp, 1884; *An. culicifacies* Giles, 1901; *An. fluviatilis* James, 1902; *An. jeyporiensis* James, 1902; *An. nigerrimus* Giles, 1900; *An. maculatus* Theobald, 1901; *An. minimus* Theobald, 1901; *An. pallidus* Theobald,

1901; *An. pulcherrimus* Theobald, 1902; *An. splendidus* Koidzumi, 1920; *An. subpictus* Grassi, 1899; *An. stephensi* Liston, 1901; *An. theobaldi* Giles, 1901; *An. vagus* Doenitz, 1902 and *An. varuna* Iyengar, 1924) were collected from 87 sampling sites (Fig. 1; Table 1) covering 24 tehsils/blocks under seven districts in Garhwal region during January 2000 to December 2005. On comparing percent-wise composition of vector and non-vector species in all the 87 sampling sites, it was 23.5 and 76.5% respectively.

Incrimination studies revealed the following three species namely *An. culicifacies*, *An. fluviatilis* and *An. stephensi* collected from some particular localities as vector of malaria (Table 2). While remaining 15 anopheline species were found as non-vectors. Higher species diversity and abundance was found at lower elevation (up to 1000 m). There were a few species of mosquitoes like *An. aconitus*, *An. splendidus* and *An. theobaldi* whose adults were collected but the immatures could not be traced from that particular zone. *An. subpictus* and *An. maculatus* were found distributed throughout the range of elevation, as they were collected from Tharali (S<sub>80</sub>) and Joshimath (S<sub>81</sub>) localities respectively. This was followed by occurrence of the following species namely *An. lindesayi*, *An. fluviatilis*, *An. annularis*, *An. culicifacies* and *An. vagus*/*An. gigas* from Daira (S<sub>45</sub>), Dhumakot (S<sub>42</sub>), Kotdwar (S<sub>40</sub>), Dogadda (S<sub>39</sub>) and Lansdown (S<sub>38</sub>) localities respectively. However, *An. gigas* was confined above the elevation of 600 m. Population of *An. minimus* was recorded from few localities only like Sahaspur (S<sub>1</sub>) and Sahastradhara (S<sub>3</sub>) in District Dehradun (S<sub>4</sub>), and Shyampur (S<sub>10</sub>) and Mohand (S<sub>11</sub>) in Hardwar district. Likewise, *An. pulcherrimus* and *An. nigerrimus* were encountered from few sampling sites. However, the population of *An. maculatus*, *An. subpictus*, *An. fluviatilis* and *An. culicifacies* was comparatively dense in comparison to other mosquito species. The specimens of *An. subpictus*, *An. gigas* and *An. lindesayi* were also collected above the elevation of 2400 m. As far as the

species diversity of anophelines in the Garhwal region is concerned, a maximum of 12 species have been recorded from Mohand (250 m) and Raiwala (450 m) in Hardwar while 11 species were recovered from the following seven sites, namely Sahaspur (S<sub>1</sub>), Sahastradhara (S<sub>3</sub>), Dehradun City (S<sub>4</sub>), Shyampur (S<sub>10</sub>), Roorkee (S<sub>15</sub>), New Tehri (S<sub>22</sub>) and Pauri town (S<sub>50</sub>). At the elevational range of 950 m, 10 species of anophelines were recorded from Narendranagar (S<sub>31</sub>) in New Tehri (S<sub>22</sub>) district. Likewise, from the following four localities namely Badshapur (S<sub>20</sub>), Niranjanpur (S<sub>21</sub>), Lansdown (S<sub>38</sub>) and Badkot (S<sub>58</sub>) covering the elevation between 200 to 1500 m, only nine species were recorded.

The species-wise details along with ecological notes are being enumerated as under:

*An. gigas* Giles, 1901: Its occurrence has been recorded from 39 localities in the range of 450–2500 m elevation. The species is known for its distribution at high altitudinal zones. Mountainous streams and pools have been found to produce maximum number of larvae than other habitats such as rice-fields ditches and rock holes. The species has been usually found breeding in villages, often in very small and temporary collections of water among the houses. The adults have been very rarely found in houses. There is no evidence that either *An. gigas* or any of its varieties are concerned in the transmission of malaria and they are exceedingly unlikely to play any part in the spread of the disease owing to their habitats and the height at which they are found.

*An. lindesayi* Giles, 1900: The species has been recorded as one of the higher elevation species (distributed above 500 m) and collected from 45 localities. Its abundance has been recorded higher on an increase in the elevation whereas the immatures are collected at 700–1800 m of elevation. Maximum number of adults was recorded at 1400 m altitude while the immatures were encountered from forest pools, streams and rock holes. It is noticed that the

Table 1. Occurrence of anopheline fauna and their

District	Tehsil/ Block	Altitude (m)	Study sites* (S <sub>1</sub> -S <sub>87</sub> )	Vector species				
				1	2	3	4	5
Dehradun	Dehradun	350-2100	S <sub>1</sub> -S <sub>6</sub>	9.8	11.7	11.2	2.9	8.7
	Chakrata	500-2050	S <sub>7</sub> -S <sub>9</sub>	5	13.4	14.2	0	9.2
Hardwar	Hardwar	150-250	S <sub>10</sub> -S <sub>13</sub>	12	10.7	12	1.9	7.1
	Roorkee	180-250	S <sub>14</sub> -S <sub>17</sub>	12.1	8.7	9.5	1.8	3.1
	Lakshar	180-210	S <sub>18</sub> -S <sub>21</sub>	8.9	9.4	17.8	0	0
Tehri	Tehri	1100-2500	S <sub>22</sub> -S <sub>24</sub>	4.3	6.4	7.5	0	5.3
	Pratapnagar	950-2100	S <sub>25</sub> -S <sub>28</sub>	9.2	3.3	4.9	0	5.7
	Narendranagar	450-950	S <sub>29</sub> -S <sub>32</sub>	9.6	12	5.4	0	9.6
	Devprayag	500-1100	S <sub>33</sub> -S <sub>35</sub>	5.8	10.4	0	0	6.9
Pauri	Lansdown	750-1300	S <sub>36</sub> -S <sub>38</sub>	12.5	9.8	0	0	4.4
	Kotdwar	250-1100	S <sub>39</sub> -S <sub>41</sub>	14.2	12.4	11.1	2.4	1.8
	Dhumakot	750-1000	S <sub>42</sub> -S <sub>44</sub>	16.1	17.2	6.8	0	5.7
	Thailsen	1450-2100	S <sub>45</sub> -S <sub>48</sub>	0	0	0	0	23.3
	Pauri	650-1300	S <sub>49</sub> -S <sub>52</sub>	8.5	12.8	5.4	0	9.7
Uttarkashi	Purola	1300-2450	S <sub>53</sub> -S <sub>56</sub>	0	0	0	0	4.4
	Rajgarhi	1350-1800	S <sub>57</sub> -S <sub>60</sub>	6.7	7.4	0	0	11.1
	Dunda	650-800	S <sub>61</sub> -S <sub>63</sub>	0	11.7	7.8	0	0
	Bhatwari	750-1950	S <sub>64</sub> -S <sub>66</sub>	4.3	6.5	0	0	10.8
Rudraprayag	Rudraprayag	675-1050	S <sub>67</sub> -S <sub>69</sub>	7	0	0	0	14
	Ukhimat	1150-1450	S <sub>70</sub> -S <sub>73</sub>	0	0	0	0	18
Chamoli	Karanprayag	1750-2300	S <sub>74</sub> -S <sub>76</sub>	0	0	0	0	0
	Tharali	1350-2100	S <sub>77</sub> -S <sub>80</sub>	0	0	0	0	0
	Joshimath	850-1800	S <sub>81</sub> -S <sub>84</sub>	0	0	0	0	9.6
	Gopeshwar	950-1250	S <sub>85</sub> -S <sub>87</sub>	5.1	0	0	0	4.2

\*Study sites location are shown in Fig. 1; 1—*An. culicifacies*; 2—*An. fluviatilis*; 3—*An. stephensi*; 4—*An. aconitus*; 11—*An. splendidus*; 12—*An. subpictus*; 13—*An. theobaldi*; 14—*An. vagus*; 15—*An. varuna*; 16—*An. gigas*;

species preferred clean natural breeding habitats of permanent conditions with shady, quiet/stagnant along with moderate vegetation at a water depth of 0.1–0.5 m. Temporary habitats with thick vegetation also harbored large number of specimens. Streams, rock holes, rice fields and ditches also shared immature of this species along with larvae of *An. gigas* showing good association. Both, Rao *et al*<sup>13</sup> and Bhat<sup>14</sup> have made similar reports on the distribution

of *An. lindesayi* above 500 m. This species is unlikely to be an important carrier owing to occurrence at high altitudes.

*An. aconitus* Doenitz, 1902: This species has been recorded at low elevation area (180 to 650 m) of Sahaspur (S<sub>1</sub>), Dehradun City (S<sub>4</sub>), Shyampur (S<sub>10</sub>), Roorkee (S<sub>15</sub>) and Kotdwar (S<sub>40</sub>) localities. The larvae were found primarily in flooded rice-fields,

## locations in Garhwal region during the study period

Non-vector species												
6	7	8	9	10	11	12	13	14	15	16	17	18
1.3	13.1	1.8	0.9	1.1	7.8	13.5	0	6.4	3.6	0.9	0.6	3.9
0	17.6	0	0	0	3.3	15.1	3.3	13.4	0	0	5	0
3.5	14	2.2	1.3	1.9	3.9	12.3	0	12.3	0	0	0	4.2
0	7.1	0	2.3	2.1	3.1	5.8	0	8.4	0	0	0	0
0	12.8	0	5.4	2.9	7.9	13.3	0	18.3	2.9	0	0	0
0	10.7	0	0	0	6.4	22.5	4.3	6.4	0	10.7	15	0
0	11.5	0	0	0	4.9	16.5	11.5	7.4	0	9.1	16.5	0
0	18	0	0	0	9	12.6	2.4	6	0	5.4	6.6	3
0	18.6	0	0	0	12.7	16.2	10.4	6.9	0	6.9	4.6	0
0	18.7	0	0	0	4.4	19.6	12.5	2.6	0	10.7	4.4	0
3.1	14.9	0	0	0	6.8	18	3.7	8.6	0	0	2.4	0
0	20.6	0	0	0	0	16	0	0	0	12.6	4.5	0
0	26.6	0	0	0	0	31.6	0	0	0	10	8.3	0
0	17.6	0	0	0	8.5	14.6	3.6	6	0	3.6	9.1	0
0	14.6	0	0	0	0	21.3	12.3	0	0	22.4	24.7	0
0	18.6	0	0	0	0	10.4	2.9	4.4	0	19.4	18.6	0
0	29.4	0	0	0	0	21.5	0	0	0	21.5	7.8	0
0	17.3	0	0	0	5.4	9.7	4.3	6.5	0	16.3	18.4	0
0	16.9	0	0	0	14	19.7	9.8	0	0	5.6	12.6	0
0	22.9	0	0	0	0	29.5	4.9	6.5	0	4.9	13.1	0
0	24	0	0	0	0	12	13.3	0	0	26.6	24	0
0	20.1	0	0	0	4.3	24.5	12.2	7.8	0	21	9.6	0
0	25.8	0	0	0	0	20.4	11.8	5.3	0	11.8	15	0
0	11.9	0	0	0	4.2	19.6	15.3	3.4	0	20.5	15.3	0

5—*An. annularis*; 6—*An. jeyporiensis*; 7—*An. maculatus*; 8—*An. minimus*; 9—*An. pallidus*; 10—*An. pulcherrimus*; 17—*An. lindesayi*; 18—*An. nigerrimus*.

grassy ponds, swiftly flowing water of irrigation channels and stream margins, besides their occurrence in stream pools, fresh water swamps, rock pools, seepage pools and ditches. According to Strickland<sup>25</sup> the species delights particularly in swift-running water of irrigation channels while Watson<sup>26</sup> noted its occurrence in fast-running water. In India, this species has been found naturally infected with malarial parasite, centralized to an area but in our

studies no such results have been recorded.

*An. annularis* Van der Wulp, 1884: Though it is most commonly found in the plains but it has also been recorded from 40 localities up to an elevation of 2100 m. The larvae have been found most frequently in seepage pools, riverbeds, rice-fields, ditches, streams and tree holes. However, the natural habitats of temporary conditions with shady to partially shady habitats were

**Table 2. *Anopheles* mosquitoes found positive with malarial parasites in different localities in Garhwal region**

Species	Districts	No. dissected	No. of species with infection		Infection rate (%)
			Gut	Gland	
<i>An. culicifacies</i>	Dehradun	424	1	5	1.41
	Hardwar	120	1	0	0.83
<i>An. fluviatilis</i>	Dehradun	233	0	3	1.28
	Pauri	45	0	1	2.22
	Hardwar	78	0	1	1.28
<i>An. stephensi</i>	Dehradun	907	1	7	0.88
	Tehri	48	0	2	4.16
	Hardwar	215	0	2	0.93
		147	0	2	1.36

the main characteristics of the habitats of this species. Adults have been found mostly zoophilic in nature during our study. No evidence of malarial parasites was found while examining the guts and glands.

*An. culicifacies* Giles, 1901: This species occurred throughout the southwestern part of Garhwal region in 39 localities within 150–1800 m. The maximum abundance was recorded at 700 m. while it was low at higher level. The species has been found as one of the highly domestic and zoophilic one and apparently feeds almost entirely on human beings. The species has been found ubiquitous in nature in terms of breeding preference, though it breeds in almost any clear water of natural collection like seepage pools, rivers, rice-fields, irrigation canals, streams, tanks, forest pools and rock holes. Partially shady habitats either slow flowing or quiet and clear to slightly turbid, were the main characters of the habitats. Immatures were also found in tree holes in which the water depth varied from 0.01–1.5 m. Females avoided oviposition site with emergent vegetation. It was also found that two sibling species—A and B of *An. culicifacies* have been confined to Garhwal region. This is in accordance with the findings of Subbarao *et al*<sup>27</sup>. During the incrimination studies, some specimens from Dehradun City (1.41%) and Roorkee (0.83 %) locali-

ties were found infected with malarial parasites. Keeping in view the findings of the present study and earlier records *An. culicifacies* seems to be a most efficient malaria carrier in nature and in the transmission of disease.

*An. fluviatilis* James, 1902: This species was found to scatter in 42 localities of southwestern part of the Garhwal region up to an elevation of 1350 m. Maximum abundance was recovered from higher elevation and the density decreases below 600 m. However, at 900 m highest abundance was recorded. The immatures have been found mainly in swiftly running clear water, especially in irrigation channels and in streams overgrown with vegetation. But the specimens were also found in seepage pools, rivers, rice-fields, irrigation canals, streams, tanks, forest pools and rock holes in some localities. The adult specimens of *An. fluviatilis* were mainly collected from indoor shelters like houses that come readily to feed on man. In some localities (Sahastradhara, Mohand and Mangalore) a good number of specimens were found collected from cattlesheds. Two sibling species—T and U of *An. fluviatilis* have been found in this region, this supports the findings of Nanda *et al*<sup>28</sup>. Incrimination studies of gut and gland of the mosquitoes collected from Kalsi (S<sub>7</sub>), Kotdwar (S<sub>40</sub>) and

Roorkee (S<sub>15</sub>) localities encountered malarial infection with 1.28, 2.22 and 1.28% respectively. Earlier, *An. fluviatilis* was reported as a vector of malaria in forested areas of Doon Valley<sup>3</sup>.

*An. jeyporiensis* James, 1902: The adults have been found in cattlesheds and human habitats at Raiwala (S<sub>6</sub>), Shyampur (S<sub>10</sub>), Mohand (S<sub>11</sub>) and Kalagarh (S<sub>41</sub>) localities at the altitudinal range of 180 to 450 m. Immatures have been found up to 300 m of height. However, the ideal breeding places have been recorded as grassy edges of slow running streams, channels and shallow tanks. The specimens have also been found to breed in seepages, rice-fields and a variety of breeding places with clear water, with marginal vegetation. The species has been found to feed on man and cattle, depending on the availability. There are no records of this species being found infected with malarial parasites either experimentally or in nature.

*An. nigerrimus* Giles, 1900: The species was found to distribute in five localities (Sahaspur and Raiwala from Dehradun, Shyampur and Mohand from Hardwar and Muni ki Reti from New Tehri district) at an elevation of 180 to 550 m. It has been found breeding in stagnant water with much vegetation in ditches, swamps and rice fields usually at some distance from human habitations. No infection has been found in incrimination studies.

*An. maculatus* Theobald, 1901: A good density of this species has been observed during the present study. Less abundance was encountered below 600 m and an increase in the population was noted on increasing the altitudinal range up to 1100 m. Instead of its wide range of distribution, the species is of little or no importance as a vector of human malaria. The immatures were collected during April and May before monsoon from sun-lighted clear swallow pits, seepage pools, springs and streams. Their distribution was restricted and no immature was encountered above the elevation of 1300 m. The species shows

high positive association with *Culex mimeticus* but a good association was also found with other anophelines like *An. culicifacies*, *An. fluviatilis*, *An. nigerrimus*, *An. splendidus* and *An. vagus*. Other habitats such as rice-fields and rock holes also shared some immatures of this species. Partially shady habitats either slow flowing or quiet and clear to slightly turbid, were the main characters of the habitats.

*An. minimus* Theobald, 1901: The adults have been recorded from four localities within the altitudinal range of 180 to 1250 m. However, the larvae have been found in small-to-moderate sized streams of clear, cool unpolluted water with partially shaded and grassy margins. The adults occurred freely in outdoor habitations and readily feed on man, showing anthropophilic behaviour.

*An. pallidus* Theobald, 1901: The adults have been found chiefly in cattlesheds but also entered in human habitations. Present study envisages the occurrence of this species at Raiwala (S<sub>6</sub>), Mohand (S<sub>11</sub>), Roorkee (S<sub>15</sub>), Bhagwanpur (S<sub>16</sub>), Badshahpur (S<sub>20</sub>) and Niranjapur (S<sub>21</sub>) localities of Garhwal at altitudinal range of 180 to 650 m. This is a zoophilic species but in the absence of cattle it rapidly bites man. The larvae have been found in rice-fields, tanks with weeds, water collected in embarked fields and in burrow pits in the neighbourhood of rice cultivation. As per our studies this species has not been found to play any part in the transmission of malaria. However, Iyengar<sup>29</sup> and Roy & Biswas<sup>30</sup> considered it as a carrier of malaria in West Bengal and Orissa, respectively.

*An. pulcherrimus* Theobald, 1902: Larvae have been recorded in warm and sunny stagnant habitats with abundant submerged vegetation while the adults are caught in houses and in cattlesheds. The specimens have been found to feed preferably at night, but are often quite active by day. This species is found to distribute within the altitudinal range of 180–650 m. Its power for flight and resistance to desiccation has



been found very high, as is expected from its distribution in the areas where mean annual rainfall was less than 20 inches. No infection has been found during incrimination studies.

*An. splendidus Koidzumi, 1920:* The immatures were collected from rice-fields, forest pools and hill streams of the study region. Species association of immatures was found with *An. culicifacies*, *An. fluviatilis*, *An. nigerrimus*, *An. maculatus* and *An. vagus* depending on the type of habitats. In some localities the breeding was found in tree holes in which the water depth varied from 0.01–1.5 m. Adults were collected from indoor shelters of cattle and human dwellings in 36 localities within the altitudinal range of 150 to 2100 m. Incrimination studies show that this species is not taking any part in the transmission of malaria.

*An. subpictus Grassi, 1899:* This is probably the most common species of anophelines occurring in different parts of the study area. It is found mainly in the plains, though it has been recorded several times at a height of over 2000 m. Adults have been found in large numbers in cattlesheds and human habitations but they prefer to bite human beings. In the present study both adults and larvae have been recorded from 81 localities, within the range of 180–2450 m altitude. The immatures have been encountered almost from all the aquatic habitats but high density was found in pools, often muddy rain pools and in almost any temporary collection of water. No infection was found in our studies.

*An. stephensi Liston, 1901:* Specimens of *An. stephensi* were encountered from the localities within the range of 150–1300 m and numerically higher number was recorded below 600 m (maximum at 380 m) but the immatures were restricted to 300–345 m, recovered from seepage pools, riverbeds, tanks, streams, rock holes and intradomestic containers like flower pots and discarded containers. Partially shady to sun-lighted, quite/stagnant to slow flowing and

clear water were the qualitative characters of the breeding habitats of this species. In urban areas, the larvae have been recorded from a wide variety of artificial containers, cisterns, wells, tubs and fountains. A good relation in terms of species association was found with *An. vagus*. Some specimens of *An. stephensi* collected from Kalsi (S<sub>7</sub>), Sahaspur (S<sub>1</sub>), Dehradun City (S<sub>4</sub>), New Tehri (S<sub>22</sub>), Hardwar (S<sub>12</sub>) and Roorkee (S<sub>15</sub>) localities were found infected with malarial parasites. This is supported by earlier findings of Singh *et al*<sup>2</sup>.

*An. theobaldi Giles, 1901:* It is high land mosquito found in 30 localities within the range of 500 to 2400 m. But only adults were found above the elevational range of 2000 m. The larvae have been found chiefly in shallow running water with much weed and algae. Further, the larvae are found at the margins of large ponds among the weeds and also in shallower streams.

*An. vagus Doenitz, 1902:* The immatures of this species were collected mostly from intradomestic containers and household tanks while the adults were found in large numbers in both cattle sheds and human dwellings. The larvae are typically found in small pools and puddles, often among the houses in villages. Tanks, streams, rock holes and intradomestic containers of both natural and artificial temporary habitats have been found to be the positive breeding habitats. During the present investigation no specimen of *An. vagus* was found infected with malarial parasite.

*An. varuna Iyengar, 1924:* Its occurrence has been recorded in houses, cattlesheds and mixed dwellings at Sahastradhara (S<sub>3</sub>), Dehradun City (S<sub>4</sub>), Raiwala (S<sub>6</sub>) and Niranjapur (S<sub>21</sub>) localities of the study area. The specimens have also been recorded from outdoor in foothill areas. The adults have been found to feed on both cattle and human but prefer cattle. The specimens have been found to breed in a variety of places both in stagnant and flowing waters. Profuse breed-

ing has been recorded in freshwater tanks, ponds, rice-fields, drains, irrigation channels, wells, etc. with algal and other aquatic vegetation. Earlier, the species was considered as a vector from different parts of the country but in our study no symptoms of infection has been recorded from the study sites<sup>21</sup>.

### Discussion

From Garhwal region, *An. lindesayi*, *Nyssorhynchus maculatus* and *Neocellia indica* were recorded earlier in the vicinity of District Dehradun<sup>5,7</sup>. In the mean time, a list of Indian species of *Anopheles* recorded from Garhwal region was published<sup>8</sup>. *Neocellia indica* was considered as a synonym of *An. willmorei*<sup>31</sup>. Subsequently, there have been many changes mainly due to sinking of specific names and also as a result of addition of new species. In the monograph *The distribution of anopheline mosquitoes in India*<sup>9</sup>, 13 species of *Anopheles* namely, *An. culicifacies*, *An. fuliginosus* (*annularis*), *An. gigas*, *An. hyrcanus*, *An. lindesayi*, *An. listonii* (*fluviatilis*), *An. maculatus*, *An. maculipalpis* (*splendidus*), *An. pulcherrimus*, *An. stephensi*, *An. subpictus*, *An. theobaldi* and *An. turkhudi* were recorded from Dehradun. The following three anopheline species, namely, *An. fuliginosus*, *An. listonii* and *An. maculipalpis* as named by Thomson<sup>6</sup> were later on recognized as *An. annularis*, *An. fluviatilis* and *An. splendidus*, respectively.

The subgenera *Cellia* was reviewed by incorporating synonyms and listing 11 species namely, *An. aconitus*, *An. culicifacies*, *An. fluviatilis*, *An. maculatus*, *An. minimus*, *An. jeyporiensis*, *An. stephensi*, *An. splendidus*, *An. subpictus*, *An. vagus* and *An. theobaldi* from Garhwal region<sup>32</sup>. While compiling the record of *An. maculatus* subspecies *willmori* (*indica*, Theobald 1907) was mentioned from Dehradun as the type locality.

The Himalayan region has been the most neglected one from the point of view of the distribution of mosquitoes<sup>13</sup>. Bhat<sup>14</sup> described mosquito fauna from

Himalayan region of Uttar Pradesh (now in Uttarakhand) covering an altitudinal range from 340–3530 m and found that the *Anopheles* fauna of Chamoli district was comparatively rich followed by Dehradun, Uttarkashi, Tehri (now New Tehri) and Pauri in succession. While discussing the present status of anophelines occurrence, it seems none of earlier workers<sup>10–14</sup> had taken into consideration the very earlier studies<sup>5–9</sup> about the records of mosquitoes from Garhwal region before 1934.

In the present study, it has been found that the number of species of Culicidae is rapidly increasing and numerous species have been recorded/described after the publication of Bhat<sup>14</sup>. Moreover, the literature pertaining to the mosquito fauna of Garhwal region seems to be still in scattered form keeping in view the changed scenario. In fact, much valuable information on mosquitoes of Himalayan region is given by Bhat<sup>14</sup>, but without taken into consideration the work mentioned by earlier eminent scientists, the picture seems to be hazy.

Pemola & Jauhari<sup>16</sup> recorded as many as 17 species of *Anopheles* from Garhwal region with more emphasis to the altitudinal range (300 to 2000 m) of sampling spot. Out of these 17 species, 14 were collected from Dehradun excluding *An. gigas*, *An. lindesayi* and *An. theobaldi*. However, present study yielded availability of 18 species of *Anopheles*. The mosquito species, *Anopheles pallidus* has been recorded from Garhwal region for the first time. Earlier, it was recorded from Nainital and Saharanpur districts<sup>9</sup>. It has been found that, *An. pallidus* has no role in the transmission of any of the mosquito borne diseases but it is supposed to create nuisance to the local people.

Based on the occurrence of anopheline species at varying altitudes where fluctuation is supposed in the humidity, rainfall and temperature, the possible explanation has been worked out. The humidity is one of the most important environmental factors affecting the mosquito distribution. The distribution of *An.*

*vagus* and *An. minimus* corresponds very closely to those areas where the mean annual rainfall exceeds 50 inches. It is seen that the species like *An. maculatus* occurs generally throughout the region but the area of distribution does not cross the line beyond which the rainfall is less than 20 inches per annum.

The effect of altitude is well correlated to the temperature as at higher altitude the temperature is less while at low altitude the temperature increases thus ultimately exerts its impact on the survival of immatures and emergence of pupae into adults. The species like *An. theobaldi*, *An. lindesayi* and *An. gigas* were confined to high altitudes—above 500 m, while *An. subpictus* and *An. maculatus* have been found to distribute at all elevational levels, however, the maximum population was gathered at lower altitude.

There is a major role of humans in affecting the distribution of mosquito species also. Certain species (*An. fluviatilis*) breeds only in forests and hence tend to disappear while urbanization advances and the forests are destroyed. This leads to the spread of *An. maculatus*. Presence of human and cattle favoured the spread of species like *An. culicifacies*, *An. stephensi* and *An. subpictus*.

Another way in which human influences the distribution of anophelines is by the type of cultivation employed. It has been found that *An. pallidus* is pre-eminently a rice-field breeder. The species such as *An. aconitus* and *An. fluviatilis* are noted breeders in irrigation channels, so an increase of irrigated areas is favourable to their spread. Conclusively, it can be said that certain species of *Anopheles* are climate determined and their distribution is localized while some are found every where. Such type of study if taken on a large scale would certainly bring into light more in respect of site selection by the mosquitoes.

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