HABITAT BIODIVERSITY OF MOSQUITO RICHNESS IN CERTAIN PARTS OF GARHWAL (UTTARANCHAL), INDIA

N Pemola Devi and RK Jauhari

Parasitology Laboratory, Department of Zoology, DAV (PG) College, Dehra Dun, India

Abstract. The present study gives an overview of data on the habitat biodiversity of mosquitoes occurring in certain parts (viz, Pauri, Tehri and Uttarkashi) of Garhwal (Uttaranchal), India. The study was based on the mosquito sampling in 450 sites/spots in all the 3 districts, each spot having an area of 25 km^2 and geographically located at varying altitudes between 300 to 3,000 m. While compiling the data, published sources in the recent past were also considered. The species richness was categorized as most species and least species by estimating the top and least 5 percentile of species density in each grid cells/spots, respectively. Our database showed that the area harbors 45 species from 3 genera. As many as 17 species of *Anopheles* and 15 species of the genus *Aedes* were recorded during November 2000 to October 2002. Further, there were 13 species of *Culex,* besides few specimens that could not be identified correctly because of damage body parts. Collected species of Anophelines were grouped as common, uncommon, and rare species depending to their percentage of occupying in grid cells/spots. There were 9 common species, while the number of rare species and uncommon species were 3 and 5, respectively. The sites/spots nearer to riverine areas or thick-forested areas showed more diversity of mosquitoes than those nearer to non-forested or thin-forested areas. However, the biodiversity rich spots were up to 1,200 m altitudes.

INTRODUCTION

Biodiversity refers to the variability of both plants and animals. Broadly, it is the 'richness' of an ecological community. The diversity among insects has always been of keen interest, not only to entomologists dealing with structure and function, but also to those who are engaged in different environmental programs. Relating to the biodiversity of insect richness, Prendergast *et al* (1993) compared the coincidence of diversity hotspots of some different groups of insects (viz butterflies and dragonflies) and examined the extent to which species-rich areas for different taxa coincide and whether species-rich areas contain substantial numbers of rare species. It is relevant to note that India has been considered as one of the mega-diversity countries possessing a rich measure of all living organisms when biodiversity is viewed as a whole. According to Mittermeier *et al* (1999) and Myers *et al* (2000) biological-rich areas are found in a high range across the altitudinal variation associated with diverse habitats. Further, as per their views, most of the hot spots and areas of high biological diversity are concentrated in hilly and mountainous ranges where there are diverse habitats.

There is a scarcity of literature on habitat biodiversity hotspots regarding mosquito presence. In fact, reports on mosquito fauna in different regions of India dominate the literature, while information on mosquito biodiversity hotspots is lacking in general, and in the state of Uttaranchal in particular. In Garhwal region, earlier records (Wattal *et al*, 1958; Wattal and Kalra, 1965; Kalra and Wattal, 1965; Rao *et al,* 1973; Bhat, 1975; Jauhari *et al*, 1992; Srivastava and Jauhari,1992; Mahesh *et al*, 1997; Singh *et al*, 1997; Mahesh and Jauhari, 2000) evidenced the rich mosquito fauna diversity, but there is almost no record about species richness and its composition in diverse habitats. As far as the environmental scenario of the chosen area, namely Garhwal (Uttaranchal) is concerned, a change is being observed because of developmental activities. This has resulted in the creation of damp conditions in the landscape that

Correspondence. RK Jauhari, Parasitology Laboratory, Department of Zoology, DAV (PG) College, Dehra Dun 248001, India.
Tel: +91 (0135) 2741152
E-mail: jauharirk@hotmail.com

have a direct impact on the mosquito presence. Further, there is some early evidence that mosquito diversity in Garhwal is responding to climatic changes that have occurred during the previous decades. With this background, it warrants to undertake fresh, extensive, and intensive surveys to determine the total range of mosquito species diversity in terms of species richness, rarity, and least species-rich sites across high-altitude variations in the three districts (viz, Pauri, Tehri, and Uttarkashi) of Garhwal (Uttaranchal) with specific habitat diversity.

MATERIALS AND METHODS

Study site

The study area is located centrally in the western part of Garhwal (Uttaranchal), India covering three districts (viz, Pauri, Tehri, and Uttarkashi) (Fig 1). Geographically, the sites are located between 29º26´N to 31º26´N latitude and 77º47´E to 79º36´E longitude, between the altitudinal gradients from 300 to 3,000 m. The main water bodies of this region are the River Ganges, the Yamuna, and their tributaries. Other water bodies that support mosquito breeding are streams, rock holes, seepage pools, forest pools, rice fields, etc. The area is represented by different forest types, thus providing an enormous diversity of habitats for hematophagous insects, including mosquitoes. Moreover, the increasing exploitation of mountainous and hilly regions for the construction of power projects and dams, development of townships, deforestation, natural calamities etc has created many sites for mosquito breeding.

Development of site sampling database

The district planning maps of the study area were procured from Survey of India, and thereafter each of the maps was scanned to get its complete view. The total area under each district boundary was divided into grid cells, each being 5 km x 5 km (25 km^2). Then, the grid cells were selected with a view to the possibility of mosquito sampling. Earlier information about mosquito catch for that particular area was taken into consideration. The location of each square was also recorded, along with its geographical details.

Mosquito sampling

Mosquito collection was carried out in the selected sites using standard methods (WHO 1975). A close search for mosquitoes was made in every possible habitats, such as human dwellings, cattle sheds, mixed dwellings, and other outdoor resting sites, for obtaining the maximum number of specimens from fixed points. Random collection was also made while sampling fixed localities. From the possible water habitats, collection of immature mosquitoes was, also done. Information about mosquito species, habitats, geographical location, etc was recorded on a data sheet. Soon after collection, the mosquitos were immobilized with petroleum ether, then sorted and separated, firstly by genera and thereafter by species. Identification of mosquitoes is mainly based on adult characteristics using the standard keys and catalogues (Christophers, 1933; Barraud, 1934; Wattal and Kalra, 1961; Knight and Stone, 1977; Darsie and Pradhan, 1990; Nagpal and Sharma, 1995).

Data compilation and analysis

To estimate the species-richness, Per Man Hour Density (PMHD) of mosquitoes was taken into consideration using standard formulae (WHO, 1975). The categorization of species richness was made arbitrary as per methods developed by Williams *et al* (1995) and Prendergast *et al* (1993). Most species-rich site were considered on the basis of the top 5% of species richness among the grid cells/spots, while the least species-rich sites were the most species-poor 5% of recorded grid cells. Those species occupying less than 20% of the grid cells were listed as rare species, while those species occupying less than 40% were included in the list of uncommon species.

RESULTS

There were 762 squares (grid cells), each of 5 km x 5 km in area, in all 3 districts (viz, Pauri, Tehri, and Uttarkashi) in Garhwal. Of these, 450 grid cells were surveyed for mosquito sampling during November to October 2002. It was observed that 387 squares or cells harbored mosquito specimens. In total, 45 species of mosquitoes under 3 genera were recorded. Of the

total sites (grid cells) surveyed, both most species- and least species-rich sites were sorted on the basis of the top 5% of the number of species present. There were 21 most species-rich sites, while 49 were the least species-rich sites (Fig 1). The density of mosquito richness in terms of PMHD ranged from 0.1 to 3.0 (Fig 2). Out of 21 most species-rich sites, 85.7% were confined to Pauri district, and 9.5% and 4.7% in Tehri and Uttarkashi districts, respectively (Fig 1). Considering the genera presence (Table 1), 313 sites had a population of *Aedes* species with 42 and 50 most and least species-rich spots, respectively. For the Anopheline species, out of 292 grid cells, there were 44 most species-rich and 93 least species-rich spots. The maximum number of grid cells/spots (317) were found, with *Culex* species, however, there was a decrease in the number of species-rich spots, that is, 41. On the other hand, poor species presence areas accounted for 62. Some species of unidentified mosquitoes were also recovered from 160 grid cells or sites. If the occurrence of most species-rich sites was considered, there were 7 areas, while the least species-rich sites numbered 53.

During the present study, 45 species of mosquitoes excluding some unidentified forms were recovered either as adult or immature mosquitoes. Under the genus *Aedes*, there were 15 species, namely, *Ae. aegypti*, *Ae. albolateralis, Ae. albopictus, Ae. aureostriatus, Ae. assamensis, Ae. dissimilis, Ae. gilli, Ae. pulchriventer, Ae. thomsoni, Ae. shortti, Ae. subalbopictus, Ae. suffusus, Ae. unilineatus, Ae. vittatus,* and *Ae. w-albus*. As many as 17 species of *Anopheles* were recorded in this study (Table 3). There were 13 species of *Culex* viz., *Cx. barraudi, Cx. brevipalpis, Cx. mimeticus, Cx. mimulus, Cx. pallidothorax, Cx. pipiens fatigans, Cx. quinquefasciatus, Cx. raptor, Cx. ramakrishnui, Cx. vagans, Cx. viridiventer, Cx. univittatus,* and *Cx. vishnui* collected in the present study.

It was recorded that most pairs of groups exhibited non-random positive association. The proportional overlapping of species-rich sites for three groups of mosquitoes is given in Table 2. It was observed that 11 squares, that is, 8.2%

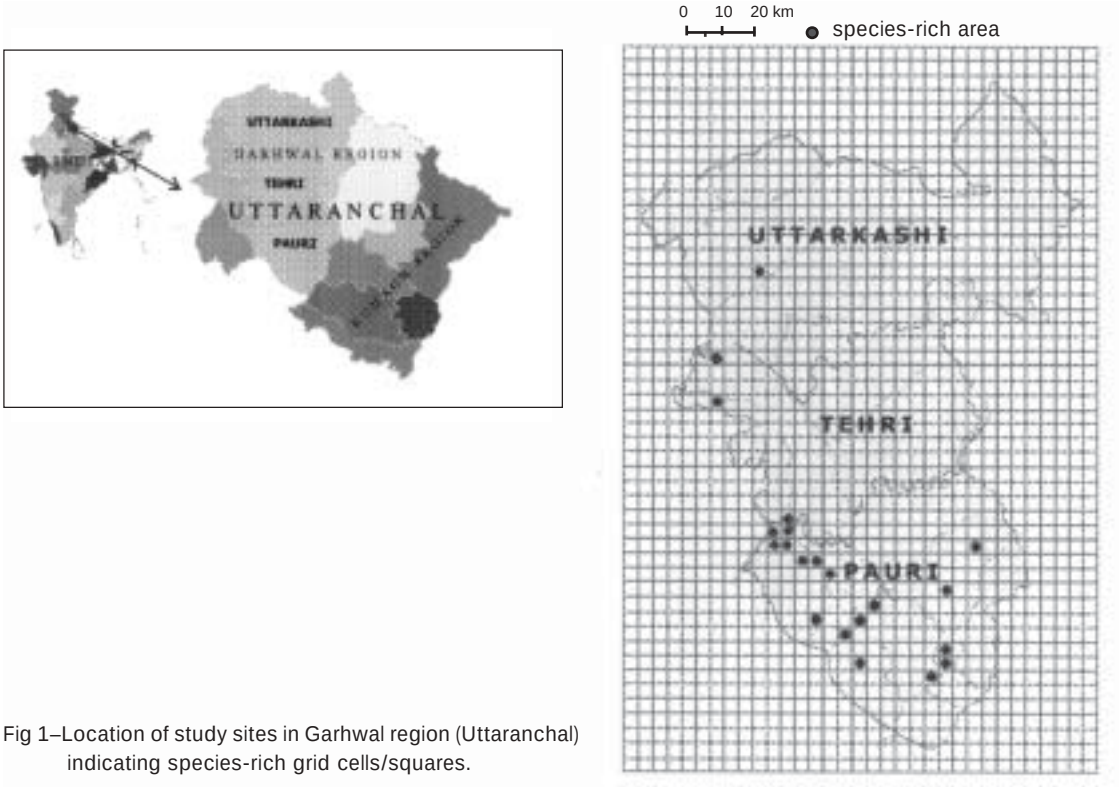

Fig 1–Location of study sites in Garhwal region (Uttaranchal) indicating species-rich grid cells/squares.

Table 1
Mosquito occurrence data in the study sites.

Name of mosquito	No. of squares containing records	No. of grid cells found as rich spots		No. of mosquito species
		Most species	Least species	
Aedes sp	313	42	50	15
Anopheles sp	292	44	93	17
Culex sp	317	41	62	13
Unidentified	160	7	53	-

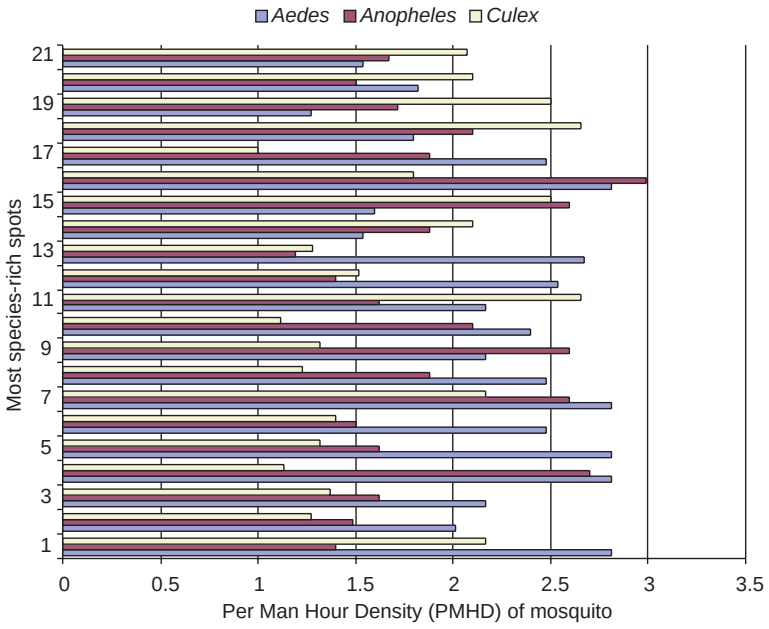

Fig 2–Per man hour density of mosquitoes collected from 21 species-rich grid cells of certain parts of Garhwal region during November 2000 to October 2002.

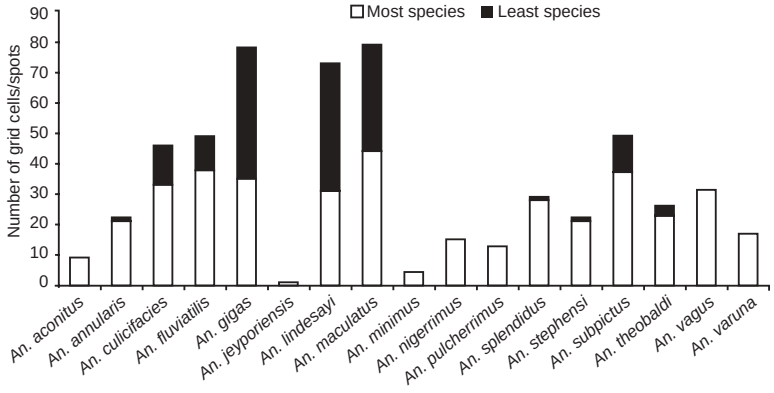

Fig 3–Total number of most and least species-rich spots occupied by Anopheline species in Garhwal region (Uttaranchal).

of most species-rich sites of both *Aedes* and *Anopheles* overlapped one another, while the overlaps between *Aedes* - *Culex* and *Anopheles* - *Culex* were recorded, each in 6 squares (4.47%). Among the least species-rich-sites, the overlaps between *Aedes* - *Anopheles*, *Aedes* - *Culex* and *Anopheles* - *Culex* were in 12, 9, and 18 squares, respectively. There was no overlapping between most and least species-rich sites among different genera, except an overlapping between most species-rich sites of *Anopheles* and least species-rich sites of *Culex*. Overlapping was especially low when groups had different ecological requirements. In fact, more overlapping existed between the least species-rich sites. It was also observed that, beyond pair comparisons, there were 12 most species-rich sites and 5 least species-rich-sites belonging to all the three groups of mosquitoes.

Keeping in view the prevalence of malaria disease in all the 3 selected districts of Garhwal in the past,

the study concentrated on Anophelines so that a correlation may develop at a later stage. Depending on the percentage of occupying in grid cells/ spots, common, uncommon, and rare species of Anophelines are given in Table 3. All the Anopheline species are more likely to be found in most species-rich spots, while randomly in the selected least species-rich sites (Fig 3). Rare and uncommon species were not found in the least species-rich areas.

Considering the geographical variations in the species richness of different groups of mosquitoes, most of the species-rich sites were located near riverine areas, that is, approximately 2-3 km from rivers or tributaries, and that below 1,200 m in elevation. According to records, Pauri district harbored 80% of most species-rich sites. Most species-rich sites of all groups were found overlapping except few sites of either one or two groups. Two rare species, namely, *An. aconitus* and *An. minimus,* were collected below 600 m of elevation, while *An. jeyporiensis* was recorded up to 1,200 m. Human and animal habitation also influenced the density of all groups of mosquitoes. If the habitation was less, the mosquito density was also less. Further, it is observed that the square chosen by most species rich method are mainly in the western parts of the selected area. This reflects the general trend towards increasing species richness of mosquitoes towards the west, as there is a decrease in elevation and an increase of riverine and other water bodies.

Table 2
Most and least species-rich spots overlap data in respect of mosquito occurrence in the study area.

Least species	Most species		
	Aedes	*Anopheles*	*Culex*
Aedes sp	-	11 (8.2)	6 (4.47)
Anopheles sp	12 (4.65)	-	6 (4.47)
Culex sp	9 (3.49)	18 (6.97)	-

DISCUSSION

Considering the available literature on mosquitoes in Garhwal region (Wattal *et al*, 1958; Rao *et al*, 1973; Bhat, 1975; Jauhari *et al,* 1992; Srivastava and Jauhari, 1992; Mahesh *et al,* 1997; Singh *et al,* 1997; Mahesh and Jauhari, 2000) there is almost no study conducted on the site selection of species richness, rarity, and least species richness. Almost all the studies are concentrated on the diversity of the mosquito, with a little emphasis on distribution across varying altitudes. In fact, studies based on a correlation between mosquito diversity and varying ecological and physiographical features of the studied areas and other places are lacking. Thomas and Mallorie (1985), Prendergast *et al* (1993), Kershaw *et al* (1995), William *et al* (1995), Mittermeier *et al* (1999) and Myers *et al* (2000) made their studies on the site selection of

Table 3
List of common, rare, and uncommon species of Anopheline mosquitoes collected from selected sites of Garhwal.

Sl no.	Common species	Rare species	Uncommon species
1	*An. culicifacies*	*An. aconitus*	*An. annularis*
2	*An. fluviatilis*	*An. minimus*	*An. varuna*
3	*An. gigas*	*An. jeyporiensis*	*An. stephensi*
4	*An. lindesayi*		*An. pulcherrimus*
5	*An. maculatus*		*An. nigerrimus*
6	*An. splendidus*		
7	*An. subpictus*		
8	*An. theobaldi*		
9	*An. vagus*		

biodiversity hotspots of species richness and rarity on different groups of plants and animals, besides conservation planning. The results of this present investigation on coincidence and overlapping of species-rich areas are in accordance with the findings of Prendergast *et al* (1993) to some extent. The difference is that their findings were based on other insects. Further, our findings revealed that areas having rich species for one group will also be species-rich for the other two groups, since most of the species-rich sites overlapped. However, in the case of rare and restricted species, there is no indication about their occurrence in most species-rich sites, but in the present findings, all the rare species of Anophelines were found in species-rich areas. Generally, all species-rich sites do not represent all mosquito species in our findings. This is may be due to the fact that the distribution of rare and uncommon species was not found within the distribution of more widespread species. The existence of most and least species-rich sites is closely related to disturbance and fragmentation of habitats, such as emerging new habitatation, deforestation, development of urban areas, etc. Most of the species-rich cells were found close to the riverine and human habitations, thus supporting the fact that water bodies favor mosquito breeding. Varying elevation was found to have a major role in the distribution of the different groups of mosquitoes. This shows that a mosquito species requires a particular ecological niche where it can survive very well.

Conclusively, it can be mentioned that the results of this present study may form a baseline for further studies about mosquito distribution patterns and mapping in a wider variety of habitat types. The combination of 3 factors: geographic distribution, habitat specificity, and population size yielded different forms of rarity. There are many possible mechanisms likely to cause overlapping and coincidence of the observed bias. Since mountains may act as barriers to dispersal between biogeographical units, the possibility arises to circumscribe the edge of many species ranges, especially with poor dispersal abilities. Simultaneously, species richness in mountainous regions may increase, in part by the edge effect resulting from overlaps in species elevational replacements.

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