Indian J Med Res 131, May 2010, pp 711-719

Spatio-temporal variations in adult density, abdominal status & indoor resting pattern of *Culex quinquefasciatus* Say in Panaji, Goa, India

Mahesh B. Kaliwal, Ashwani Kumar[*], A.B. Shanbhag[**], A.P. Dash[+] & S.B. Javali[#]

National Vector Borne Diseases Control Programme (Directorate of Health Services), Panaji, Goa [*]National Institute of Malaria Research, Field Station (ICMR), Panaji, Goa, [**]Department of Zoology, Goa University, Taleigao Plateau, Goa, [+]National Institute of Malaria Research (ICMR), New Delhi & [#]S.D.M. College of Dental Sciences & Hospital, Dharwad, India

Received October 3, 2008

***Background & objectives*: Goa is one of the filariasis endemic states of India. However, information on density pattern and resting behavior of *Culex quinquefasciatus* Say, the principal vector of filariasis in Goa is lacking. Therefore, current longitudinal study was undertaken to investigate these aspects.**

***Methods*: Panaji was divided into six zones and a total of 240 man hours were spent in 60 fixed catching sites to collect the adult *Cx. quinquefasciatus* mosquitoes on fortnightly basis from indoor resting sites during 2005-06. The female mosquitoes were classified as unfed, fed, semi-gravid and gravid to ascertain the resting behavior of *Cx. quinquefasciatus* adults. The data were analysed to evaluate the spatio-temporal variations in adult density, abdominal status and indoor resting sites and linked to meteorological variables like temperature, relative humidity, rainfall and number of rainy days.**

***Results*: *Cx. quinquefasciatus* adults were prevalent perennially in Panaji with highest per man hour density of females (48.6) in February and the lowest density (6.6) in September. Monthly variations in the densities between different months was significant (F=15.3; *P*<0.05). Rainfall significantly influenced the population of *Cx. quinquefasciatus* (t=2.63; *P*<0.05). Fed group and semi-gravid group showed a strong correlation with the relative humidity (*P*<0.05), rain fall (*P*<0.05) and number of rainy days (*P*<0.05). 62.4 per cent of females and 65.1 per cent of males preferred to rest on hanging objects. Spatio-temporal variations in the number of *Cx. quinquefasciatus* females and males resting on different sites and also the variations in different sites (*P*<0.05) were significant.**

***Interpretation & conclusion*: The density of female *Cx. quinquefasciatus* encountered in all the months was higher than the estimated tolerated level of density of 34 per ten man hours up to which there is no risk of filariasis transmission. The strong correlation between the abdominal conditions and relative humidity, rainfall and number of rainy days imply that these meteorological variables significantly influenced the feeding and fecundity of the species. 85.3 per cent of the indoor resting population comprising of fed, semi-gravid and gravid females confirmed the endophilic nature of the species. The preferential resting behavior of both females and males on hanging objects suggest that use of insecticide treated long-lasting bed nets as personal protective measure can be exploited to reduce the density of the vector species.**

Key words Bancroftian filariasis - *Culex quinquefasciatus* - density pattern - meteorological variables - resting behavior

Lymphatic filariasis is a major cause of acute and chronic morbidity among humans in tropical and sub-tropical areas of Asia, Africa, the western pacific and some parts of the Americas[1]. The unabated population growth particularly in developing countries of Asia, Africa and Latin America and consequent all round deterioration in the ecology and environment, has also reflected in the magnitude of lymphatic filariasis (LF) and other vector borne diseases[2]. Of the estimated global 128 million lymphatic filarial cases, 91 per cent are caused by *Wuchereria bancrofti* Cobbold[3]. India alone contributes 40 per cent to the world's LF disease burden[4]. Goa is one of the filariasis endemic states of the country[5]. The estimates of disease burden due to filariasis suggest that 2.06 million disability adjusted life years (DALYs) are lost in India and annual wage loss is estimated at 811 million US dollars[6].

Global Programme to eliminate LF (GPELF), launched in 2000 aim to interrupt transmission of the disease through annual mass drug administration (MDA). Despite progress, this approach has raised questions regarding the effectiveness of MDA alone to eliminate LF without the inclusion of supplementary vector control[7]. MDA alone may not be able to interrupt LF transmission in area of *Culex* transmission of LF due to their high vectorial efficiancy[8]. Therefore, vector control is essential for sustained interruption of LF transmission[9]. Accordingly, incorporation of vector control in the global LF elimination programme has been advocated as it potentially decreases the time required for elimination of LF[1]. At lower level of community microfilaria load (CMFL) and higher level of vector density, vector control would be more cost effective[10], in spite of some natural bearings operating in limiting transmission[11].

Globally, the majority of LF caused by *W. bancrofti* is transmitted by *Culex quinquefasciatus* Say[12]. In India, *Cx. quinquefasciatus* is the principal vector of bancroftial filariasis[13]. *Cx. quinquefasciatus* is also the vector of JE virus[14], WN virus[15] and secondary vector of WEE virus[16]. Rapid urbanization and industrialization without proper drainage facilities are responsible for the proliferation of the vector species[17,18]. Transmission of infection through vectors is considered density-dependant. The estimated level of tolerated density of *Culex quinquefasciatus* up to which there is no risk of filariasis transmission is 34 per ten man hour density[19,20]. The density pattern depicted by vector species in any area is influenced by the gross ecology of the terrain and the meteorological variables[21] and as such, the findings on vector populations of one geographic region cannot be applied to other.

There are no data on *Cx. quinquefasciatus* in Goa to understand the seasonal density build up pattern and abundance of the vector species which influence the disease transmission in time and space. Understanding resting behavior can help initiate appropriate anti-vector measures to prevent/reduce the risk of transmission and hence the present study.

Material & Methods

Study area: Panaji, the capital city of Goa state is situated between 15° 53′ N latitude and 73° 52 ′ E longitude on the western coast of India. Panaji has a moderate climate without any extremes of summer and winter: mean temperature: 26.7° C to 30.1° C, relative humidity 65.5 to 90.7 per cent. The total rainfall was 3387.4 mm the study period. The number of rainy days was : April'05-2, May-1, June-24, July-30, August-24, September-25, October-7 and March' 06-2. The year was divided into three seasons *viz*., Pre-monsoon (February to May), Monsoon (June to September) and Post-monsoon (October to January) to study the seasonal trends of *Cx. quinquefasciatus* population.

For the purpose of present study, Panaji was divided into six zones (Fig.1) based on certain similarities within the localities. The areas covered under different zones were : Zone I – EDC and Patto; Zone II – Mala and Bhatulem ; Zone III – Central Part and Market area ; Zone IV – Campal, Miramar, St. Inez and Tonca ; Zone V – Caranzalem ; Zone VI – Altinho and Donapaula. The city has open and closed drains which were blocked at places while at others they lacked proper gradient leading to the creation of ideal breeding grounds. In zones IV and V, there is a wide nallah which is approximately 3 km long and carries sullage water and domestic waste and meets Mandovi river which runs along the northern expanse of the city. Some areas of zones I and II are submerged in the back waters of this river. The cesspits, cesspools and building construction sites were other potential breeding habitats.

Mosquito collection: Ten mosquito catching sites were fixed in each zone. The collection of indoor resting mosquitoes was done from sixty catching stations using aspirator tube and three celled torch from 06.30 to 09.30 h at fortnightly interval from April, 2005 to March, 2006. Ten minutes were spent in each catching station to collect the mosquitoes resting on different surfaces *viz.,* walls, hanging objects (clothes, gunny

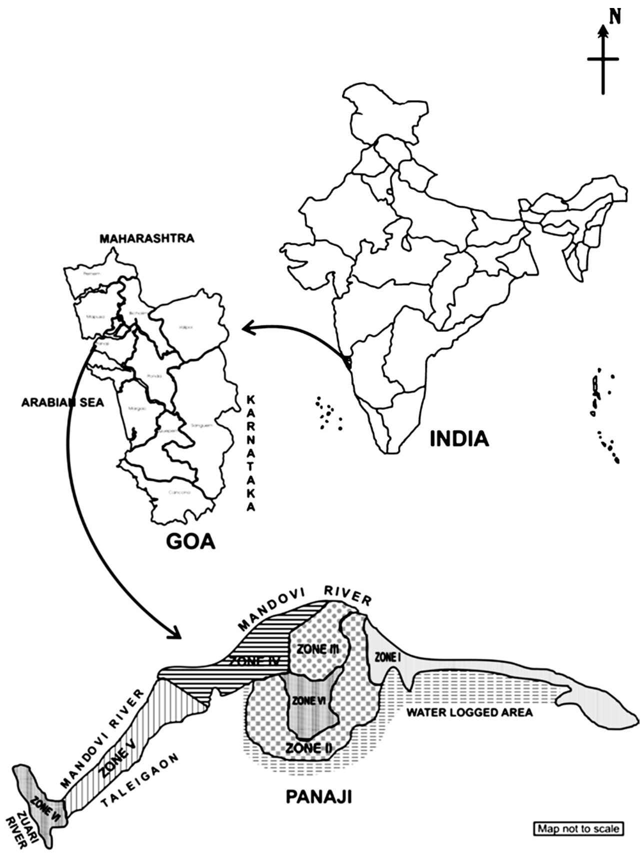

Fig. 1. Map of India showing location of Goa and Panaji with different study zones (I-VI).

bags, wires, umbrellas, baskets, *etc.*), objects on the floor (cots, tables, chairs, benches, cycles, *etc.*) and horizontal surfaces (shelves, wooden planks, ceiling, *etc*). Every month 20 man hours were spent to collect the mosquitoes from all the zones. Mosquitoes were brought to the Laboratory alive in 30 cm x 30 cm x 30 cm cotton cages, anaesthetized with ether solvent and identified up to species level using standard identification keys[22,23]. Based on their abdominal conditions, *Cx. quinquefasciatus* females were classified as unfed, fed, semi-gravid and gravid by the external examination to ascertain the feeding and ovary developmental status using the hand lens (10X)[24]. The objective of the abdominal classification was to obtain information on different gonotrophic stages of females and also the resting behavior of mosquitoes of different physiological stages.

Data analysis: The indoor resting density of mosquitoes was expressed as the number of males/females collected per man hour. After zone-wise analysis, the entire monthly data on *Cx. quinquefasciatus* from all six zones were pooled for analysis. Two way factorial ANOVA was applied to analyze the significance of spatio-temporal variations of adult density of *Cx. quinquefasciatus* in different months and zones, variations in abdominal conditions of females and resting of females and males on different resting sites[25]. Further, Tuckey a *post hoc* test was applied to justify the variations within different abdominal conditions and different resting sites. Regression analysis was done to analyze the impact of temperature, relative humidity, rainfall and number of rainy days on the abundance of *Cx. quinquefasciatus*. Correlation analysis was done to find out association between the abdominal status and the meteorological variables.

Results

A total of 11,673 mosquitoes belonging to five genera were collected from six zones. Six species each belonging to genus *Culex* and *Anopheles*, two species to genus *Aedes* and one species each to genus *Armigeres* and genus *Mansonia* were collected. *Cx. quinquefasciatus* was the predominant species with 9571 mosquitoes, contributing 82 per cent to the total indoor collection. Out of 9571, 7018 (73.3%) were females and 2553 (26.7%) were males. Male to female ratio ranged from 1: 1.6 to 1: 4.5 in different months.

Total number of *Cx. quinquefasciatus* females and males collected from six zones was: 1149 and 572, 1191 and 402, 1016 and 342, 1249 and 509, 1279 and 387, 1134 and 341 in I- VI zones respectively. Monthly female per man hour density (PMHD) ranged between 10.5 and 52.7, 8.1 and 54.9, 3.6 and 51.9, 8.7 and 56.4, 1.8 and 55.3, 1.2 and 69.1 and monthly male PMHD ranged between 4.5 and 28.5, 2.7 and 22.8, 2.1 and 29.1, 1.5 and 34.5, 2.7 and 15.6, 1.8 and 21.8 respectively.

Cx. quinquefasciatus was prevalent in all months in Panaji. Monthly prevalence (PMHD) of *Cx. quinquefasciatus* females and males is shown in Fig. 2. Per man hour densities of vector species were very

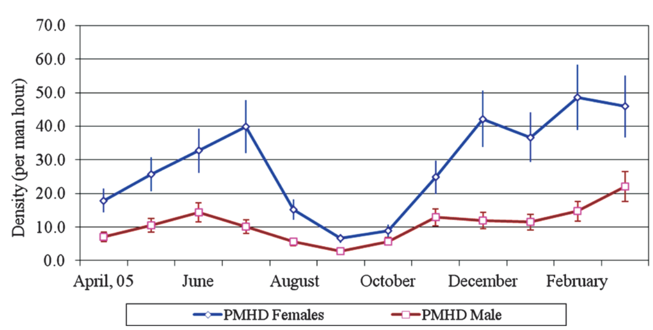

Fig. 2. Monthly prevanence (PMHD) of *Cx. quinquefasciatus* females and males in Panaji from April, 2005 to March, 2006.

high in February (48.6) and March (46.0) and very low in September (6.6) and October (8.9). Two peaks of *Cx. quinquefasciatus* population were observed; first in July and second in February. After the first peak, the population showed declining trend from August and reached the lowest prevalence in September. The next ascending phase of *Cx. quinquefasciatus* population started in October-November hitting the second peak in February, followed by a declining phase in March.

The seasonal distribution (PMHD) of *Cx. quinquefasciatus* females and males (Fig. 3) shows highest seasonal prevalence (PMHD=34.5) in pre-monsoon season followed by the post-monsoon season (PMHD=29.5). The vector had the lowest prevalence (PMHD=23.6) during the monsoon season. Seasonally, PMHD of males ranged between 6.4 (monsoon) and 13.6 (pre-monsoon).

The number of *Cx. quinquefasciatus* females with different abdominal conditions were: unfed- 1033 (14.7%), fed- 4547 (64.7%), semi-gravid- 861 (12.3%) and gravid- 577 (8.2%). The collection of *Cx. quinquefasciatus* from different resting sites revealed that 1502 (21.4%), 4379 (62.3%), 723 (10.3%) and 414 (5.8%) of females and 567 (22.2%), 1661 (65%), 229 (8.9%) and 96 (3.7%) of males rested on walls, hanging objects, objects on floor and horizontal surfaces respectively. The mean number of *Cx. quinquefasciatus* both females and males, resting on different sites shows that hanging objects were the most preferred resting sites for both females and males (Fig. 4).

The other mosquito species encountered during the study, their number and per cent contribution to total indoor resting mosquitoes were as follows- *Culex tritaeniorhynchus* Giles-176 (1.5%), *Cx. gelidus* Theobald- 37 (0.3%), *Cx. vishnui* Theobald- 26 (0.2%), *Cx. pseudovishnui* Theobald -19 (0.2%), *Cx. bitaeniorhynchus* Giles - 9 (0.09%), *Mansonia uniformis* Theobald- 668 (5.7%), *Aedes aegypti* Linnaeus -257 (2.2%), *Ae. albopictus* Skuse-14 (0.1%), *Armigeres subalbatus*-114 (1.0%), *Anopheles subpictus* Grassi- 575 (4.9%), *An. vagus* Donitz- 129 (1.1%), *An. stephensi* Liston -54 (0.5%), *An. jamesi* Theobald- 12 (0.1%), *An. barbirostris* Van der Wulp-9 (0.07%) and *An. hyrcanus* variety *nigerimus* Giles- 3 (0.03%).

Statistical analysis: Two way factorial ANOVA test results (Table I) revealed that the density variations of females between the months were significant (F =3.46; *P*<0.01). The density variations between different zones and also the two way interaction of zones and months were non-significant. Regression analysis (Table II) revealed that the actual rainfall (t = 2.63; *P*<0.05) significantly influenced the population density pattern of female *Cx. quinquefasciatus*. There was no significant impact of temperature, relative humidity and number of rainy days on the density pattern in Panaji. The density variations of male population between the months was significant (F=15.36; *P*=0.0000), but not between the zones. The influence of meteorological variables on male population was non-significant.

Two way factorial ANOVA using month and abdominal status on number of *Cx. quinquefasciatus* females (Table III) revealed that the variations in abdominal status in different months (F=25.02; *P*=0.0000), the variations within different abdominal status (F= 345.33; *P*=0.0000) and also the two way interactions of month and abdominal status (F=11.84; *P*=0.0000) were significant.

Similar analysis using zones and abdominal status revealed that the variations within the abdominal status was significant (F=102.66; *P*=0.0000) and it was non-significant both in the zones and two way interactions of zones and abdominal status. Further, a *post hoc* Tukey test (Table IV) justified the differences between

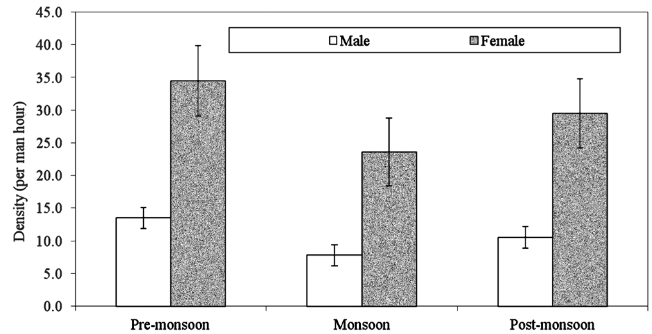

Fig. 3. Seasonal distribution (PMHD) of *Cx. quinquefasciatus* females and males in Panaji during April, 2005 to March, 2006.

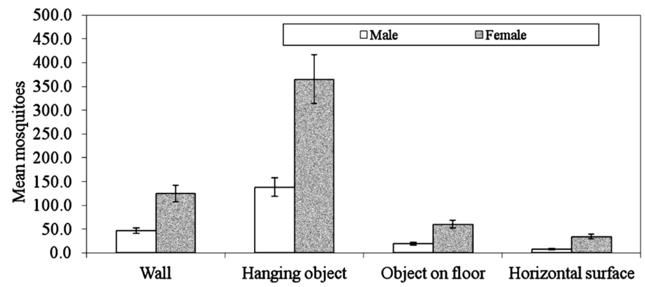

Fig. 4. Resting behavior *Cx. quinquefasciatus* females and males on different sites in Panaji during April, 2005 to March, 2006.

Table I. Two way factorial ANOVA using month and zone on number of *Cx. quinquefasciatus* female

Source of variation	Df	SS	MSS	F value	*P* value	Significance
Main effects						
Month	11	38069.0369	3460.8215	3.4694	0.0002	S
Zone	5	667.2674	133.4535	0.1338	0.9844	NS
2- way interactions						
Month x Zone	55	14404.3570	261.8974	0.2625	1.0000	NS
Error	216	215463.2563	997.5151			
Total	287	268603.9176				

S, significant; NS, non significant

the different abdominal status ($P<0.05$). The difference between semi-gravid and gravid groups was non-significant. There was a strong correlation between the fed group and the relative humidity (r = 0.79, $P<0.05$), rain fall (r = 0.65, $P<0.05$) and number of rainy days (r = 0.73, $P<0.05$). Similar strong correlation was found between semi-gravid group and relative humidity (r = 0.77, $P<0.05$), rain fall (r = 0.69, $P<0.05$) and number of rainy days (r = 0.70, $P<0.05$). The gravid group showed strong correlation only with relative humidity (r = 0.73, $P<0.05$).

Two way factorial ANOVA using month and resting sites on number of *Cx. quinquefasciatus* females (Table V) revealed significant variations in the number resting in different months (F=36.71; *P*=0.0000) and the significant variations within different resting sites (F= 490.24; *P*=0.0000). Two way interactions of month and resting sites (F=9.77; *P*=0.0000) was also significant. Similar analysis using zones and resting sites on females revealed that the variations within the resting sites was significant (F=136.50; *P*=0.0000) but, it was non-significant both in the zones and two way interactions of zones and resting sites. Further, a *post hoc* Tukey test (Table VI) justified the differences between the different resting sites ($P<0.05$).

Two way factorial ANOVA using month and resting sites on number of *Cx. quinquefasciatus* males (Table VII) revealed significant variations in the number resting in different months (F=11.89; *P*=0.0000) and the significant variations within different resting sites (F= 193.18; *P*=0.0000). Two way interactions of month and resting sites was also significant (F=3.84; *P*=0.0000). Similar analysis using

Table II. Effect of Meteorological variables on the prevalence of *Cx. quinquefasciatus* females and males- Regression equations

Sex	Regression equation	R-value	R^2-value	F-value
Female	PMHD(Y) = 242.7936 -1.3509 RH + 0.0558 AR -4.0730 T – 1.2468 RD	0.8353	0.6977	4.0405*
Male	PMHD (Y) = 48.6276 -0.2997 RH + 0.0168 AR -0.5259 T – 0.5033 RD	0.6880	0.4734	1.5732**

*Significant ($P<0.05$); **Non significant ($P>0.05$)

Table IV. Tukey a *post hoc* test between abdominal status of female *Cx. quinquefasciatus*

Abdominal status	Unfed	Fed	Semi-gravid	Gravid
Mean	14.29167	62.97222	11.77778	8.888889
Unfed	1.0000			
Fed	0.0000*	1.0000		
Semi-gravid	0.5740	0.0000*	1.0000	
Gravid	0.0298*	0.0000*	0.4533	1.0000

**P* value less than 0.05 are significant at 5% level ($P<0.05$)

Table III. Two way factorial ANOVA using month and abdominal status on number of female *Cx. quinquefasciatus*

Source of variation	Df	SS	MSS	F-value	*P* value	Significance
Main effects						
Month	11	38069.0369	3460.8215	25.0254	0.0000	S
Abdominal status	3	143271.5391	47757.1797	345.3349	0.0000	S
2- way interactions						
Month x Abdominal status	33	54073.1708	1638.5809	11.8487	0.0000	S
Error	240	33190.1660	138.2924			
Total	287	268603.9127				

S, significant

Table V. Two way factorial ANOVA using month and resting sites on number of female *Cx. quinquefasciatus*

Source of variation	Df	SS	MSS	F-value	*P* value	Significance
Main effects						
Month	11	37445.3723	3404.1248	36.7101	0.0000	S
Resting site	3	136381.9219	45460.6406	490.2481	0.0000	S
2- way interactions						
Month x Resting site	33	29915.6984	906.5363	9.7761	0.0000	S
Error	240	22255.1660	92.7299			
Total	287	225998.1586				

S, significant

Table VI. Tukey a *post hoc* test between resting sites of female *Cx. quinquefasciatus*

Resting site	Wall	Hanging object	Object on floor	Horizontal surface
Mean	20.86111	60.81944	10.01389	5.736111
Wall	1.0000			
Hanging object	0.0000*	1.0000		
Object on floor	0.0000*	0.0000*	1.0000	
Horizontal surface	0.0000*	0.0000*	0.0385*	1.0000

**P* value less than 0.05 are significant at 5% level ($P<0.05$)

zones and resting sites on number of males (Table VIII) revealed that the variations within the zones ($F=3.03$; $P<0.05$) and variations within the resting sites ($F=114.08$; $P=0.0000$) were significant but, two way interactions of zones and resting sites was non-significant. Further, a *post hoc* Tukey test (Table IX) justified the differences between the different resting sites ($P<0.05$). The difference between resting on objects on floor and horizontal surfaces was non-significant.

Discussion

The prevalence of *Cx. quinquefasciatus* in all the months in Panaji confirms earlier data from different parts of the country[26-29]. The density variations between

Table VII. Two way factorial ANOVA using month and resting sites on number of male *Cx. quinquefasciatus*

Source of variation	Df	SS	MSS	F-value	*P* value	Significance
Main effects						
Month	11	4731.0104	430.0919	11.8967	0.0000	S
Resting site	3	20952.0659	6984.0220	193.1845	0.0000	S
2- way interactions						
Month x Resting site	33	4584.1424	138.9134	3.8425	0.0000	S
Error	240	8676.5002	36.1521			
Total	287	38943.7190				

S, significant

Table VIII. Two way factorial ANOVA using zone and resting sites on number of male *Cx. quinquefasciatus*

Source of variation	Df	SS	MSS	F-value	*P* value	Significance
Main effects						
Zone	5	928.7813	185.7563	3.0343	0.0111	S
Resting site	3	20952.0659	6984.0220	114.0842	0.0000	S
2- way interactions						
Zone x Resting site	15	901.2882	60.0859	0.9815	0.4750	NS
Error	264	16161.5838	61.2181			
Total	287	38943.7192				

S, significant; NS, non-significant

Table IX. Tukey a *post hoc* test between resting sites of male *Cx. quinquefasciatus*

Resting site	Wall	Hanging object	Object on floor	Horizontal surface
Mean	7.861111	23.05556	3.180556	1.361111
Wall	1.0000			
Hanging object	0.0000*	1.0000		
Object on floor	0.0000*	0.0000*	1.0000	
Horizontal surface	0.0000*	0.0000*	0.2659	1.0000

*P value less than 0.05 are significant at 5% level (P<0.05)

the zones though not statistically significant, the high densities of *Cx. quinquefasciatus* encountered in zone IV and V is attributed to the presence of nallah which is running in zigzag fashion and providing breeding ground, as the vector species prefers to breed in polluted waters. The zone-wise prevalence in Panaji is in line with the locality-wise density variations in Raipur[29], India.

Density variations between the months in Panaji were significant. The first peak in adult density during July appeared to be associated with the pre-monsoon showers in April-May months and the onset of monsoon rains in the month of June in Goa. The subsequent decline in the adult density in August and September months can be attributed to flushing of drains, flooding of other outdoor breeding foci and the mortalities caused due to physical impact of heavy rains. There was 2229.4 mm of rain from July to September months in the year 2005. The impact of rainfall was significant on the density of *Cx. quinquefasciatus*. The population of *Cx. quinquefasciatus* started building up again in October due to the cessation of heavy rains and the stagnations in the drains, cesspits *etc*., during the post-monsoon season the density gradually attained the second peak in February month followed by the decline in March due to the drying of breeding sites.

The different density patterns[27-32] and the impact of climatic and environmental factors[21,28-30] on the prevalence of vector in different seasons have been studied elsewhere in India and abroad[33]. Temperature in Arthala[21] and both temperature and humidity in Rajahmundry[28] played vital role in regulating the population density. On the contrary, the temperature did not play any role, but the physical environment appeared to regulate the population growth in Puducherry[30]. The density pattern of *Cx. quinquefasciatus* population in Panaji did not fully conform to any of the above studies, but it appeared somewhat similar to the pattern observed in Puducherry, excepting the impact of North East monsoon seen in Puducherry.

The present finding on sex ratio is closely similar to earlier observations made in Arthala[21] and Rajhamundry[28]. Less proportion of males in indoor resting collection is attributed to their exophagic and exophilic[34] behavior and their lower life expectancy[21]. The studies on resting behavior have shown mainly endophilic nature of the species from different areas[26-29]. The collection of 85.3 per cent of *Cx. quinquefasciatus* females comprising fed, semi-gravid and gravid females and only 14.3 per cent unfed in Panaji was found to be on the similar lines as observed in Mysore[32], India and confirmed the endophilic behavior of the vector in Panaji.

The various abdominal conditions depict the stage of gonotrophic cycle regulated by endogenous rhythms apart from the climatic conditions[35]. The frequency of feeding by the mosquito is linked with the digestion of blood, the maturation of eggs and oviposition and these processes proceed simultaneously which is known as the gonotrophical relationship[35]. Influence of temperature (25.5^0C-31^0C) and relative humidity (54.4%-84.5%) on the length of the gonotrophic cycle (LGC) of *Cx. quinquefasciatus* under ambient laboratory conditions demonstrated a significant correlation between the LGC and temperature and relative humidity and observed greater LGC (Median: 20.64) in cooler months (October to March) than in warmer months (Median: 4.69) of April through September in Delhi[36]. The significant variations between the different abdominal conditions over different months and the two way interactions of abdominal conditions and months emphasizes the existence of relationship of feeding and gonotrophic cycle with the meteorological variables in the wild populations. Panaji being located on the coastal line without climatic extremities, the length of gonotrophic cycle is expected to be shorter, which in turn would influence frequency of feeding.

Resting behavior observed in Panaji city conforms to the findings made in Ernaculum[26] and Rajahmundry[28], however the extent of preference for hanging objects was higher in Panaji than in both the places. Spatio-temporal variations in the number of *Cx. quinquefasciatus* both females and males resting on different sites were significant over the months and also in different zones, showing the uniform pattern of resting behavior of the vector species irrespective of the seasons and different geographical zones of Panaji city. High preference for resting on hanging objects, can be exploited for reducing the high densities of vector mosquitoes of filariasis by using long lasting insecticide treated nets (LLINs) as personal protective measure under integrated vector management.

A clear understanding of density build up pattern, seasonal prevalence of vector mosquitoes and their resting behavior helps to plan appropriate and timely vector control measures. In spite of density variations, *Cx. quinquefasciatus* was prevalent higher than the tolerated density[19,20] of 34 per ten man hours in all the seasons. Mass drug administration with single dose of diethyl carbamazine citrate (DEC) tablets is being administered in Goa by National Vector Borne Diseases Control Programme (NVBDCP) once in the month of November every year from 2004 with a target to cover the entire population of Goa. In the light of the present findings showing high vector prevalence and the detection of 20 new microfilaria carriers during a very limited sentinel parasitic survey (*Source*: NVBDCP, Goa), coupled with the increased mf rate *i.e.*, 0.02 in 2005 to 0.04 in 2007, the risk of active transmission of filariasis is high in Goa. Integrated vector management involving personal protective measure with LLINs, environmental sanitation to eliminate the breeding through source reduction methods and adequate anti-larval operation under National Vector Borne Diseases Control Programme can bring down the density of vectors and also prevent the active transmission of filariasis.

Acknowledgment

The authors thank Department of Zoology, Goa University for the facilities and Meteorological Department (GOI), Panaji for providing the meteorological data.

References

1. Sunish IP, Rajendran R, Mani TR, Munirathinam A, Dash AP, Tyagi BK. Vector control complements mass drug administration against bancroftian filariasis in Tirukoilur, India. *Bull World Health Organ* 2007; *85* : 138-45.
2. Dhanda V, Das PK, Lal R, Srinivasan R, Ramaiah KD. Spread of lymphatic filariasis, re-emergence of leishmaniasis & threat of babesiosis in India. *Indian J Med Res* 1996;*103* : 46-54.
3. Michael E, Bundy DA. Global mapping of lymphatic filariasis. *Parasitol Today* 1997; *13* : 472-6.
4. Michael E, Bundy DA, Grenfell BT. Re-assessing the global prevalence and distribution of lymphatic filariasis. *Parasitology* 1996; *112* : 409-28.
5. *Operational guidelines on elimination of lymphatic filariasis*. New Delhi: Directorate of National Vector Borne Diseases Control Programme, Directorate General of Health Services, Ministry of Health & Family Welfare, Government of India; 2004. p. 87.
6. Shenoy RK. Management of disability in lymphatic filariasis– an up date. *J Commun Dis* 2002; *34* : 1-14.
7. Bockarie MJ, Pedersen EM, White GB, Michael E. Role of vector control in the global program to eliminate lymphatic filariasis. *Annu Rev Entomol* 2009; *54* : 469-87.
8. Jayasekera N, Kalpage KS, De Silva CS. The significance of low density microfilaraemia in the transmission of *Wuchereria bancrofti* by *Culex (Culex) quinquefasciatus* Say in Sri Lanka. *Trans R Soc Trop Med Hyg* 1991; *85* : 250-4.
9. Burkot TR, Durrheim DN, Melrose WD, Speare R, Ichimori K. The argument for integrating vector control with multiple drug administration campaigns to ensure elimination of lymphatic filariasis. *Filaria J* 2006; *5* : 10.
10. Das PK, Vanamail P. Probability risk transmission matrix as a decision tool for assessing methods of transmission interruption of *Wuchereria bancrofti* infection. *Epidemiol Infect* 2008; *136* : 520-4.
11. Chandra G. Nature limits filarial transmission. *Parasit Vectors* 2008; *1* : 13.
12. Curtis CF, Feachem RG. Sanitation and *Culex pipiens* mosquitoes - a brief review. *J Trop Med Hyg* 1981; *84* : 17-25.
13. Das M. Vectors of filariasis with special reference to India. *J Commun Dis* 1976; *8* : 101-9.
14. Sucharit S, Surathin K, Shrestha SR. Vectors of Japanese encephalitis virus (JEV) : species complexes of the vectors. *Southeast Asian J Trop Med Public Health* 1989; *20* : 611-21.
15. Molaei G, Andreadis TG, Armstrong PM, Bueno R Jr, Dennett JA, Real SV, *et al*. Host feeding pattern of *Culex quinquefasciatus* (Diptera: *Culicidae*) and its role in transmission of West Nile virus in Harris County, Texas. *Am J Trop Med Hyg* 2007; *77* : 73-81.
16. Aviles G, Sabattini MS, Mitchell CJ. Peroral susceptibility of *Aedes albifasciatus* and *Culex pipiens* complex mosquitoes (Diptera : *Culicidae*) from Argentina to western equine encephalitis virus. *Rev Saude publica* 1990; *24* : 265-9.
17. Singh D. The *Culex pipens fatigans*, problem in South-East Asia with special reference to urbanization. *Bull World Health Organ* 1967; *37* : 239-43.
18. Mukhopadhyay AK, Patnaik SK, Babu P Satya. Status of lymphatic filariasis in parts of east Godavari district of Andhra Pradesh, India. *J Vector Borne Dis* 2007; *44* : 72-4.
19. Bhatia ML, Wattal BL. Tolerated density of *Culex fatigans* Weid in transmission of bancroftian filariasis. *Bull Natl Soc India Mal Mosq Borne Dis* 1958; *6* : 117-22.
20. De SK, Chandra G. Studies on the filariasis vector - *Culex quinquefasciatus* at Kanchrapara, West Bengal (India). *Indian J Med Res* 1994; *99* : 255-8.
21. Kaul HN, Wattal BL. Studies on *Culicine* mosquitoes v. density pattern of adult *Culex fatigans* population under meteorological variables in a changing terrain in village Arthala near Delhi. *Bull Indian Soc Mal Commun Dis* 1968; *5* : 53-64.

22. Barraud PJ. *The fauna of British India including Ceylon and Burma*, vol. V. London: Taylor and Francis; 1934.
23. Christophers SR. *The fauna of British India including Ceylon and Burma*. vol. IV. London: Taylor and Francis; 1933.
24. World Health Organization. *Manual of practical entomology in malaria,* Part II: *Methods and techniques*. WHO Offset Publication no. 13. Geneva: WHO; 1975.
25. Stata 9.2 version statistical software. Stata Corp LP, 4905 Lake Drive College Station, TX77845 USA; 2007.
26. Pal R, Nair CP, Ramalingam S, Patil PV, Ram B. On the bionomics of vectors of human filariasis in Ernakulam, Kerala, India. *Indian J Malariol* 1960; *14* : 595-604.
27. Kanhekar LJ, Patnaik SK, Rao PK, Narayana MV, Raina VK, Kumar A. Some aspects of the bionomics of *Culex quinquefasciatus* (Diptera : *Culicidae*) in Rajahmundry town, Andhra Pradesh. *J Commun Dis* 1994; *26* : 226-30.
28. Dhar SK, Das M, Srivastava BN, Menon PK, Basu PC. Seasonal prevalence, resting habits, host preference and filarial infection of *Culex fatigans* in Rajahmundry town, Andhra Pradesh. *Bull Indian Soc Mal Commun Dis* 1968; *5* : 79-87.
29. Dixit V, Gupta AK, Kataria O, Prasad GB. Population dynamics of *Culex quinquefasciatus* filaria vector in Raipur city of Chhattisgarh state. *J Commun Dis* 2002; *34* : 193-202.
30. Rajagopalan PK. Population dynamics of *Culex pipiens fatigans*, the filariasis vector in Pondicherry - Influence of climate and environment. *Proc Indian Natl Sci Acad* 1980; *B46* : 745-52.
31. Rajagopalan PK, Menon PK, Brooks GD. A study of some aspects of *Culex pipiens fatigans* population in an urban area, Faridabad, northern India. *Indian J Med Res* 1977; *65* (Suppl) : 65-76.
32. Gowda NN, Vijayan VA. Indoor resting density, survival rate and host preference of *Culex quinquefasciatus* Say (Diptera : *Culicidae*) in Mysore city. *J Commun Dis* 1992; *24* : 20-8.
33. Subra R. Ecological studies on *Culex pipiens fatigans* Wiedmann 1828 (Diptera : *Culicidae*) in an urban zone of the West African Sudan Savanna - Dynamics of the adult populations. *Ser Entomol Med et Parasitol* 1973; *11* : 79-84.
34. Laporta GZ, Urbinatti PR, Natal D. Aspectos ecologicos da populacao de *Culex quinquefasciatus* Say (Diptera, *Culicidae*) em ambrigos situados no Parque Ecologico do Tiette, Sao Paulo, SP. Abstract. *Revista Brasileira de Entomologia* 2006; *50* : 125-7.
35. Rao TR. *The anophelines of India.* New Delhi: Indian Council of Medical Research; 1981.
36. Kaul HN, Chodankar VP, Gupta JP, Wattal BL. Influence of temperature and relative humidity on the gonotrophic cycle of *Culex quinquefasciatus*. *J Commun Dis* 1984; *16* : 190-6.

Reprint requests: Dr Ashwani Kumar, Scientist 'E' & Officer Incharge, National Institute of Malaria Research, Field Station
DHS Building, Campal, Panaji, Goa 403 001, India
e-mail: ashwani07@gmail.com