ISSN: **2348-5906**
CODEN: **IJMRK2**
IJMR 2014; 1 (3): 04-09

Received: 06-07-2014
Accepted: 11-07-2014

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Spatial and temporal distribution of mosquitoes (Culicidae) in Virudhunagar district, Tamil Nadu, South India

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ABSTRACT
In the past few years, in many villages of Virudhunagar district, cases of dengue, chikungunya and viral fever have been suspected and hence in the present study an attempt has been made to find out the distribution of dengue and chikungunya vectors in different villages of Virudhunagar district, South India. The study period was nine months from May 2013 to January 2014. The distribution of mosquitoes recorded in the study area showed that nine species of mosquito belong to five genera namely; *Aedes, Anopheles, Armigeres, Culex*, and *Mansonia*. Totally 2147 adult mosquitoes were collected from all the study sites during the study periods. *Culex quinquefasciatus* (100%) and *Aedes aegypti* (90%) were constantly distributed during the study period. *Aedes albopictus* (70%) and *Armigeres subalbatus* (80%) were frequently distributed in the study areas. *Anopheles subpictus* (60%) and *Culex gelidus* (60%) were moderately distributed and *Culex tritaeniorhynchus* (30%) were distributed infrequently.

Keywords: Dengue, chikungunya, *Aedes aegypti, Aedes albopictus.*

1. Introduction
Monitoring vector communities is an integral part of disease surveillance and control programs. Nearly 30% of the emerging infectious disease events are caused by vector-borne pathogens with wildlife origins [1]. Mosquitoes are distributed throughout the world and have occupied many niches including higher altitudes. Effect of natural factors like temperature, humidity and rain fall also have impact on the mosquitoes. Climate has been established as an important determinant in the distribution of vectors and pathogens [2].
Dengue is one of the mosquito borne diseases in India like Malaria. It is a viral borne disease. Dengue commonly occurs in urban, semi urban and rural areas. Occasionally it causes severe haemorrhagic manifestations, which may lead to the death of an individual. Also it causes economical loss and affects the social functions. About 50 million cases of dengue occur in India every year and 2.5 million people are under the risk of dengue viral infection [3]. Continuing process of urbanization may cause dengue to become a more serious problem in the future, unless strict environmental control measures are enforced. Environmental degradation has serious public health consequences, since vectors and pathogens rapidly adapt to exploit new ecological niches whenever they appear [3].
The mosquitoes responsible for the transmission of the dengue virus, *Aedes aegypti* (L.) and *Aedes albopictus* (Skuse), are considered important vectors of the arbovirosis. These species present in abundance are influenced by the female behavior of oviposition, as well as their temporal space distribution, which has predominant dependency on the environment and the local climate in which they occur, with female mosquitoes searching for conditions favorable to survival of progeny [4]. Hence, the present study was focused to survey the distribution of medically important mosquitoes especially dengue and chikungunya vectors and other vectors in the selected rural area of the Virudhunagar district. The objective of this work is to examine the spatiotemporal distribution of theses mosquitoes and to find out the acceptable measures to minimize or eradicate the proliferation of mosquito population.

2. Materials and Methods
2.1 Study area
The study was conducted in selected rural areas of Virudhunagar district, Southern Tamil Nadu, India. The study sites were selected on the basis of randomly selection methods. The geographic

location of Virudhunagar district is $11^0$56'21.84" North latitude to $79^0$29'51.23" East longitude with a mean sea level of 53.6 m. The total area of Virudhunagar District is 3445.73 (km^2). The net irrigated area in the Virudhunagar district is 59,300 hectare and open well system (58.3%) forms the major source of irrigation in the district. The major crops cultivated in the district are paddy (28,200 hec), maize (13,200 hec), green gram (10,400 hec), sorghum (9,300 hec), cotton (8,700 hec) and ground nut (7,700 hec). The horticultural crops cultivated in the district were onion (1,300 hectare), tomato (2,000 hectare), brinjal (2,000 hectare), bhendi (1,000 hectare) and fodder sorghum (7,1000 hectare). Multiplicity of cropping systems has been one of main features of Indian agriculture and it is attributed to rain fed agriculture and prevailing socio-economic situations of farming community.

2.2 Study Period

This study was undertaken for nine months from May 2013 to January 2014, including three different seasons *viz*., Pre monsoon (June – September, 2013), retreating monsoon or South west monsoon (October – November, 2013) and North east monsoon (December 2013 – January 2014).

2.3 Methodology

2.3.1 Mosquito collection and preservation

The study areas were selected by random sampling method. Most of the study sites are located in the riverine places. The study areas are the part of the composite east flowing river basin, between Gundar and Vaippar as per the Irrigation Atlas of India. Vaippar, Arjuna, Gundar, Deviar, Nichibanadhi, Kovilur and Periyar are the important watersheds of the study areas. The systematic collection of adult female mosquitoes was made for twenty four hours at ground level in dim light and in the dark phase of the day, following the method adopted by Pandian and Chandrashekaran [5]. To minimize the damage of body parts and to collect the biting mosquitoes, a very thin and transparent (1x1 inch size) plastic vials were used, etherized, separated (hours wise) and preserved in the naphthalene filled vials for further studies and identification.

2.3.2 Identification of collected mosquito species

All preserved wild caught mosquitoes were identified up to species level by Entomologists, Indian Council for Medical Research (CMRE), Madurai. The identified mosquitos were categorized and was used to calculate various parameters of spatiotemporal distribution.

2.4 Pattern of occurrence

Knowledge on the distribution pattern of mosquitoes reveals the dimension of spatial distribution and the rate of existence in the selected study sites. Based on the density, the distribution pattern of the mosquitoes was classified into 5 categories. This distribution pattern of mosquitoes was analyzed by adopting the method adopted by Rydzonicz and Lonc [6]. The following formula was used

$$C = n/N \times 100$$

Where,

C = Distribution pattern

n = Number of sites positive for the occurrence of mosquitoes

N = Total number of sites studied

If C = 0 – 20% the distribution pattern is sporadic
= 20.1 – 40% the distribution pattern is infrequent
= 40.1 – 60% the distribution pattern is moderate
= 60.1 – 80% the distribution pattern is frequent and
= 80.1 – 100 % the distribution pattern is constant

3. Result

In the present investigation, the distribution of mosquito fauna of Virudhunagar district has been observed and prevalence throughout the period of study was analyzed. The distribution of mosquitoes recorded in the study area showed that nine species of mosquito belong to five genera namely; *Aedes*, *Anopheles*, *Armigeres*, *Culex*, and *Mansonia*.

Table 1: Distribution of mosquito species recorded in the study area during the study period (May 2013 – January 2014).

S. no	Name of the Species
1.	*Aedes (Stegomyia) aegypti* (Linn.)
2.	*Aedes (Stegomyia) albopictus (Skuse)*
3.	*Anopheles (Cellia) subpictus (Grassi)*
4.	*Anopheles (Anopheles) barbirostris (Vander wulp)*
5.	*Armigeres (Armigeres) subalbatus (Coquillett)*
6.	*Culex (Culex) quinquefasciatus (Say)*
7.	*Culex (Culex) tritaeniorhynchus (Giles)*
8.	*Culex (Culex) gelidus (Theobald)*
9.	*Mansonia (Monsonioides) uniformis (Theobald)*

Totally, 2178 adult mosquitoes were collected from all study sites during the study periods. To know the distribution of mosquitoes, the pattern of occurrence of mosquitoes was studied in the study area. *Culex quinquefasciatus* (100%) and *Aedes aegypti.* (90%) were constantly distributed during the study period. *Aedes albopictus* (70%) and *Armigeres subalbatus* (80%) were frequently distributed in the study areas. *Anopheles subpictus* (60%) and *Culex gelidus* (60%) were moderately distributed in the study sites. *Culex tritaeniorhynchus* (30%) were distributed infrequently. *Mansonia uniformis* (10%) and *Anopheles barbirostris* (10%) were sporadically distributed in the study areas during the study periods.

Table 2: The pattern of occurrence of mosquito species collected in the study area during the study period (May 2013 - January 2014).

Name of the Species	Distribution pattern of mosquitoes	Percentage of distribution	Total no. of species
Aedes aegypti	Constant	90%	2 species
Culex quinquefasciatus	Constant	100%	
Aedes albopictus	Frequent	70%	2 species
Armigeres subalbatus	Frequent	80%	
Anopheles subpictus	Moderate	60%	2 species
Culex gelidus	Moderate	60%	
Culex tritaeniorhynchus	Infrequent	30%	One species
Anopheles barbirostris	Sporadic	10%	2 species
Mansonia uniformis	Sporadic	10%	

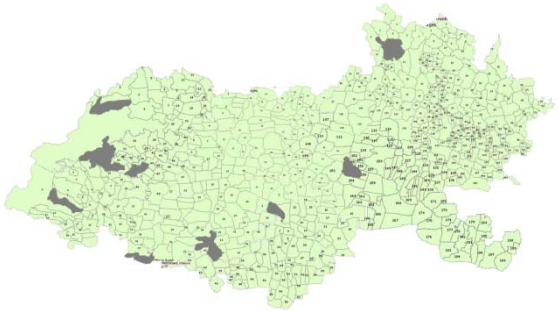
The pattern of occurrence shows that the dengue and chikungunya vectors (*Aedes aegypti* and *Aedes albopictus*) were distributed predominantly in the study areas.

The study has been carried out in the three different seasons *viz.*, Pre monsoon (June–September, 2013), retreating monsoon or South west monsoon (October – November, 2013) and North east monsoon (December 2013 – January 2014), in which 9 different species were predominantly distributed in the northwest monsoon during the study periods followed by retreating monsoon (7 species) and pre monsoon season (six species).

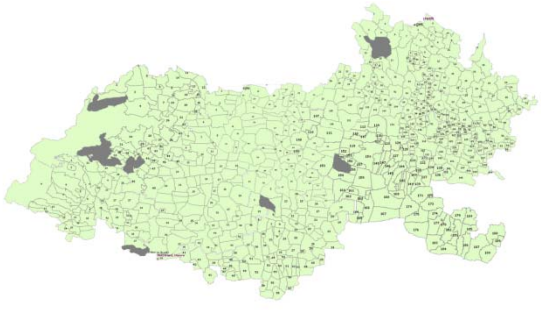
Table 3: Temporal distribution and species richness of the mosquitoes recorded in the study area during the study period (May 2013 – January 2014).

Name of the Species	Species richness								
	Pre monsoon			Retreating monsoon or southwest Monsoon			Northeast monsoon		
	May 2013	June 2013	July 2013	Aug 2013	Sep 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014
Aedes aegypti	+	+	+	+	+	+	+	+	+
Aedes albopictus	+	+	+	+	+	+	+	+	+
Anopheles subpictus	-	-	+	+	+	+	+	+	-
Anopheles barbirostris	-	-	-	-	-	-	+	+	+
Armigeres subalbatus	+	+	+	+	+	+	+	+	+
Culex quinquefasciatus	+	+	+	+	+	+	+	+	+
Culex gelidus	-	-	+	+	+	+	+	+	+
Culex tritaeniorhynchus	-	-	-	-	+	+	+	+	+
Mansonia uniformis	-	-	-	-	-	-	-	+	-
Total no. of species	**4**	**4**	**6**	**6**	**7**	**7**	**8**	**9**	**7**

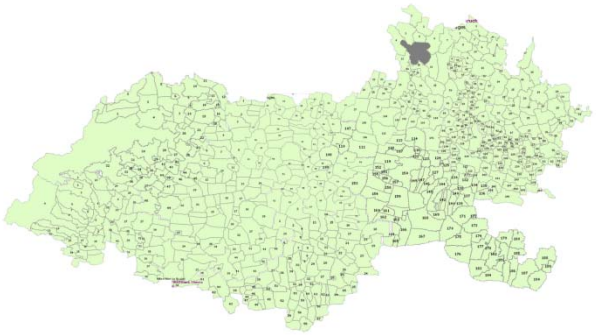
In the present investigation 10 different villages have been selected to study the distribution of mosquitoes on the basis of random sampling methods. *Aedes aegypti, Aedes albopictus* and *Culex quinquefasciatus* were evenly distributed in all the study places. During the investigation, Aladipatti rural area of Aruppukottai had only one species and six different mosquitoes species were distributed in Kambikudi, Thenkarai and E. Muthulingapuram. *Anopheles barbirostris* were observed only in E. Muthulingapuram and *Mansonia uniformis* were observed in the Vembakottai.



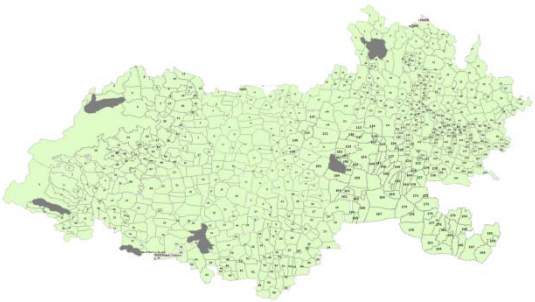
Aedes aegypti



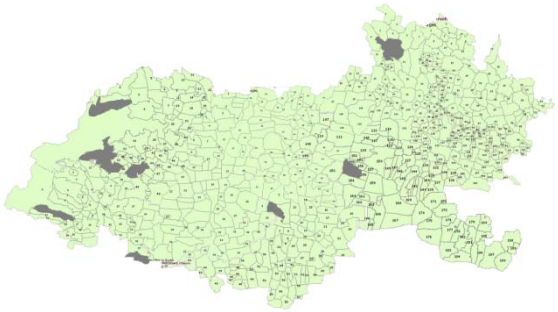
Aedes albopictus



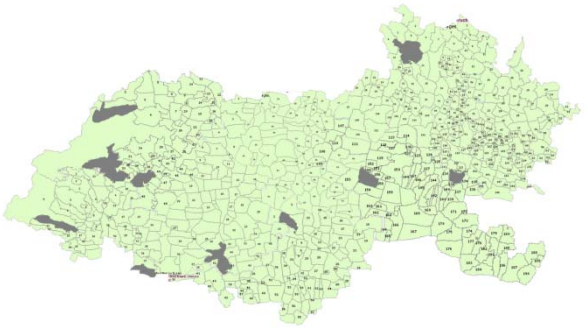
Anopheles subpictus



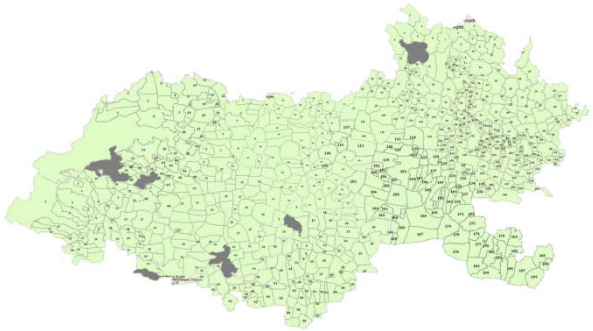
Anopheles barbirostris



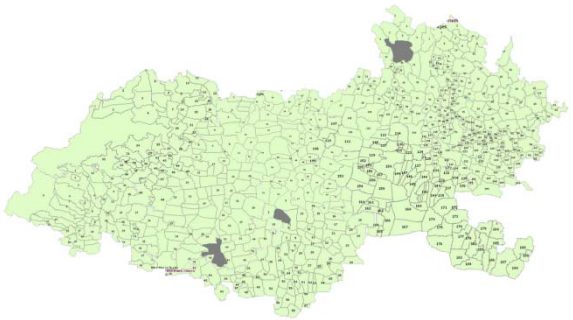
Armigeres subalbatus



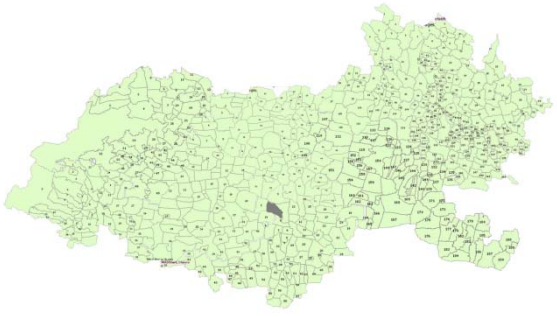
Culex quinquefasciatus



Culex gelidus



Culex tritaeniorhynchus



Mansonia uniformis

Fig 3: Spatial distribution of mosquitoes in different study sites of Virudhunagar district during the study period (May, 2013-January, 2014).

The temperature and rainfall are determining the distribution of mosquitoes in the study areas. In the month of October and November, the study area had Northeast monsoon in which 307mm of rainfall have been recorded and more number of species also recorded in these months. The temperatures also favors for the mosquito distribution in this season.

Table 4: Average temperature* and rainfall* of Virudhunagar district during the study period

Month	Season	Max Temperature °C	Min Temperature °C	Rain fall (mm)	Average rainfall (mm)
May, 2013	Pre monsoon	38	28	52	62.66
June, 2013		37	28	53	
July, 2013		35	26	83	
Aug, 2013	Retreating monsoon	35	26	124	169.66
Sept, 2013		34	25	118	
Oct, 2013		32	24	267	
Nov, 2013	Northeast monsoon	29	23	309	157.33
Dec, 2013		28	21	139	
Jan, 2014		29	20	24	

*Source - India Meteorological Department

Table 5: Temporal distribution and relative abundance of mosquitoes in the study areas during the study periods (May 2013-Jan 2014)

Name of the Species	Temporal distribution (in terms of relative abundance)										Total
	Athikulam	Mamsapuram	Aladipatti	Mattupatti	Konkalapuram	Thenkarai	Vembakottai	Thiruviruntalpuram	Kambikudi	E.Muthulingapuram	
Aedes aegypti	12	3	-	15	16	106	34	55	67	19	327
Aedes albopictus	8	8	-	-	3	47	-	48	95	78	287
Anopheles subpictus	-	-	-	2	2	8	3	9	9	-	33
Anopheles barbirostris	-	-	-	-	-	-	-	-	2	-	2
Armigeres subalbatus	3	9	-	11	19	67	-	49	78	61	297
Culex quinquefasciatus	5	37	22	58	102	169	209	197	223	121	1143
Culex gelidus	2	3	-	-	-	3	8	-	20	13	49
Culex tritaeniorhynchus	-	-	-	-	-	-	6	-	14	18	38
Mansonia uniformis	-	-	-	-	-	-	-	-	-	2	2
Total No. of species	4	4	6	6	7	7	9	9	7	7	2178

4. Discussion

The result showed that dengue and chikungunya vectors were observed in maximum. *Aedes aegypti* and *Aedes albopictus* predominantly preferred to breed in artificial container and due to water scarcity, householders stored water in containers and such practices have been often associated with the proliferation of mosquito larvae because of that these two species were distributed throughout the study period. The abundance of these vectors is associated with biotic and abiotic factors. *Aedes aegypti* prefers the clean water found in many types of domestic containers inside or near human dwellings, whereas *Ae. albopictus* is more likely to be found in natural containers or outdoor man-made habitats containing a greater amount of organic debris [7].

Cx. quinquefasciatus predominantly breeds more in sewage water than other habitats. Most of study places that had open sewage favored the constant distribution of *Cx. quinquefasciatus, An. subpictus* were frequently distributed in the study area and *Cx. gelidus* moderately distributed during the study period. Similar observations were studied by Mwangangi *et al*. [8] and reported that *Culex quinquefasciatus* was predominantly associated with urban areas but occurring also in rural. This Cosmo-tropical urban mosquito *Cx. quinquefasciatus* preferentially breeds in organically rich water. Stagnant pools were the preferred sites of *An. subpictus* and *Cx. gelidus*. The larvae of *Armigeres subalbatus* predominantly breed more in sewage water.

More number of species have been recorded during the northeast monsoon season (Nov 2013-Jan 2014) followed by southwest monsoon (Aug-Oct 2013) and pre monsoon because of northeast monsoon season with heavy downpour (48%) than other season. Increased environmental temperature likely drove mosquito abundance by increasing metabolic rates, reproductive output, and host-seeking behavior of these vectors [9]. The pattern of rainfall also affects larval habitats and vector population size. In some cases, increased rainfall increased larval habitat and vector population by creating new habitats, while excessive rain

eliminated habitats through flooding, thus, decreasing the vector population. During the dry season, limited rainfall also formed temporary stagnant water bodies. Water in the rivers channelized, provide few permanent breeding sites for the emergence of various mosquito larvae and adult species and thus favoring diseases transmission [10].

Mosquito distribution and species richness were high during the month of November 2013 and December 2013 and the remaining season showed moderate distribution. This is because of the availability of different kinds of breeding habitats like modern agricultural practices and 'above the ground' water habitats. The same result was reported by Muturi *et al*. [11] in Mwea, Kenya where the distribution was more during the cultivation season.

Azil *et al*. [12] noted that the minimum and daily average temperatures were the most significant factors associated with short- and long-term vector abundance and suggested the prospective use of meteorological variables in predicting changes in the dengue-virus vector abundance. According to Braks *et al*. [13], the spatial distribution and abundance of *Ae. aegypti* are related to the effects of anthropogenic changes on the environment. Conversely, the distribution of *Ae. albopictus* was more associated with the presence of vegetation in urban and rural areas, whereas its abundance was generally limited to spaces modified by human activity. Among the environmental variables, rainfall, temperature, and relative humidity are key determining factors the presence and frequency of these species [12]. According to Focks *et al*. [14], meteorological factors affect mosquito metabolism, oviposition activity, and consequently, the number of eggs laid by females.

5. Conclusion

Examining the temporal and spatial distribution of mosquito communities, when disease transmission is likely to occur, it is integral for implementing surveillance programs and control measures. The purpose of this study was to establish general seasonal distribution of various mosquito species that might be implicated in the spread of infectious disease and relate it to local transmission dynamics. While the information presented here contributes to the existing survey of mosquito communities in Virudhunagar district, it is important to consider that seasonal fluctuations of mosquito communities are variable across years, affecting both the abundance of individual species and the community composition, and their subsequent response to meteorological variables.

6. Acknowledgement

Authors profoundly thank UGC, New Delhi, for providing financial support to carry out this project under Major Research Project Scheme. The authors are also thankful to the Management and Principal, Ayya Nadar Janaki Ammal College, Sivakasi for the facilities provided.

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