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The effects of climatic factors on the distribution and abundance of Japanese encephalitis vectors in Kurnool district of Andhra Pradesh, India

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Abstract

Background & objectives: Climatic attributes have been associated with relative mosquito abundance and transmission of mosquito borne infections in many parts of the world, especially in warm and tropical climatic regions. The main objectives of this study were to assess the change in seasonal pattern of Japanese encephalitis (JE) vectors, their density, to elucidate whether the lagged climate variables (precipitation, temperature and humidity) are associated with JE vector density, and to determine if temperature and precipitation are similarly important for the rise in the number of potential mosquito vectors for JE virus in the temperate climate of Andhra Pradesh, India.

Methods: Mosquito samples were collected from Kurnool district of Andhra Pradesh using hand catch and light-trap methods during 2002 to 2006. The type and abundance of recovered species were compared to ecological correlates. In each geographic area, temperature and precipitation are the two possible proxy variables for mosquito density, in conjunction with other seasonal factors for JE epidemics.

Results: Out of the various mosquito species collected, *Culex gelidus* and *Cx. tritaeniorhynchus* were noticed in high numbers. There was considerably high prevalence of *Cx. gelidus* (68.05%) in urban area than in rural areas whereas, *Cx. tritaeniorhynchus* (57.51%) was found to be more in rural areas than in the urban area. It is noticed that the factors such as rainfall and temperature were found to be correlated with the per man hour (PMH) density, whereas the humidity was inversely correlated with the PMH.

Interpretation & conclusion: The environmental and eco-climatic factors are assisting in enhancing the breeding of these mosquitoes in Kurnool district of Andhra Pradesh, India. Both *Cx. tritaeniorhyncus* and *Cx. gelidus* are quite adaptable to these environmental conditions and this necessitates immediate control measures in both rural and urban areas of Kurnool district.

Key words *Culex gelidus*; *Culex tritaeniorhynchus*; Japanese encephalitis; per man hour (PMH) density; rainfall; temperature

Introduction

Among many species of mosquitoes that transmit Japanese encephalitis virus (JEV), *Culex tritaeniorhynchus* (Diptera: Culicidae) is the most important vector of this virus in many south-east Asian countries. About 50,000 cases and 15,000 deaths are reported worldwide annually[1]. JE not only causes death but also leads to permanent and neuropsychiatric sequale. The case-fatality rate varies across regions ranging from 10 to 30%[1–3]. In India alone, JEV has been isolated from 16 species of mosquitoes, out of which 10 are from *Culex*, three from *Anopheles*, and three from *Mansonia* mosquitoes[4].

This virus undergoes a zoonotic cycle in mosquitoes breeding in paddy-fields, domestic pigs, water birds and humans, the humans are mostly incidental hosts[5]. From the socioecological view point, an outbreak of JE may be facilitated by two factors, *i.e.* global climate change and the modulation of agriculture practices. Temperature and precipitation are the proxy variables that have been representing the density level of mosquitoes[6,7].

In Andhra Pradesh (southern state of India), many cases of JE were reported during 1981, 1986, 1993 and 1999, especially in the year 1999 higher number of cases were reported in the districts of Ananthapur, Kurnool, Prakasam and Warangal of the state. In the following year 2000, about 343 cases with 72 deaths were reported and in the year 2003, 329 cases with 183 deaths were reported. Earlier, the presence of JEV in these areas was confirmed by monitoring the animal serum samples[8]. Still many cases were being reported from these districts even after the implementation of various control measures. The disease dynamics were found to be more significant in the study areas, hence, longitudinal studies were carried out in and around Kurnool district of Andhra Pradesh for better understanding of the seasonal abundance of JE vector population and their associated environmental parameters. The information from the present study will be instrumental and very useful to the health officials about the seasonal distribution and abundance of JE mosquitoes to make an attempt for more detailed analysis and effective diagnosis of this disease in due course of time.

Material & Methods

Study area: The region chosen for the present study falls in Kurnool district of Andhra Pradesh, the reason for selecting Kurnool being that highest number of JE cases were reported since 1996. The study area lies at 15.83° N and 78.05° E. Patchy paddy fields and waterloggings are commonly seen in Kurnool district. Most of the population is involved in agricultural practices. Domestic animals commonly share the habitat with human population. Climatically, Kurnool district is warm and humid for a major part of the year. The agricultural activities are at their peak during the south-west monsoon which persists between June and October of a year. Out of the 69 Primary Health Centres (PHCs) in Kurnool district, six areas—Peddathumbalam, Nandanapalli, Nandikotkur, Gudur, Cherukulapadu and Kurnool (Urban) have been selected for this study (5 villages and 1 urban area) which showed highest number of JE cases since 1996. Data on epidemiology, entomology and climatic parameters were collected periodically from the study area by the researchers of the Biology Division of Indian Institute of Chemical Technology, Hyderabad and Centre for Research in Medical Entomology, Madurai.

Mosquito collection: Mosquitoes were collected from identified villages at monthly (JE transmission period) and bimonthly (JE non-transmission period) intervals between July 2002 and May 2006. Both blood engorged and unfed adult mosquitoes, resting on bushes and thatched roofs of cattlesheds and human dwellings were trapped from different parts of the villages using aspirator and suction tube, and light-traps and then subsequently transported to the field laboratory for further processing. Fully-fed mosquitoes were held for 24–48 h for digestion of blood meals, anesthetized with ether, identified to species level using the key developed by Reuben[9] and stored in ice into pools comprising of 50 each, and transported to the Centre for Research in Medical Entomology (CRME), Madurai, Tamil Nadu for further validation.

Meteorological data: Besides vector prevalence studies, surveillance studies of JE, data on other parameters like maximum and minimum temperature, rainfall, relative humidity and wind speed were also collected from the Meteorological Department, Hyderabad, Govt. of India during the study period.

Results

Mosquito collections were conducted in selected study areas (rural and urban) of Kurnool district, to recognize the seasonal prevalence of JE vectors. Out of all the prevailing mosquito species, *Cx. gelidus, Cx. tritaeniorhynchus, Cx. quinquefasciatus* and *An. subpictus* were found to be the most common in these areas. The distribution of *Cx. tritaeniorhynchus* and *Cx. gelidus* with weather data of Kurnool are shown in Figs.1 & 2.

A total number of 24,709 mosquitoes were collected using light-trap method, out of which 68.99% were collected from urban and 31.11% from rural areas.

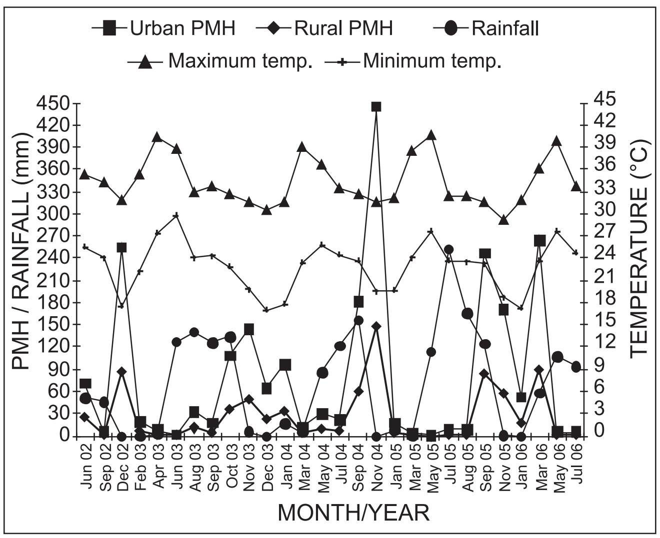

Fig. 1: Seasonal prevalence of *Cx. tritaeniorhynchus* with temperature and rainfall in rural and urban areas of Kurnool district

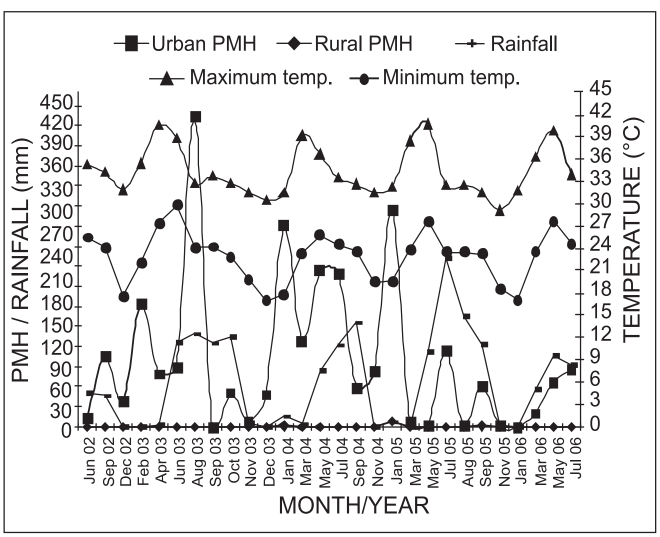

Fig. 2: Seasonal prevalence of *Cx. gelidus* with temperature and rainfall in rural and urban areas of Kurnool district

In urban areas, *Cx. gelidus* was found to be the predominant species (68.05%) followed by *Cx. tritaeniorhynchus* (25.74%), whereas other species like *Cx. quinquefasciatus* (2.88%), *An. subpictus* (2.38%) constituted less percentage of the total collection. But in rural areas, *Cx. tritaeniorhynchus* (57.51%) was found to be the dominant species followed by *Cx. quinquefasciatus* (21.84%), *An. subpictus* (14.8%) and *Cx. gelidus* (2.53%). The other species of mosquitoes were ranged between 1 and 1.5% in both rural and urban areas (Table 1).

In dusk method, about 37,139 mosquitoes were collected, out of which 42.19% were from urban and 57.8% were from rural areas. In urban areas, *Cx. gelidus* (49.74%), was the important vector of JE and was found to be predominant, followed by *Cx. tritaeniorhynchus* (44.54%), *Cx. quinquefasciatus* (2.32%), *An. subpictus* (1.88%) and other species were found to be <1% of the total mosquitoes collected. Similarly, in rural areas *Cx. tritaeniorhynchus*

Table 1. Percent species composition of mosquitoes in Kurnool district (light-trap and dusk collection) from July 2002 to May 2006

Mosquito species	Light-trap		Dusk collection	
	Rural	Urban	Rural	Urban
Cx. tritaeniorhynchus	57.51	25.74	78.94	44.54
Cx. vishnui	0	0.12	0.58	0.16
Cx. pseudovishnui	0	0.02	0	0.06
Cx. gelidus	2.53	68.05	1.1	49.74
Cx. infula	0.01	0	–	–
Cx. (Lut) *fuscanus*	–	–	0.08	0.04
Cx. quinquefasciatus	21.84	2.88	10.78	2.32
An. stephensi	0	0.08	0.12	0.5
An. subpictus	14.8	2.38	7.13	1.88
Ar. subalbatus	1.02	0.39	0.46	0.31
Ae. aegypti	0.04	0.09	0.14	0.19
Ae. (Vex) *vexans*	0	0.01	0	0.03
Ae. albopictus	–	–	0	0.02
Ae. vittatus	0.01	0.01	–	–
An. peditaeniatus	0.23	0	0.08	0.03
An. barbirostris	1.28	0.04	0.36	0.02
An. vagus	0.01	0	0.02	0.01
An. hyrcanus	0.7	0.05	0.2	0.04
M. uniformis	0	0.16	0	0.13
M. indiana	0	0.01	0	0.01

Table 2. Mean weather variables of Kurnool district during the study period (July 2002 to May 2006)

Weather variables	Mean ± S.D. (n=12)
Rainfall (mm)	62.395**
Wind speed (km/h)	3.137 ±1.691**
Maximum temperature (°C)	34.538 ±3.610**
Minimum temperature (°C)	22.826±3.532**
Maximum RH (%)	69.664±8.384*
Minimum RH (%)	42.774±11.761*

*p <0.01; ** p <0.001; ; S.D.– Standard deviation.

was predominant (78.94%), followed by *Cx. quinquefasciatus* (10.78%) and *An. subpictus* (7.13%) whereas other mosquito species comprised only <2% of the total collection (Table 1). Among the entire mosquito species collected, only *Cx. tritaeniorhynchus* and *Cx. gelidus* are reported to be the most important JE vectors in Kurnool district due to their vast prevalence in the study areas.

From Fig. 1, it could be understood that there is a significant difference in *Cx. tritaeniorhynchus* density (PMH) in the rural and urban areas during different seasons of a year. The *Cx. tritaeniorhynchus* population was more in the urban area than in the rural areas, in all the seasons except from July 2002 to September 2002. So, it is assumed that irrespective of the seasons the *Cx. tritaeniorhynchus* is more abundantly found in the urban areas. *Cx. gelidus* were found mainly confined to the urban areas and very less number of *Cx. gelidus* were captured in rural areas except during November–January of the whole study period (Fig. 2). Hence, it was observed that seasonality appeared to be the major influencing factor in comparing the densities of the two mosquito species. In the seasonal abundances, the PMH density ranged from 100 to 250 for *Cx. tritaeniorhynchus* and *Cx. gelidus* during the study period. The mean values of all the meteorological parameters for different seasons of the year are mentioned in Table 2. Optimum temperature was between 22.8 and 34.53°C (p <0.001); relative humidity (RH) connecting 42.77 to 69.66% (p <0.01) and rainfall reaching 62.395 mm (p <0.001) was observed throughout the study period. These factors are generally conducive for mosquito breeding and proliferation.

Correlation of weather variables with Cx. tritaeniorhynchus: The mean mosquito density of *Cx. tritaeniorhynchus* in rural areas varied from 26.96 to 36.04 PMH during various seasons of the study period. While analyzing the correlations of PMH with wind speed, it was highly significant statistically (p <0.001). The minimum and maximum temperature was also found to influence the PMH of *Cx. tritaeniorhynchus* (p <0.001). Whereas maximum and minimum relative humidity was inversely correlated with PMH. The average rainfall was also found to be positively correlated with PMH of *Cx. tritaeniorhynchus* (p <0.001) (Table 3).

In the urban areas, high mosquito density of *Cx. tritaeniorhynchus* was noticed compared to rural areas which varied from 67.75 to 83.21 through out the study period. The correlations of *Cx. tritaeniorhynchus* PMH with the wind speed was found to be statistically significant. The minimum and maximum

Table 3. Analysis of correlation between the meteorological parameters and PMH density (n=12) of *Culex tritaeniorhynchus* or *Culex gelidus* in the rural and urban areas

Comparisons	Rural areas		Urban areas	
	CC	*p*-value	CC	*p*-value
Culex tritaeniorhynchus				
Wind speed *vs* PMH	–0.451	0.001	–0.559	0.001
Max. temp. *vs* PMH	–0.810	0.001	–0.585	0.001
Min. temp. *vs* PMH	–0.839	0.001	–0.671	0.001
Max. RH% *vs* PMH	0.680	0.800	0.464	0.444
Min. RH% *vs* PMH	0.312	0.248	0.091	0.085
Rainfall *vs* PMH	–0.426	0.001	–0.244	0.008
Cx. gelidus				
Wind speed *vs* PMH	0.005	0.051	–0.414	0.001
Max. temp. *vs* PMH	–0.158	0.017	–0.341	0.003
Min. temp. *vs* PMH	–0.126	0.021	–0.467	0.001
Max. RH% *vs* PMH	0.114	0.096	0.228	0.107
Min. RH% *vs* PMH	0.113	0.096	–0.046	0.037
Rainfall *vs* PMH	–0.069	0.032	–0.279	0.006

CC– Correlation coefficient; PMH– Per man hour density.

temperature also highly influenced the PMH of *Cx. tritaeniorhynchus* in the urban areas, whereas maximum RH was noticed to have less correlation with PMH ($p > 0.05$) and minimum RH was highly correlated with PMH of *Cx. tritaeniorhynchus* in urban areas ($p > 0.05$). The average rainfall was found to exhibit high correlation with PMH of *Cx. tritaeniorhynchus* ($p < 0.008$) (Table 3).

Correlation of weather variables with Cx. gelidus: Least number of *Cx. gelidus* was reported from the rural areas than the urban areas. The mean *Cx. gelidus* PMH in the rural areas was 0.588 per season, yet their population was also influenced by the ecological factors such as wind speed ($p > 0.05$), minimum temperature ($p < 0.05$) and maximum temperature ($p < 0.05$) at a reasonably higher extent. Even rainfall, maximum and minimum RH have also influenced the PMH of *Cx. gelidus* in rural areas (Table 3).

The *Cx. gelidus* population reported mainly from the urban areas that varied from 67.56 to 98.38% during various seasons of the year. This high density of *Cx. gelidus* was greatly influenced by average wind speed ($p < 0.001$), maximum temperature ($p < 0.05$), minimum temperature ($p < 0.001$), maximum and minimum relative humidity ($p > 0.05$ and $p < 0.05$). The average rainfall was found to be highly correlated with the PMH ($p < 0.05$) (Table 3).

Discussion

There are more than few risk factors involved in the disease transmission which include rainfall, temperature, relative humidity, virus infection from the reservoirs and the upshots of social and economic conditions etc[10]. It is crucial to study the impact of weather on the transmission of Japanese encephalitis, as global warming might change the pattern of temperature and rainfall which may directly or indirectly influence the mosquito density.

Relative humidity is a critical factor affecting the life cycle pattern of mosquitoes[11]. It has been observed that temperature at 28°C with 50–55% RH is the most appropriate condition for the elevation in mosquito density than the condition of lower temperature with higher humidity (22°C/80–85% RH). In the present investigation also, the temperature was between 22 and 34°C with lower to medium humidity (42.7 to 69.6%), which might have facilitated the higher mosquito density in both rural and urban areas. Similar kinds of results have also been reported on the maximum survival rate of mosquitoes for the same temperature and humidity[12].

The pattern of rainfall also affects larval habitats and vector population size. In some cases, increased rainfall may increase larval habitat and vector population by creating a new habitat, while excessive rain would eliminate habitats through flooding, thus, decreasing the vector population[13–15]. During the dry season limited rainfall can also create new habitats, when water in the rivers is drawn into pools, providing the perfect breeding sites for a number of mosquito species and thus favouring diseases transmission[13]. In the present investigation, among many mosquito species collected, the two main vectors of JE, *Cx. tritaeniorhynchus* and *Cx. gelidus* were considered in support of their abundance. It is noticed that the prevalence of *Cx. tritaeniorhynchus* varied among different years during the study period. This difference in their population may be due to the change occurring in the agricultural practices during each year[16]. Surprisingly, about 98.5% *Cx. gelidus* were reported only from the urban area and only 1.5% from the rural areas which may be due to several environmental or eco-climatic factors that might have hindered the occurrence of *Cx. gelidus* during the study period. The other possible reasons for their less occurrence may be: (i) *Cx. gelidus* is reported to be highly susceptible than *Cx. tritaeniorhynchus* to various types of insecticides which are normally used in the agricultural fields[17]; and (ii) medium to high humidity (61–77% RH) which influences the evaporation of water from the breeding sites[11].

In contrast, high numbers of *Cx. gelidus* were reported in the urban area which implies the availability of congenial environmental and ecological factors like breeding sites, temperature, humidity and hosts for blood meal. Though high numbers of *Cx. gelidus* were reported in the urban areas during the whole study period, their population was at its peak in only some seasons of the year. Some of the enhancing sources which are typical in urban areas, viz. the availability of many breeding sites, low to medium levels of humidity (55– 61%) and optimum temperature (25–30°C) might have collectively favoured the high density of *Cx. gelidus* in urban areas over the rural areas[18].

In urban areas, high *Cx. tritaeniorhynchus* density was also observed when compared with the rural areas. The PMH recorded was 83.21 and 36.04 in the urban and rural areas respectively. In the urban areas of Kurnool district, the congenial environmental conditions aided the breeding of mosquito species has become evident due to the presence of high numbers of both the species *Cx. tritaeniorhynchus* and *Cx. gelidus*. Hence, from the present investigation it is inferred that the environmental and ecoclimatic factors are assisting in enhancing the breeding of these mosquitoes in Kurnool district of Andhra Pradesh, India, which is augmented by the reports of higher number of JE cases recorded in the recent years. The densities of the two most important vectors undertaken in this study demonstrate the disease load present in these regions. Both these species are quite adaptable to these environmental conditions and this necessitates immediate control measures in both rural and urban areas of Kurnool district. Further studies are being undertaken to analyze the JE virus load and its transmission in these regions and the possible control measures.

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