CHAPTER IV

Diversity of mosquitoes

Introduction

Public health scientists are increasingly discovering the fact that the recent emergence or re-emergence of infectious diseases has an origin in environmental changes exhibited by human race. These environmental changes encompass social processes such as urbanization and creation of transportation infrastructure, as well as ecologic processes such as, land and water use, biodiversity loss, and climate change (McMichael and Martens, 2002). Concern surrounding these trends has inspired much exploratory research because these phenomena are often anthropogenic, interrelated and accelerating. Yet there remains a pressing need to more clearly define the casual relationships, leading from a distal environmental change to alterations in more proximal environmental characteristics and disease transmission cycles, which eventually lead to a shift in the prevalence, distribution, or severity of diseases transmitted through vectors.
Most emerging diseases are driven by human activities that modify the environment or otherwise spread pathogens into new ecological niches. Due to environmental modifications, in most of the South-east Asian countries including India, mosquitoes have been highly adapted and exist as one among the serious vectors of several vector-borne diseases like dengue fever, Japanese encephalitis, malaria and recently chikungunya, which make serious public health problem on an annual basis causing considerable serious morbidity and mortality (WHO, 2006). Hence, it is essential to be familiar with the host-vector rapport that plays an important role in the distribution of pathogens and the ability of these diseases to colonize previously uninfected areas may be explained by the diversity of hosts and vectors, the favourable ecological conditions and the successful adaptations of vectors to new ecosystem (Chevalier et al., 2004).

The information about host-vector relationship is essential in order to create control measures. The survey of mosquito species in a region may provide valuable information on occurrence, distribution, prevalence and species composition of various mosquitoes, which assumes implication due to the public health importance (Prakash et al., 1998). Therefore, it is essential to know the diversity of various mosquitoes available before finding effective management strategy in a particular region. Diversity of mosquitoes has been studied systematically in various countries including India and it has been reported that the species composition and diversity of mosquitoes have been constantly changed everywhere. With this perspective, the present study has been designed to study the diversity of various mosquito fauna in
16 rural sites at Srivilliputhur Taluk to understand whether there is uniformity in mosquito species in all the 16 sites throughout the year or number of species fluctuates over seasons in these various study sites.

**Materials and Methods**

Diversity of mosquitoes was recorded by the collection of adult mosquitoes while they were resting in their roosting sites, larval mosquitoes at various breeding water sources and also landing adult mosquitoes on human bait for sucking blood. Two study areas such as A located near forest and B located away from the forest were chosen. Eight sites from each area were randomly selected and systematic collections were made for 15 months from October 2000 to December 2001. The collection of female mosquitoes was made by the method adopted by Pandian and Chandrasekaran (1980). The biodiversity indices like species richness, species diversity and species evenness were calculated to assess the species diversity in the study areas.

**Results**

A total of 42 species of mosquitoes belonging to six genera namely *Armigeres, Culex, Aedes, Anopheles, Mansonia* and *Megarhinus* were collected and recorded from 16 different study sites in Srivilliputhur Taluk, Virudhunagar District, Tamil Nadu between October 2000 and December 2001(Table 1). Intra-generic diversity was observed. Among the six genera of mosquitoes collected, the genus *Culex* represented with the maximum number of 16 species, *Anopheles* with 15 species, *Aedes* with
seven species, *Mansonia* with two species and the genus *Armigeres* and *Megarhinus* each represented with single species (Table 2).

Diversity of mosquitoes recorded during the study was categorized under four seasons. They are, post-monsoon (December 2000 to February 2001), late post-monsoon (March 2001 to May 2001), pre-monsoon (June 2001 to August 2001) and monsoon (September 2001 to November 2001) seasons (Tables 3 to 6; Figs. 2 to 5). Twenty-five and twenty-six mosquito species belonging to 6 genera, were recorded during post-monsoon (11504 mosquitoes) and late post-monsoon seasons (6312 mosquitoes) respectively (Tables 3 and 4). In pre-monsoon, 12 species with least number of 4661 mosquitoes belonging to 4 genera were recorded (Table 5). Twenty-six mosquito species with the maximum number of 13194 mosquitoes were recorded under 5 genera during the monsoon season (Table 6). Intra-generic diversity was observed in *Culex, Aedes, Anopheles* and *Mansonia* in post-monsoon, late post-monsoon and monsoon seasons. *Armigeres* and *Megarhinus* were represented by single species each. *An. theobaldi* was the only species belonging to the genus *Anopheles* recorded in pre-monsoon season. The genus *Mansonia* was recorded during the post-monsoon and late post-monsoon seasons only.

The number of mosquito species collected from each study sites during the study period was shown in the Table 7. The species richness differed in the selected 16 study sites. The number of mosquito species collected in study sites, such as, Achamthavilthan, Coomapatti, Karisalkulam, Kansapuram, Krishnankovil, Malli, Nathampatti, Pattakulam, Pilavakkal, Shenpagathoppu, Srivilliputhur,
Sundarapandiam, Thambipatti, Vanniampatty, Watrap and W.Pudupatti were 10, 14, 10, 16, 13, 9, 9, 8, 21, 26, 19, 11, 16, 14, 14 and 13 respectively. A maximum of 26 species was recorded in the study site Shenbagathoppu whereas, the minimum of eight species in the study site Pattakulam.

Among the selected sixteen study sites, eight sites such as Shenbagathoppu, Pilavakkal, Krishnankovil, W.Pudupatti, Watrap, Coomapatti, Kansapuram and Thambipatti were located near forest area represented as study area A, whereas, the remaining eight study sites like Srivilliputhur, Vanniampatty, Malli, Achamthavilthan, Sundarapandiam, Pattakulam, Nathampatti and Karisalkulam were located away from the forest represented as study area B. Forty mosquitoes species were recorded in study area A and 21 mosquitoes species in area B (Table 8). Student’s “t” test revealed that the number of mosquitoes species collected in sites located near forest (area A) were statistically more (t= -7.591; df=119; P<0.001) when compared with the sites located away from the forest (area B). Similarly the total number of mosquitoes collected near the forest in area A was statistically more (t= -2.852; df= 119; P<0.01) than the sites located away from the forest area B during the study period.

The mosquitoes collected during the entire study period in study area A and B were given in the Table 9. Number of species in each genus (1-50 individuals, 51-1000 individuals and more than 1000 individuals) collected during the study period was given in the Table 10. Among the nine species collected more than 1000 individuals, four species belong to the genus Culex, Aedes and Anopheles represented by two species in each genus and Armigerus represented by a single species (Table 11). A
maximum number of 16 species belonging to five genera collected 51 to 1000 individuals in the study sites. Among these 16 species, the genus *Culex* represented with the maximum number of seven species, five species in the genus *Anopheles*, two species in the genus *Mansonia* and one species each in the genera *Aedes* and *Megarhinus* (Table 12). The genus *Anopheles* was represented by seven species and the genera *Culex* and *Aedes* each represented with five species were collected a minimum number of 1 to 50 individuals during the study period (Table 13).

The most predominant mosquito species collected with more than 1000 individuals in the study sites were *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus* which were recorded 18235 and 13111 respectively during the entire study period. Other mosquito species such as, *An. sinensis, Ae. vittatus, Ar. kuchingenesis, Cx. vishnui, An. subpictus, Ae. aegypti* and *Cx. bitaeniorhynchus* were also found predominant and they were represented with, 3748, 2673, 2418, 1992, 1779, 1035 and 1022 individuals respectively (Table 11).

Sixteen species such as *Cx. fuscifurcatus, Cx. infula, Cx. fuscocephalus, Cx. gelidus, Cx. mimeticus, Cx. epidesmus, Cx. mimulus, An. maculates, An. vagus, An. barbirostris, An. theobaldi, An. nigerrimus, Mn. uniformis, Mn. annulifera, Megarhinus edwarsi* and *Ae. albopictus* were recorded moderate numbers between 51 individuals and 1000 individuals (Table 12) during the study period.
The remaining 17 mosquito species such as *An. tessllatus, Ae. albotaeniatus, Ae. gubernatoris, Ae. pallirostris, Ae. pseudotaeniatus, An. annularis, An. culicifacies, An. culiciformis, An. majidi, An. pallidus, An. stephensi, An. varuna, Cx. cornotus, Cx. edwarsi, Cx. pseudovishnui, Cx. sitiens* and *Cx. theobaldii* were recorded in minimal numbers between 1 and 50 individuals respectively (Table 13). Among these 17 species, *An. majidi* was recorded only once and three species namely *Cx. sitiens, Cx. theobaldii* and *An. varuna* were recorded twice and considered to be the least species in the study areas.

The diversity and distribution of mosquitoes in all 16 sites of study area for about 15 months were continuously studied and shown in Tables 14 to 28; Figs. 6-20. The number of species as well as number of individuals constantly varied in various months of the year during the study period. Number of mosquito species as well as individuals collected in all 16 sites for 15 months was given in the Table 29. Maximum number of individuals and species were collected in the month of December 2001 than the remaining months, whereas, minimum number and species were found during May, June, July and August 2001. The species *Cx. quinquefasciatus* was the most predominant mosquito collected in all the selected study sites than rest of the species. In contrast, only a single individual of the species *An. majidi* was collected on a single occasion in the site Shenbagathoppu during the entire study period.

The relative occurrence of 42 mosquito species recorded in the study sites during the study period was shown in Table 30. Based on the percentage of occurrence (Table 31) these mosquito species were classified into 5 types. Eight
species such as *Ar. kuchingensis*, *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus*, *Cx. bitaeniorhynchus*, *Cx. vishnui*, *Ae. aegypti*, *An. sinensis*, and *An. subpictus* exhibited constant species status, occurred in all the selected study sites. *Cx. gelidus* and *Ae. albopictus* exhibited frequent status, *Cx. epidesmus* and *Ae. vittatus* showed moderate species status. Infrequent status was shown by *Cx. infula*, *An. vagus* and *Mn. annulifera* and the remaining 27 species exhibited sporadic species status (Table 32).

**Diversity indices:**

Mosquito community characteristics such as richness, diversity and evenness in each of 16 different study sites for 14 months were given in Tables 33 to 48. The Margalef index (*R*₁) and Menhinick index (*R*₂) were found to be maximum in monsoon (*R*₁=1.73; *R*₂=0.61) and postmonsoon (*R*₁=1.74; *R*₂=0.59) seasons in the site 1 Srivilliputhur. The *R*₁ and *R*₂ drastically decreased in pre-monsoon (*R*₁=0.58; *R*₂=0.3) months. Fluctuations in the index were observed during the entire period of investigation. The Simpson's index (*λ*) was found to be maximum in pre-monsoon (0.6), minimum in monsoon (0.18) season. Simpson’s index also fluctuated over the season. The Shannon-Weiner index (*H’*), Hill’s index 1 (*N*₁) and Hill’s index 2 (*N*₂) were found to be maximum in monsoon (*H’*=1.84; *N*₁=6.27; *N*₂=5.37) and post monsoon (*H’*=1.93; *N*₁=6.9; *N*₂=4.7) months, whereas these parameters showed minimum value in pre-monsoon (*H’*= 0.82; *N*₁=2.26; *N*₂=1.66) months. Fluctuation in *H’*, *N*₁ and *N*₂ were observed during the entire study period. The evenness index values moderately fluctuates over seasons (*E*₁ 0.45 to 0.83; *E*₂ 0.37 and 0.75; *E*₃ 0.25 and 0.68; *E*₄ 0.68
and 0.86; Eₜ 0.60 and 0.83). Similar trend have been observed in the remaining 15 study sites (Tables 33 to 48).

Discussion

Humans depend on natural ecosystems and the services they provide, including food, energy, clean air and water, and recreation for the successful survival. But human beings have been involving in habitat alteration like deforestation and creation of cultivable crop land around human inhabiting area which increase the risk of vector-borne infectious diseases by mosquitoes like malaria and dengue fever (Vittor et al., 2006; Gubler and Kuno, 1997). To overcome these vector-borne diseases of mosquitoes, adequate information about their composition, species diversity, density and distribution, feeding and biting behaviour are essential for successful implementation of vector management programme (Pandian et al., 1997).

In order to take prerequisite step with the intention to manage mosquito species in Srivilliputhur Taluk at Virudhunagar district, present status of species diversity, distribution and abundance, and feeding and biting activities of various mosquitoes species available in 16 different villages were carried out in the present study. A total of 49531 adult mosquitoes were collected by various sampling methods for 15 months belonging to 5 genera and 42 species (Table 1). High environmental variability in combination with a mild climate is likely to be cause for high mosquito diversity. The high diversity of mosquito species in the study area may be due to the presence of
many mosquitogenic habitats for breeding and availability of suitable host for feeding for the adult mosquitoes.

High diversity of 47 mosquito species covering 6 genera and dytiscids were positively influenced by a high proportion of permanent water and amount of open areas in Uppasala, Sweden (Schafer, 2004). There are about 50 mosquito species found in Massachusetts, some are common and others are found less frequently. Each species has its own unique combination of characteristics. The presence of a particular mosquito species dependent on the types of nearby habitat. Different habitats that produce different mosquito species include permanent swamps, temporary woodland pools, river flood plains, swamps or artificial containers, which can hold stagnant water for at least a week, including roadsides drains, old rimless tyres, unused swimming pools, uncovered empty cans and bird baths (Cranes, 2004).

The diversity of mosquito species in the monsoon (26 species), post-monsoon (25 species) and late post-monsoon (26 species) was found to be higher when compared with pre-monsoon period where less number (12 species) of species was collected (Tables 3 to 6: Figs. 2 to 6). The reason for the maximum diversity in the study area during monsoon, post and late monsoon seasons may be due to the occurrence of more temporary and permanent water bodies for the oviposition of female mosquitoes and larval inhabiting. The same result was recorded in the study undertaken in Kenya where the rainfall enhanced the diversity of mosquitoes and its larval forms (Hutchings et al., 2005). The population of this species was associated with the cultivation of paddy. Kanojia et al. (2003) from Gujarat showed a bimodal
pattern of Japanese encephalitis vector, *Cx. tritaeniorhynchus* population with short and tall peaks during dry month (March) and tall during rainy months (August to October). Seasonal variation of mosquito abundance is a rather well-documented pattern and can often be associated with weather and hydrological conditions. Schafer (2004) reported seasonal variations of mosquito species in Dalaven region in Sweden.

The decreased number of species in the pre-monsoon may be due to dry condition and reduced breeding sites in the study sites. According to Adebote *et al.* (2008) when the number of breeding sites are more in the rainy and less after rainy months, the diversity of mosquitoes varied. Low mosquito diversity was reported in the dry season of 2002 in 2 villages of Gedaref state, NewJersy (Chevalier *et al.*, 2004). This result merges with the finding of the present study. The present findings also coincide with the report of Muturi *et al.* (2006) in Mwea, Kenya where the diversity was more during the cultivation season. The species of mosquito found at any one time in an area is dependent on temperature and seasons. The diversity and distribution of mosquito species showed variation in different seasons such as, early spring, late spring, summer and mid summer in Northern eastern United States (Cranes, 2004).

The number as well as diversity of mosquito species in the areas near forest (A) are more than the areas away from forest (B) (Table 8 and 9). This may be due to the availability of various breeding resources for the mosquito species (Plate). However, in Srivilliputhur, the site away from the forest area, maximum number of species was recorded, this may be due to poor sanitation and availability of many fresh water, sewage stagnant water bodies and fields of agro-ecosystem like paddy, banana and
other resources favourable for the successful breeding, availability of large number of anthropogenic and non-anthropogenic hosts for feeding of mosquito species. Similar report has been attributed recently by Muturi et al. (2007).

Diversity of different mosquito species varied in the different study sites. A maximum number of 26 species was recorded in Shenbagathoppu, one of the sites located near forest area (A) and a minimum of 8 species in Pattakulam, a site located in the area away from the forest (B) (Table 7). The reason for high species richness in Shenbagathoppu was due to the presence of many perennial stagnant water bodies, rock holes, slow moving stream and tree holes for breeding and availability of many domestic and non-domestic mammalian, avian, human and other hosts for feeding, whereas, Pattakulam had less number of temporary breeding habitats. Highest number of species and functional groups of all study areas was found in Southern most wetland with forested areas in Sweden (Schafer, 2004); availability of hosts and breeding habitats in near forest area as reported by Amerasinghe and Munasinghe (1985) in Ceylon.

Mosquitoes were collected by various sampling methods namely biting, resting and larval collections directly in the breeding sites. In the present study the genus Culex considered to be the most predominant species. Among 42 species, nine species belong to six genera were collected with more than 1000 individuals during the study period. The genus Culex represented by four species, Aedes and Anopheles represented each with two species and Armigerus represented with a single species which accounted more than 1000 individuals in the study sites. Among the sixteen
species collected with 51 to 1000 individuals, *Culex* represented seven species, other genera *Anopheles, Mansonia, Aedes* and *Megarhinus* collectively account nine species. The genus *Anopheles* represented seven species whereas *Culex* and *Aedes* each represented with five species out of 17 species collected between 1-50 individuals (Table 11 to 13). The diversity of intra-generic mosquito population may be due to the availability of different types of habitats owing to negligence of ecosystem and application of agricultural practices around human inhabitants (Pandian *et al.*, 1997).

The mosquito species such as *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus* were found to be most predominant species, recorded 18235 and 13111 individuals respectively during the study period (Table 11). Similar findings were made in 1994 at Madurai, Tamil Nadu by Pandian *et al.* (1997). They have reported twenty-seven species of mosquitoes belonging to five different genera such as, *Aedes, Anopheles, Armigeres, Culex* and *Mansonia* from the larval and adult collections. Among the twenty seven species, *Ae. aegypti, An.stephensi, An. subpictus, Ar. sabalbatus* and *Cx. quinquefasciatus* were the predominant species and they occurred in many areas of the city. Muturi *et al.* (2006) had reported three species such as *Cx. quinquefasciatus, An.arabiensis* and *An. pharoensis* were most abundant among the 25 species recorded which is associated with agro-ecosystem in Mwea, Kenya. The present report reveals the fact that the mosquitoes of the genus *Culex* withstands and thrives in all the adverse conditions like turbid and sewage water in the study area. Amerasinghe and Munasinghe (1985) reported that the genus *Culex* was found to adapt in various habitats due to its wide variety of breeding habitats and host preference in Ceylon. *Culex* found to feed principally on birds, pigs and cattle in India (Reuben, 1971) and
on bovid in Pakistan (Reisen et al, 1982). Wild bird hosts are abundant within Udawattakele and are probable hosts, but it is equally likely that *Cx. pseudovishnui* could be attracted to the abundant domestic chicken and cattle hosts available in the urban areas at the periphery of the forest and return into the forest during ovarian maturation (Amerasinghe and Munasinghe, 1985).

Diversity of mosquito species varied in different study sites and study period as shown in Tables 14 to 28. Varied diversity and distribution of mosquito species in different study sites in the study period was due to the availability of many mosquitogenic habitats and variety of domestic, non-domestic and human host for breeding and feeding in different study period. Similar results were reported by Schafer (2004) in Sweden and Cranes (2004) in Massachusetts.

Based on the occurrence, the mosquito species of the study area were grouped into 5 groups (Table 29 and 30). Eight species such as *Ar. kuchingenesis*, *Cx quinquefasciatus*, *Cx. tritaeniorhynchus*, *Cx. bitaeniorhynchus*, *Cx. vishnui*, *Ae. aegypti*, *An. sinensis* and *An. subpictus* exhibited constant occurrence in the study area. This may be due to the presence of constant breeding habitats in all the selected study sites. Similar study was carried out in Orissa by Chand et al. (1993). They have listed out 15 *Anopheles* Sp., 9 *Culex* species and one each of *Aedes*, *Armigera* and *Manson*. They reported that *An.culicifacies*, *An. subpictus*, *An.annularis*, *An.vagus*, *An.pallidus*, *An.nigerrimus*, *Cx. quinquefasciatus* and *Cx.tritaeniorhynchus* were available throughout the year. Prevalence of these mosquitoes was high during rainy season. Stagnant sewage water bodies in the rural and urban areas were suitable breeding habitats for *Ar. kuchingenesis* and *Cx quinquefasciatus*. Presence of agro-ecosystem
was associated with the breeding of *Cx. tritaeniorhynchus*, *Cx. bitaeniorhynchus*, *Cx. vishnui* and *An. sinensis* become the constant species. Many perennial water bodies like rock holes, man made artificial tanks, rimless tyres and other water bodies in the study sites were suitable for reproduction of *Aedes* species acquired the constant status in the study area during the study period.

The mosquitoes *Cx. gelidus* and *Ae. albopictus* exhibited frequent status. The selected study sites had maximum cultivable land, many rock holes and artificial containers which provided suitable habitats for their occurrence. Two species such as *Cx. epidesmus* and *Ae. vittatus* showed moderate status of occurrence indicating the availability of all kinds of mosquitogenic conditions in the study sites. Infrequent status was exhibited by *Cx. infula*, *An. vagus* and *Mn. Annulifera* in the study area indicated the presence of moderate mosquitogenic habitats. The remaining 27 species exhibited sporadic status of occurrence, indicating that the study area had variety of mosquitogenic habitats suitable for the breeding of many species in the study area.

Forty two mosquito species recorded in Srivilliputhur Taluk indicated the diversity and richness of mosquito species. The heterogeneity of inter and intra-generic variation among the mosquito species is mainly due to the availability of suitable hosts and appropriate breeding habitats for phytophilic, zoophilic and anthropophilic mosquitoes.
The indices such as species, diversity and evenness for mosquito species collected during the study period were given in tables 33 to 48. The number of species available in a given study area is often a straightforward measure of comparing diversity between different sites over seasons (Southwood and Henderson, 2000). In this regard, the high and low R1 values may be correlated with the maximum and minimum number of species in the 16 study sites. Further, it is to be noted that Margalef’s index ($R_1$) and Menhinick index ($R_2$) are species richness indices, based on the relationship between number of species (S) and total number of individuals observed (n). The $R_1$ and $R_2$ values increase with increasing “S” and “n” size (Ludwig and Reynolds, 1988). The $R_1$ values range between a minimum of “0” (sites 3–7 and 13) due to occurrence of a single mosquito species in pre-monsoon and a maximum of 3.15 at Shenbagathoppu (site 16) in monsoon seasons.

The minimum and maximum indices values of $R_2$ are 0.14 (site 7; Nat) and 1.19 (site 16; She) located away and near forest area respectively. When number of breeding sites and feeding sources are more, mosquito species (S) and numbers (n) increased. Mosquitoes in sites located near forest had dual purpose; the first one is it has more temporary and permanent breeding sites and the second is wide range of feeding sources like wild beasts in addition with human. In both the areas, pre-monsoon seasons was almost dry, and hence $R_1$ and $R_2$ decreased in months around this season. According to Ludwig and Reynolds (1988), $\lambda$ indices values increase with decreasing diversity. Simpson’s index ($\lambda$) varied between 0.1 (site 16; She) and 1.0 (sites 3, 6 and 13; Ach, Sun and Kan) in pre-monsoon and monsoon seasons. In most of the study sites, maximum and minimum Simpson’s index values fell in pre-monsoon and monsoon months respectively over the study period which confirmed the
fact that mosquito diversity was more in monsoon months and it was less in pre-
monsoon months.

Shannon’s diversity index (H’) is a combination of both species richness and
evenness components and it is an overall index of stability of the community. Though
Shannon’s index values slightly modulating among different sites over seasons, the
values well correlated with various seasons during the study period, where minimum
H’ values are notable during pre-monsoon and maximum values during monsoon and
adjacent months. The minimum and maximum H’ values were noticed between 0 (sites
3, 6, 7 and 13) and 2.48 (site16) respectively during the study period. Hill’s diversity
index 1(N_1) and 2 (N_2) also revealed the similar trend that higher N_1 (11.97; site 16)
and N_2 (10.62; site 16) values were noticed in monsoon months, whereas, these two
tend to show minimum values (N_1 0.17; N_2 0.08 in site 3) in pre-monsoon months.

The evenness indices indicate whether all the species in a given site of areas A
and B are equally abundant or not. E_1 to E_3 are sensitive to species richness
dependent on “S” and “n”, whereas, E_4 and E_5 are independent and unaffected by
species richness (Peet, 1974). From the available information it is clear that, though
the values of evenness E_1 to E_3 and also E_4 and E_5 modulate among these 16 study
sites over the seasons, high evenness values of E_1 to E_5 (Tables 33 to 48) were
evidenced in months of monsoon and adjacent durations are due to the reason that
during rainy months temporary and permanent water bodies filled with water in study
sites which bring about favourable situation for larval growth by having plenty of food
for the developmental stages of mosquito-ontogeny in aquatic life leads multiplication
and diversification of mosquito species during the study period in study sites.