CHAPTER – I

BIODIVERSITY OF MOSQUITO FAUNA IN RURAL AND URBAN POCKETS IN MADURAI WITH SPECIAL REFERENCE TO BITING AND RESTING BEHAVIOUR

1.1 INTRODUCTION

The term “biodiversity” is usually used as a synonym for ‘variety of life’ and is widely applied not only in scientific context but also in media and political discussions (Gaston, 1996). Most analysis of biodiversity is performed at the species level of living organisms. The importance of biodiversity for ecosystem processes has been the focus in studies on functional diversity, looking at the extent of functional differences among the species in community (Schafer, 2004). Several studies have been carried out to find out the diversity of mosquitoes in the given environment. Diversity of Culex mosquitoes in two rice agro-ecosystem, namely Murinduku and Kiamachiri, in Mwea, Kenya was carried out by Muturi et al., (2007) and reported that Murinduku was more diverse (10 species) than Kiamachiri (7 species) because of the presence of rich source of habitats including paddies, canals, rain pools, ditches, rock pools and tree holes. Muturi et al., (2006) examined the diversity of mosquitoes and correlated it with the planned and unplanned rice agro-ecosystems and a non-irrigated ecosystem and suggested that Anopheles arabiensis, Culex quinquefasciatus and An. pharoensis were more in planned rice ecosystem whereas the An. funestus was diversified more in unplanned rice cultivation habitats.
During the history of human culture and evolution, population dispersal around the world and subsequent inter-population contact and conflict there have been several distinct transitions in the relationship of *Homo sapiens* with the natural world. Each of these transitions in human ecology and in inter-population interaction has profoundly changed the patterns of infectious disease (Nurdenozer, 2005).

The reasons behind the dramatic resurgence of vector borne diseases include the demographic changes such as global population growth and their movements, unplanned and uncontrolled urbanization; societal changes including human encroachment on natural disease focus, modern transportation, containerized shipping; agricultural changes such as changes in land use, irrigation systems and deforestation; increased epidemic potentials due to genetic changes in pathogens and changes in public health (Ozer, 2005). The tremendous abundance of increase of mosquito population is promoted by unavoidable development of human activities. The prominent of them are the increase in human population, irrigation of crops, flooded rice fields, unplanned sanitation, urban development, the bird migration, rainfall, temperature, humidity and dry arid condition and the changing life style of the population in cities, urban, sub-urban and rural areas of our nation (Devi and Jauhari, 2007). Such changes enhance the population dynamics of vector mosquitoes and play a major role in the transmission of pathogenic organisms of many dreadful diseases and enhance the incidence of vector-borne diseases.
The proliferation of disease vector mosquito has been attributed to the effects of land use change. These results have indicated that land use may not necessarily lead to higher densities of mosquitoes in larval habitats by altering the association with microinvertebrate (Leisnham et al., 2007).

Though mosquito borne diseases are found in both urban and rural areas the problem seems to be more severe in the rural areas with a well irrigated agro-ecosystem. The areas with poor sanitation facilities, several agricultural practices and lack of medical facilities enhance the diversity and density of the populations of mosquitoes and vector borne diseases. For successful implementation of vector management programmes, adequate knowledge about the species diversity and density is a prerequisite. The purpose of these entomological observations was to determine present mosquito species, their possible density changes, population dynamics and diversity of species of medical and veterinary importance (Pandian et al., 1997).

Mosquitoes are believed to have evolved around 170 million years ago during the Jurassic era (199-144 million years ago). The earliest known fossil was from the Cretaceous era (144-65 million years ago). Mosquitoes are found throughout the world except in permanently frozen zones. Of the 3500 species (3/4) three quarter are native to humid tropics and sub tropics where all the ambient bio-ecosystems enhanced the proliferation of mosquito species.

It has been demonstrated that the availability of water and associated mosquito oviposition behaviour can play an important role in determining the
distribution of vector-borne disease risk. In general, the disease transmission potential of mosquito is maximized when water and humans are both available in order to oviposit, in water bodies (Menach et al., 2005). It has been reported mosquito survey provides valuable information on occurrence, distribution, prevalence and species diversity of various mosquitoes in an area which assumes significance due to their public health importance (Prakash et al., 1998). Irrigated lands and especially rice cultivation in the agro-ecosystem has a strong association with vectors because most of the mosquitoes prefer to lay their eggs in the flooded rice fields and the irrigation and drainage channel. Extensions of agricultural processes have substantially prolonged the season, mosquito occurrence and prevalence of perennial larval habitats (Klinkenberg et al., 2003).

Malaria is endemic in many developing countries particularly in the tropical and subtropical regions and the world’s most important vector borne disease. The World Health Organization (WHO) estimates that 300- 500 million malaria cases occur each year; this leads to more than one million deaths. Almost 90 percentage of all cases occurs in sub- Saharan Africa; children are the most affected and malaria may account for as much as 20percentage of child mortality in this region (Gupta, 2005). About 2400 million people are at the risk of contacting the disease and malaria is currently endemic in 92 countries. Worldwide, malaria accounts for more than one million deaths per year and the majority of these are in children under the age of five. Of all infectious diseases, malaria continues to be one of the biggest
contributors to the global disease burden in terms of death and suffering (Pandian, 1997).

Mosquitoes prefer to breed both in the stagnant and slowly running water bodies. The availability of these water bodies plays an important role in keeping the diversity of mosquito populations to a higher degree. The main breeding habitats are ponds, irrigation canals, sewage water bodies, drains and ditches, ground water pool and cement tanks (Pandian, 1997). Mosquito larvae feed on decomposing leaves and the associated microbial fauna. Tree holes are naturally occurring breeding sites that would allow population of some mosquito species, such as *Aedes triseriatus* (Charles et al., 1994). Some of the mosquito species prefer their own choice for breeding and others may prefer to breed in all the available habitats and coexist with other mosquitoes (Senthilkumar and Pandian, 2007). It was also suggested that introduction of irrigation projects in developing nations has often been blamed for aggravating the problem of mosquito-borne diseases by creating ideal larval habitats for vector mosquitoes (Muturi et al., 2007).

*Aedes* mosquitoes of the flood water type are typically found in temporary pools on flood plains after seasonal rains, but also at the margins of wetlands following natural or other fluctuations in water levels. These species oviposit on moist situation and the eggs hatch after being flooded. The eggs can remain for many months and more than a year in few cases; some arboviruses survive in the eggs and are passed on through the hatching larvae to the next
generation, for transmission to vertebrate, hosts including humans (Russell, 1999).

An understanding of the biology and ecology of potential mosquito vectors is crucial for disease threat analysis and for the development and implementation of vector disease control strategies (Turell et al., 2008). For a mosquito, to transmit an infection to humans, it must take minimum two blood meals to facilitate uptake of the pathogens, and eventual transmission to a susceptible human. The degree of human-vector contact is, therefore, considered as one of the most important components of disease transmission and is used in planning and evaluating the risk of vector-borne disease and the impact of vector control measures (Jones et al., 1980).

The choice of blood meals is influenced by several factors including host availability, nutritional requirements and intrinsic host preferences of the species and vector density (Zimmerman et al., 2006). Therefore, more parameters are needed to be added to the society to optimize the prediction and control of existing and emerging mosquito-borne diseases in economically and socially backward areas. This can be possible only after knowing the key environmental factors involved in the diversity of mosquitoes, by understanding the epidemiological mechanisms that allow the persistence and proliferation of mosquito in terms of density, by analyzing the role of amplifying hosts in the distribution of mosquitoes and the disease transmitted by the mosquitoes, and by implementing a large scale monitoring system to
evaluate various behavioural aspects including host preference behaviour or feeding pattern, biting mechanism and breeding habits (Chevalier et al., 2004).

The species diversity, spatial distribution and behavioural expressions of adult mosquitoes are associated with various environmental factors, such as the availability of suitable hosts, adequate oviposition sites, natural resting sites, artificial resting sites and patterns of vegetation. These environmental factors could evoke significant difference in the distribution of mosquito populations, which in turn may have important implications both on the epidemiology of vector-borne diseases and in the formulation of strategies for control (Thenmozhi and Pandian, 2007). Under this context, an indepth study is warranted in both urban and rural pockets of Madurai. Therefore an attempt has been made to study biodiversity of mosquito fauna both in rural and urban pockets in Madurai with special reference to biting and resting behaviour of mosquitoes with the following objectives:

- To record the current species diversity pattern
- To assess the density of various species
- To record the spatial distribution pattern and
- To identify the feeding and breeding behavioural patterns.
1.2 REVIEW OF LITERATURE

Earlier studies on mosquitoes reported that over 3200 species are available worldwide in the existing ecosystems. Mosquitoes are found throughout the world except the Antarctic (Lehane, 1991). Mosquitoes are the vectors of a variety of hazardous diseases including malaria, yellow fever, lymphatic filariasis, dengue, West Nile, JE and chikungunya (Kettle, 1995). In recent years, vector borne diseases have emerged as a serious public health problem in countries of Southeast Asia region, including India and studies suggest that malaria claims more than a million lives every year and most of them are children (WHO, 2006). These infectious diseases are emerging or resurging as a result of changes in public health policy, demographic and societal changes, insecticide and drug resistance, shift in emphasis from prevention to emergency response, genetic changes in pathogens in the last two decades of the twentieth century. Climatic changes also influence the reemergence of these diseases (Ozer, 2005). Mosquitoes alternate between blood feeding and oviposition and suitable hosts and water are heterogeneously distributed. Human biting reflects the mosquitoes commute to complete its gonotrophic cycle, as well as inherits differences in the attractiveness, suitability and distribution of blood meal hosts (Menach, 2005).

DIVERSITY

A study on the diversity of mosquitoes carried out in the Jau National park reported that among the total of 130 taxa in 16 genera collected in Brazil, about 71% of mosquitoes were diversified habitats in forest than the remaining
areas. The possible epidemiological and ecological implications of the species were also recorded by Hutchings et al., (2005). Tubaki et al., (2004) reported that the formation of new lakes due to the Igarapava reservoir flooding in Grande River, Brazil altered the diversity of mosquitoes because of expansion of their breeding place.

Herrel et al., (2004) studied that in Pakistan, *Anopheles stephensi*, *An. culicifacies* and *An. subpictus* populations peaked in August, September and October respectively. Povoa et al., (2003) reported that malaria transmission and epidemiology in the Amazonian city of Belem was mainly due to *An. darling* and *An. phelesaquasalis*. Tadei and Dutary Thatcher (2000) reported that among the 33 species of *Anopheles* nine species were considered as the vectors of malaria in Amazon Brazilian. Lopes and Lozovei (1995) reported various mosquitoes namely *Ae. crinifer*, *An. fluminesis*, *An. intermedius* and *An. albitarsis*. *An. argyritarsis*, *An. evansae*, *An. strode*, *An. oswaldoi*, *An triannulatus*, *Cx. bidens*, *Cx. coronator*, *Cx. eduardoi*, *Cx. quinquefasciatus*, *Cx. coppenamensis*, *Cx. vaxus* and *Cx. intricatus* from southern region of Brazil.

Among *Anopheles* species recorded from Bangladesh four vector mosquitoes, such as *An. minimus*, *An. dirus*, *An. philippinis* and *An. sundaicus* were considered as the transmitters of malaria (Maheswari et al., 1994). Rattanarithikul et al., (1994) reported 28 species of mosquitoes belong to *Aedes*, *Anopheles* and *Culex* from the bank of Mekong in Northeastern
Thailand. Forattini et al., (1993) examined the ecology of adult Culicidae from January 1992 to January 1993 in the rice irrigation system of the Ribeira valley and reported that *Ae. scapularis* and *Cx. ribeirensis* were dominant group of mosquitoes from various habitats.

Among the Anopheline species recorded from Costa Margues, Rondonia, Brazil, *An. darlingi* was easily susceptible for *P. falciparum* whereas the species such as *An deaneorum*, *An barbirostris*, *An triannulatus*, *An oswaldoi* and *An mediopunctatus* were less susceptible to malaria pathogens (Klein et al., 1991).

Systematic study on the diversity of the mosquitoes was carried out in Agra and nearby cities and reported that urbanization and industrialization were considered as the main factors for the formation of breeding places for *Culex*, *Anopheles* and *Aedes* and for the occurrence of malaria, dengue cases in neighbouring cities like Delhi, Jaipur and Mathura (Andrew and Kumar, 2002). Sathiskumar et al., (2005) reported that 29 species of mosquitoes belong to 7 genera in Mysore and Mandya. Out of 29 species, 11 species were vectors of malaria, dengue, Japanese Encephalitis and filariasis.

Study on the immature of anopheline species was undertaken by Mahesh et al., (2002) and reported about 572 anopheline specimens comprising of 9 species viz., *An. fluviatilis*, *An. culicifacies*, *An. stephensi*, *An. maculatus*, *An. splendidus*, *An. vagus* and *An. nigerrimus*. 
Seasonal abundance of various mosquitoes of urban, peri-urban and rural strata in Malindi along the Kenya coast was investigated and reported. *An. gambiae*, *An. funestus* and *An. coustani* were predominant in the rural stratum while *Cx. quinquefasciatus* was mostly found in urban and peri-urban strata. *Ae. aegypti* was found only in urban stratum. In all the three strata, mosquitoes were mainly found in high numbers during the wet season (Joseph et al., 2012).

Bhattacharya et al., (2000) reported that *Ar. jolensis* a rare mosquito for the first time in India from district Dibrugarh of upper Assam. A report on the occurrence of 50 species of mosquitoes belonging to 11 genera was made out of which *Cx. peytoni*, *Cx. bailyi* and *Heizmannia veida* were the new records from Assam, India (Prakash et al., 1998). Entomological studies on anopheline species in Assam, India was carried out by Dev (1994) and reported a few malaria transmitting vectors namely *An. minimus*, *An. fluviatilis* and *An. culicifacies*.

Sagandeep et al., (1994) collected a total of 16 mosquito species from various localities of Punjab and Himachal Pradesh. Verma et al., (1991) compared the availability of various mosquitoes in two deserts and one non-desert district of Rajasthan, India and confirmed that *Cx. pseudovishuni*, *Cx. Malayi* and *An. culicifacies* were found in desert districts and *An. fluviatilis*, *Cx. gelidus* and *Ae. vittatus* found in non-desert district.
Thenmozhi and Pandian (2007) undertook a diversity study on mosquitoes in three different ecological areas and recorded 6 genera from Alagarkovil reserve forest, 4 genera from Idayapatti village (Rural) and 5 genera from Natham town (urban) of which *Aedes*, *Anopheles*, *Armigeres* and *Culex* were recorded from all the three areas.

**DENSITY**

In recent years, vector born disease has emerged as a serious public health problem in many countries of the south-East Asian region, including India. Diseases known as dengue fever, Japanese encephalitis and malaria now occur in epidemic form almost on an annual basis causing considerable morbidity and mortality. Dengue is spreading rapidly to newer areas without breaks occurring more frequently and explosively. Chikungunya has re-emerged in India after a gap of more than three decades affecting many states. The risk factors which play a key role in the spread and transmission of dengue and chikungunya include globalization, unplanned urbanization, developmental activities, poor environmental sanitation, human behaviour relating to water collection and human migration (WHO, 2006).

Mosquitoes are pestiferous insects which are responsible for the transmission of various dreadful diseases. In India most important disease-transmitting mosquitoes belong to the genera such as, *Aedes*, *Anopheles*, *Armigeres*, *Culex* and *Mansonia*. The reasons behind this dramatic resurgence of arboviral diseases are drastic demographic changes such as societal human
encroachment on natural disease foci, modern transportation, containerized shipping, agricultural changes including changes in land use in irrigation systems, deforestation changes in pathogens due to increased movements in humans and animals and genetic changes leading to increased epidemic potential changes in public health including lack of effective vector control, deterioration of public health infrastructure to deal with vector-borne diseases, disease surveillance and prevention programs (Nurdenozer, 2005).

An investigation on the density of mosquitoes in two seasons of Northern Amazon basin, Brazil has been undertaken by De-Barros et al., (2007) and revealed that rainy season enhanced population of An. albitarsis only. Ravikumar and Gururaj (2005) investigated the density of the immature Aedes spp. and Anopheles species in various domestic water containers and reported that both species mainly preferred stagnant and clear water for their proliferation. Monthly collection of mosquitoes performed in Mid Western, Brazil from July 1997 to November 1999 reported that the availability of eighty six species of mosquitoes (Gomes Ade et al., 2007).

Density of some indoor and outdoor mosquitoes was analysed by using ovitrap method and determined that the relative abundance of Ae. albopictus was high during the onset of Northeast monsoon (Surendran et al., 2007).

In Brazil, Ade et al., (2006) performed a survey of vector involved in malaria transmission and reported that among the 20 species of recorded mosquitoes; An. aquasalis was the most abundant species in the entire
municipality of Belem, Brazil. Systematic observation on certain species *Anopheles* mosquito was carried out and reported that *An. fluviatilis, An. culicifacies, An. subpictus, An. stephensi* and *An. aquasalis* density was found in various localities of urban areas of Nundanpura of Jhansi district (Baighet and Srivastav, 2004).

In Australia, Hu *et al.* (2006) carried out an intensive study on the density of mosquitoes transmitting Ross River virus (RRV) and reported that the outbreak of RRV was positively correlated with annual rainfall and mosquito density, because both *Ae. vigilax* and *Cx. annulirostris* were preferred clean water for breeding. Larval density was assessed in Honduras, USA by Diemont (2006) in the constructed wetlands and offer a low-cost waste water treatment and reported that the larval density was more in cells that were operating below design depth of 0.2m and mosquito larval development was reduced in the cells which have very low level of dissolved oxygen.

Burkot *et al.*, (2007) studied on the relative abundance of six mosquito species which was mainly bred in containers of houses of four villages in American Samevo revealed that *Ae. aegypti* was the most abundant species. *Cx. quinquefasciatus, Cx. annualirostris* and *Tx. amboinensis* were moderate in number. *Ae. polynesiensis* utilized domestic and natural containers as its breeding grounds.

Afrane *et al.*, (2007) reported that in Western Kenya, the abundance of *An. arabiensis* is either very low or absent. Climatic condition is less
permissive to *An. arabiensis* than to *An. gambiae* in Western Kenya high lands. Environmental changes such as deforestation and global warming may facilitate the establishment of *An. arabiensis* populations in high lands.

Epidemiological study was conducted in five localities of Southern Venenzuela between January 1999 and April 2000 to analyse the abundance, biting behaviour and parity of anopheline mosquitoes belong to six species. The most abundant species was *An. maeasoava* (Moreno *et al.*, 2007).

All night biting patterns and seasonal densities of adult of *Anopheles darlingi* of Caya district of Belizo, Central America were analysed from January 2002 to May 2003 and reported that among the 18,873 mosquitoes collected, 9611 were collected from indoor sites and 9262 were collected from outside sites (Achee *et al.*, 2006). Relative abundance of mosquitoes of subgenus *Nyssorhynchus* was carried out in Pre-Amazonic marannao and reported that *An. darlingi* was the most dominant vector followed by *An. evansae, An. triannulatus* and *An. nuneztorei*. The *An.oswaldoi* and *An. rangoli* were found less in number (Rebelo *et al.*, 1997).

Apiwathnasorn *et al.*, (2006) reported that, the predominant *Mansonia* species which attacked man at day time and night time were *Mn. bonneae* and *Mn. annulata*. Their biting densities were very high, reaching 50 bites per person per hour at peak periods in Ban Toh Daeng village and 25 bites per person per hour in the forest of the peat swamp forest. Muturi *et al.*, (2006) stated that, irrigated rice agro-ecosystems are considered important “hot spots”
for mosquito-borne diseases because of the numerous mosquito species present. Worldwide, more than 89 species of *Anopheles* are associated with rice cultivation and at least 23 species occur in a variety of aquatic habitats present in African rice agro ecosystems.

Derraik and Snell (2004) stated that, the endemic *Cx. pervigilans* Bergroth was New Zealand’s most common and wide spread species and was a known vector of arbo virus, which primarily infect native bird populations. Although *Cx. pervigilans* rarely bites humans, it often co-occurs with *Ae. notoscriptus* and that has been assessed as species requiring testing for its potential as a vector of human diseases.

Muriu *et al.*, (2008) demonstrated that *Anopheles* mosquitoes in the Mwea Rice Scheme were highly zoophilic and that multiple feeding within the same gonotrophilic cycle was common among these species. This study has further revealed that the degree of anthropophily by malaria vectors was in direct proportion to the area of land under rice cultivation. By pooling together available literature and the findings of this study, it can be inferred that zoo prophylaxis is a potential malaria control strategy in Mwea and similar areas, but it may also enhance arbovirus transmission. It was, therefore, essential to evaluate the impact of zoo prophylaxis on arboviruses transmission before adopting it as malaria control strategy. Findings of Rejon *et al.*, (2008) suggested that *Cx. quinquefasciatus* could be an important amplification vector of WNV (West Nile Virus). In addition, the data refute the hypothesis that the
low incidence of WNV illness in Mexico was due to the lack of interaction between *Culex* spp. mosquitoes and avian reservoir hosts in this region.

Turrell *et al.*, (2008) reviewed the potential role of *An. darling* in the resurgence of malaria and of other culicine species as potential arbovirus vectors in the region around Iquitos, Peru and also evaluated the bionomics of mosquito species in Puerto Almendra, a rural village, and an adjacent densely forested site located 300m away from the village center.

Kigadye (2006) studied the abundance of *An. gambiae* and *An. merus* on the plateau than the flood plain and it could be probably be attributed to the variation in the environmental and ecological factors such as rainfall and breeding habitats.

Muturi *et al.*, (2006) illustrated that among the irrigated crops, rice was considered to pose the greatest danger to health because it was grown under flooded conditions. Studies in various parts of Africa have demonstrated that irrigated rice agro-ecosystems can support between 10 and 35 mosquito species, making them important targets for vector control operations. However, despite the distribution and abundance of diverse mosquito species in these areas, most research efforts have been directed towards *An. gambiae* and *An. funestus*. This study provided baseline information on *Culex* mosquitoes at two sites targeted for malaria vector control by microbial larvicides.
Kozlov *et al.*, (2005) adopted human-bait method around a nickel-copper smelter at Monchegorsk, Northwestern Russia and reported that the catches of culicidae were decreased near the smelter, presumably due to the combined action of toxicity of pollutants, pollution-induced forest damage and decline in invertebrate density.

Pramanik and Raut (2003) recorded 89 species of mosquito from Goa during September 1986 to June 1987 which comprise 26 species belonging to the genera *Anopheles, Aedes, Culex, Uranotaenia, Mansonia* and *Armigeres* and also studied the impact of *Kalbaishkhi* storms on the density of adult mosquitoes of Kolkata, India and observed a steep reduction in the density of nine species of four genera immediate day after a storm but steadily increased from day there after the storm. Abundance of *Cx. tritaeniorhynchus* compared with the paddy irrigation and pointed out that JE vectors were peak between August and November in the Gorakhpur district, Uttar Pradesh (Kanojia *et al.*, 2003). Murthy *et al.*, (2002) studied the seasonal abundance of *Cx. quinquefasciatus* in rural and urban areas of West Godavari districts of Andhra Pradesh.

The interrelation of large polluted water bodies with aquatic weeds and the abundance of *Cx. gelidus* was reported by Arunachalam *et al.*, (2006) in Kurnool district of Andhra Pradesh and observed that the available water bodies showed in large scale than other species of *Culex*. 
A random collection of both adult and larval forms of *Ae. aegypti* was analysed in Tirupur, Tamilnadu above its critical level of *Ae. aegypti* was the main reason for the increasing mortality of dengue cases during July 2005 (Balakrishnan and Venkatesh, 2006). Victor and Reuben (1999) examined the abundance and occurrence of immatures of many mosquito species and insect predators in rice fields near Madurai, Tamil Nadu.

The results have demonstrated a wide spectrum of *Culex* mosquitoes in relation to rice cultivation. The study suggests that rice cultivation has a marked effect on *Culex* mosquito species diversity. It also illustrated the importance of how human-made changes could alter species diversity and abundance (Muturi *et al.*, 2007).

Mahesh and Jauhari (2008) studied that the distribution of various mosquitoes in different geographic settings has been worked out at different places with particular reference to their elevational or vertical distribution. Devi and Jauhari (2004) demonstrated the habitats that were available to the survival of mosquitoes differ with elevation and vegetation therefore, the mosquito species were specific for a habitat would be distributed according to elevation on altitude. Another interesting aspect noted in this investigation was that the larvae of some mosquito species *Ae. albolateralis, Cx. mimetrius* and *Cx. quinquefasciatus* were also collected at the low elevation but the adults were obtained from the higher elevation. Streams and seepage pools were the
habitats that shared most immature of anopheline mosquitoes followed by shallow pits, rice fields, tanks, rock holes and river beds.

Kilpatrick et al., (2005) reported that, Cx. modestus aggressively fed on people and horses and was observed as a “bridge” vector candidate in wet areas of Camargue and Cx. pipiens (more ornithophilic than Cx. modestus) also fed on horses and acted as a “bridge” vector. Rebollar – Tellez (2005) suggested that there was a vast literature on field and laboratory experiments dealing mainly with mosquitoes, suggesting that human body odor varies from person to person and that these differences are responsible for the uneven biting rates in a human population. Many vector-borne parasitic diseases (e.g. malaria, dengue fever, etc) were caused by the infectious bite of dipterian vectors.

Allan et al., (2006) observed higher responses of the Cx. nigripalpus to volatiles and other compounds associated with avian blood when compared to bovine blood in laboratory conditions. In addition, Edman et al., (1974) showed that Cx. nigripalpus tends to engorged on the most tolerant host of those to which it is exposed. As a result chickens were considered to be tolerant, whereas rodents were defensive hosts. Considering that Cx. nigripalpus may feed on variety of hosts, it might have multiple contacts during blood feeding as was observed by Anderson and Brust (1995).

Taye et al., (2006) reported that the biting behaviour, parous rate, sporozoite rate and behaviour of infected and uninfected mosquitoes provided important information for assessing the role of vectors in the epidemiology of
malaria in the area. Such information should also assist in the development and implementation of local malaria control programs. Rwegoshora et al., (2007) suggested that the rate of disease in disease transmission was dependent on vector distribution, abundance and life span, degree of host-vector pathogen contact, susceptibility of the vector to the pathogen, and the effects of the pathogen on the survivorship of both the vector and the host. These factors were further dependent on local ecologic factors such as local climatic conditions, topography, water table, occurrence and diversity of larval habitats and human life styles.

Laporta et al., (2008) reported that, *Cx. quinquefasciatus* (Say) has been a cosmopolitan mosquito that was adapted to the urban environment. Adult females of *Cx. quinquefasciatus* were demonstrated to be a competent vector for St. Louis Encephalitis (SLE) in 1981 and West Nile Virus (WNV) in 2002.
1.3 MATERIALS AND METHODS

STUDY AREA

Rural

The study was conducted in and around Sholavandan, Vadipatti Taluk, Madurai district a typical rural environment with more agricultural complexity. The study area comprised of well diversified ecological locations, such as, population rich residential site, cultivated lands, non – cultivated lands. The adjoining area consists of more cultivated crops, stagnant water bodies, highly polluted sewage water bodies and other mosquitogenic conditions. The study area also comprised of various types of human settlement and varying number of cattles and other tetrapods that favour the mosquito population. The climate is alternately humid and dry in the year. Sholavandan has continuous water supply from two major water sources such as Vaigai river and Periyar-Vaigai canal in addition to the annual rainfall and artificial water sources. Five sites have been selected on the basis of the location of breeding habitats and the availability of vertebrate hosts for the mosquitoes. Most of the cultivated areas are dependent on the periodic river water, which is oscillating due to the rainy season. The most abundant species of cultivation are paddy (*Oryza sativa*), sugarcane (*Saccharum officinarum*), banana (*Musa paradisaica*), coconut (*Coccus nucifera*) and the other species of vegetables, fruits and flowers.

Urban

The study was conducted in Madurai, a typical urban ecological situation. The area is comprised of well diversified environment such as,
population rich residential site, non-cultivated lands and industries. The area consists of more stagnant water bodies and highly polluted sewage water bodies. Five sites have been selected on the basis of the location of breeding habitats and the availability of vertebrate hosts for the mosquitoes.

Pilot study

A pilot study was carried out for a period of three months from January to March 2010 to gather knowledge on the bionomics of mosquitoes in all the five villages rural viz., Sholavandan, Thachampathu, Nedunkulam, Thiruvedakam and Melakkal and urban viz., Duraisamy nagar, Ponmeni, Ram nagar, Vasantha nagar and Ellis nagar. The survey was carried out from 18.00 hrs to 22.00 hrs for the collections of adult mosquitoes. The collected mosquitoes were sorted out and identified at Centre for Research in Medical Entomology (CRME), one of the pioneer institutes under Indian Council of Medical Research (ICMR), Madurai. The pilot studies lead to continue the study on the bionomics of biting and resting mosquitoes.

Study period

The study was conducted both in rural and urban areas and samples were obtained from the five selected villages of rural and five sites of urban areas and its Geographical positions are given below in maps I & II viz.,

(i) Sholavandan (LAT: N 10°.01.362 & LONG: E 077° 57.823),
(ii) Thachampathu (LAT: N 10°.00.025 & LONG: E 077° 59.258),
(iii) Nedunkulam (LAT: N 10°.00.547 & LONG: E 077° 59.883),
(iv) Thiruvedakam (LAT: N 09°.59.637 & LONG: E 077° 59.364) and
(v) Melakkal (LAT: N 09°.58.785 & LONG: E 077° 59.061) and urban viz., (i) Duraisamy nagar (LAT: N 09°.54.969 & LONG: E 078° 05.405), (ii) Ponmeni (LAT: N 09°.55.301 & LONG: E 078° 05.411), (iii) Ram nagar (LAT: N 09°.55.043 & LONG: E 078° 05.818), (iv) Vasantha nagar (LAT: N 09°.54.354 & LONG: E 078° 05.769) and (v) Ellis nagar (LAT: N 09°.54.836 & LONG: E 078° 06.296). The study was undertaken in all selected study sites for a period of a year covering the four seasons viz., Southwest Monsoon (from June to August 2010), Northeast monsoon (from September to November 2010), Cold dry weather (from December 2010 to February 2011) and Hot weather (from March to May 2011) and two collections were made per month. During the study period, the meteorological data were obtained from Agricultural College, Madurai.

Collection of adult mosquitoes

Collections were done at the ground level by using human baits from the selected sites. The mosquitoes were collected in dim light during the dark phase of the day. The adult mosquitoes were obtained by three modes i.e. biting, resting, and emerging adults from pupae kept for emergence in order to get maximum number of mosquito species to understand the high degree of diversity and density.

Biting of adult female mosquitoes

A systematic adult female mosquito collection was made for twenty four hours. While one person was acting as bait, another person collected the
landing mosquitoes on bait. The mosquitoes landed for biting on the exposed legs were collected by adopting the methods of Pandian and Chandrashekar (1980). To minimize the damage of body parts and to collect the alive mosquitoes, a very thin and transparent (1x1 inch size) plastic vials with screw caps were kept hours-wise. The collected mosquitoes were killed by ether and preserved in the naphthalene-filled vials for further studies and identification.

**Resting adult mosquitoes**

Resting adult mosquito collections were made to study the diversity of anthropogenic and non-anthropogenic or zoophilic mosquitoes. Weekly visits were made to each village and adult mosquitoes were collected from domestic animal habitations at dawn and dusk hours. Majority of animal shelters were closed type and made-up of stone blocks with wooden slab roofs. Similarly, adult mosquitoes were collected from inside the houses including sitting rooms, bed rooms, store rooms, and kitchens with the help of mouth aspirators, aided by torch lights. Most of the human dwellings were permanent/pucca houses. Outdoor resting habitats consisted of field grasses, cotton fields and Parthenium plants. All adult specimens were anesthetized and identified.

**Identification of mosquito species**

All the wild-caught mosquitoes were identified up to species level with the assistance of Taxonomists of CRME, Madurai following the standard keys (Barraud, 1934, Christophers, 1933, Reinert, 1973, Reuben et al., 1994 and Sirivanakarn 1976). Immatures stages (larvae and pupae) of the mosquitoes
were collected and reared up to adult stages and also identified upto species level (Plate 1).

**Data analysis**

Mosquito sampling resulted in enormous number of individuals, which was used to assess the diversity index, relative abundance, density and the behavioural aspects including biting and resting.

**Biodiversity index**

Species diversity of mosquitoes was evaluated using species richness index ($\alpha$ diversity) (Southwood, 1978). The degree of biodiversity was estimated using the following formula

$$\alpha = 1 - \sum \left( \frac{x_1}{t} \right)^2 \left( \frac{x_2}{t} \right)^2 \left( \frac{x_3}{t} \right)^2 + \ldots \ldots \left( \frac{x_n}{t} \right)^2$$

Where $\alpha = \text{species richness index}$

$x = \text{Number of each species}$

$t = \text{Total number of mosquitoes of all species}$

**Density**

Types of species were identified based on the relative density. The density was usually provided as the mean number of individuals. The density pattern was analysed using the method of Rydzanicz and Lonc (2003) and the following formula was used
\[ I \]
\[ D = \frac{I}{L} \times 100 \]

Where  
\( D \)  =  Density  
\( I \)  =  Number of specimens of each mosquito species  
\( L \)  =  Number of all specimens

By employing this index, the collected individuals of mosquito species were categorized into three types of species based on the relative density of the species as given below:

a) Satellite species  
\( D = < 1\% \)

b) Sub-dominant species  
\( D = < 5\% \)

c) Dominant species  
\( D = \geq 5\% \)

**Distribution Pattern**

Knowledge on the distribution pattern of mosquitoes reveals the dimension of spatial distribution and the rate of existence in the selective study sites. Based on the density, the distribution pattern of the mosquitoes was grouped into five categories. This distribution pattern of mosquitoes was analysed by adopting the standard method Rydzonicz and Lonc (2003). The following formula was used to calculate the pattern.
\[ \frac{n}{N} \times 100 \]

Where

- \( C \) = Distribution pattern
- \( n \) = Number of sites positive for the occurrence of mosquitoes
- \( N \) = Total number of sites studied

If \( C \) (Distribution pattern) is:
- 0-20% sporadic,
- 20.1-40% infrequent,
- 40.1-60% moderate,
- 60.1-80% frequent and
- 80.1-100% constant.

**Seasonality**

Seasonality of mosquitoes worked out based on the study in four different seasons provides meaningful information on the temporal occurrence and the relative abundance. Analysis on the density-distribution relationship is used to understand the persistence of mosquitoes in different seasons. This study also gives a reasonable data on the correlation between the role of ambient factors and the existence of mosquitoes during various seasons. Fluctuation in the adult population depends upon the seasonal variation. Appropriate control measures are to be adopted in a particular environment.
Collection of blood engorged female mosquitoes and blood meal identification

An intensive collection of blood engorged female mosquitoes was done between 07.00 hours and 08.00 hours and 17.00 hours and 18.00 hours to identify the blood of their hosts and confirm their host preference behaviour in order to verify their changing pattern of feeding behaviour in an area during the specified period of study. The blood-fed mosquitoes were collected from the study area and identified to species level. The environment of the collected sites of the study area was almost similar with humans, cattles, dogs and common birds. Only fully blood-fed female mosquitoes or those with partially digested blood were processed. After identification of the species, the abdomens of the mosquitoes were squashed on a Whatman No.1 filter paper and a thin smear of blood was prepared. The agar gel diffusion technique was used to identify the feeding pattern or host preference behaviour exhibited by vector mosquitoes (Rao, 1984).

Anthropophilic Index (AI) or Zoophilic Index (ZI)

The anthropophilic or zoophilic indices were employed in this study to observe the host preference behaviour of mosquitoes in order to analyse the nature of the host (Rydzonicz and Lonc 2003). This has been calculated by the following formula:

\[
\text{AI (or) ZI} = \frac{\text{Number of blood-fed positive mosquitoes tested}}{\text{Total number of mosquitoes collected in one season}} \times 100
\]
The more the percentage of positive results for a host, greater will be the level of host seeking behaviour. These indices were used to measure the feeding pattern of mosquitoes in connection with the anthropophilic or zoophilic nature to confirm the preference of host selection behaviour.

**Behavioural expressions**

Adequate and appropriate information on the behaviour of mosquitoes provides the basis for the implementation of suitable mosquito management strategies. Feeding and breeding behaviours are the most important activities that promote the survival and proliferation of different mosquitoes. Based on those behaviours control or management programmes could be devised against the target species.

**Resting and Biting behaviour**

The resting behaviour of mosquitoes was studied through searching their breeding habitats located above the surface of the respective habitats. The biting pattern of mosquitoes was studied by using 24 hours study in the selected sites. To study the biting rhythm, a twenty four hour collection was made and the total number of biting mosquitoes in each hour was recorded. Then the mid-points values were calculated to observe the peak period of biting activity of mosquitoes and the results were tabulated. The temporal variation in the pattern and in between the species was also studied as per the standard procedure (Pandian and Chandrashekar 1980).
1.4 RESULTS

DIVERSITY OF MOSQUITOES

The diversity of mosquitoes i.e. twenty one species belonging to the genera namely *Aedes, Anopheles, Armigeres, Culex* and *Mansonia* observed during the entire study period in different seasons viz., Southwest monsoon (season I - from June to August 2010), Northeast monsoon (season II - from September to November 2010), Cold dry weather (season III - from December 2010 to February 2011) and Hot weather (season IV - from March to May 2011) is presented in (Table 1). The number of species was relatively more in the northeast monsoon than the other seasons, indicating the influence of seasonality in the occurrence of species in the study area. The diversity of species recorded from these collections was also found to be higher in northeast monsoon than the other seasons (Table 2). The diversity of mosquitoes was not apparent in all the seasons. *Culex* species occurred relatively more in number than other genera namely *Aedes, Anopheles, Armigeres* and *Mansonia*. Diversity was observed in *Aedes, Anopheles* and *Culex* in all the seasons. *Armigeres* and *Mansonia* were represented by only one species each (Fig. 1 and 2). However, the magnitude of diversity was not similar in all the seasons indicating narrow range in the species composition.

The existence of spatial variation in the species richness of mosquitoes was observed among the five selected study sites during the survey period after conducting the adult biting and resting collections including larval collections as shown in (Table 3 to 9). The species richness was more or less
similar in most of the selected sites and there was no apparent variation between the four seasons. Biodiversity index was calculated for all the study sites.

The biodiversity index ($\alpha$) was calculated for each season for the entire study period in rural and urban areas. The biodiversity index for the study area (rural and urban) during the study period was relatively high (0.8133 and 0.8260). The biodiversity indices for the southeast monsoon, northeast monsoon, cold dry weather and hot weather were 0.8139, 0.7978, 0.8209 and 0.8144 respectively in rural and 0.7853, 0.8474, 0.82460 and 0.8169 respectively in urban area this showed the similarity in the occurrence of the species in both area (Table 10 & 11).

Based on the relative occurrence of the twenty one species during the one year study period in rural and urban areas, these species were categorized into five types. Cx. quinquefasciatus exhibited constant species status by showing its occurrence throughout the year. Ae. aegypti exhibited frequent species status whereas moderate species status was shown by Ar. subalbatus. Infrequent species status was only seen in, An. subpictus. The sporadic species status was observed for the remaining seventeen species (Fig.3) and (Table 12 & 13).

**DENSITY OF MOSQUITOES**

The density of mosquitoes recorded by man landing collections in rural and urban areas during the study period i.e. southwest monsoon (from June to August 2010), northeast monsoon (from September to November 2010), cold
dry weather (from December 2010 to February 2011) and hot weather (from March to May 2011) is shown in (Table 14 to 17). The area wise density of mosquitoes both rural and urban is given in (Table 18 & 19). The density of mosquitoes was more in northeast monsoon than the other seasons indicating the existence of seasonal variation in the density of different species of mosquitoes in the study area. Among the twenty one species recorded in the area (rural), Cx. quinquefasciatus exhibited the highest density and this was followed by Cx. tritaeniorhynchus, Ar. subalbatus and Ae. aegypti. The other species showed a moderate or less density. Among the twenty one species recorded in the urban area, Cx. quinquefasciatus exhibited the highest density followed by Cx. gelidus, Ar. subalbatus, Ae. aegypti and Cx. infula, the remaining species showed a moderate or low density.

Further, the variation in the relative abundance of mosquito species during the four seasons was observed in rural and urban. The relative abundance of Aedes species was shown in (figure 4a - d & 5a - d). The density of Ae. aegypti was reasonably higher (1927) than other species. Ae. albopictus and Ae. vittatus occurred in low density whereas, Ae. lineotopennis, Ae. jamesi and Ae. vexans exhibited a very low density.

Among the anophelines, the density of An. subpictus was relatively higher (32) than other species. The density of An. culicifacies was moderate whereas An. barbirostris and An. stephensi were found low in number. Ar. subalbatus exhibited reasonable density (2300) in the study area and the
density was more in northeast monsoon than the other seasons. *Ma. uniformis* occurred in low density in all the seasons.

*Cx. quinquefasciatus* was the most abundant species in both rural and urban areas. *Cx. tritaeniorhynchus, Cx. infula, Cx. pseudovishnui* and *Cx. vishnui* exhibited moderate density. The density of remaining *Culex* spp. was low. The status of mosquitoes on the density as dominant, sub dominant and satellite species are shown in (Table 20 & 21). In rural area, out of twentyone mosquitoes recorded *Cx. quinquefasciatus, Cx. tritaeniorhynchus, Ar. subalbatus* and *Ae. aegypti* exhibited dominant status (19%). *Cx. infula* and *Cx. pseudovishnui*, exhibited sub-dominant status (10%) and the remaining fifteen species were considered as satellite species (71%) because of low density (Fig. 6). In urban area, out of twentyone mosquitoes recorded *Cx. quinquefasciatus, Cx.gelidus, Ar. subalbatus* and *Ae. aegypti* exhibited dominant status (19%). *Cx. infula* exhibited sub-dominant status (5%) and the remaining sixteen species were considered as satellite species (76%) because of low density (Fig. 7).

**SEASONAL INFLUENCE OF MOSQUITO DENSITY**

The meteorological data obtained from Agricultural College, Madurai during the study period is given in (Table 22) and the seasonal influence of mosquito density is depicted in (fig 8). Mosquito densities obtained in rural as well as urban areas are fluctuated in four different seasons. The density of the mosquitoes was recorded in rural areas are relatively higher than urban due to
the increasing in mosquito breeding sources with the increasing in rainy days. The percentage of mosquitoes obtained both in rural and urban areas in four different seasons is narrowly lesser in urban areas. During northeast monsoon (November – December) the percentage of mosquito density in rural (39.79%) and urban (38.97%) which was found to be the highest in both the areas compared to other seasons. Unusual occurrence of rain during summer seasons lead to drastic reduction in the density due to the washing of major breeding habitats like drains, canals, pools etc., both in rural and urban areas.

The mean maximum temperature was recorded during the study period ranged from 29.83 (December – February) to 35.97 (June – August). The relative humidity ranged from 67.9 (June – August) to 83.67 (December – February). Both temperature and relative humidity recorded during the study period were found to be the conducive factors for the survival of the mosquito population.

**DISTRIBUTION PATTERN OF MOSQUITOES**

The distribution patterns of the mosquitoes showed a variation, which was modulated by various ecological factors and anthropogenic factors, availability of hosts and the mosquitogenic conditions. Each species has exhibited its own pattern of distribution as indicated in (Table 23). Three types of distribution patterns were **uniform pattern**, **discontinuous pattern** and **restricted pattern**.
In rural area, the distribution patterns exhibited by *Ae. aegypti*, *Ae. albopictus*, *Ae. lineotopennis*, *Ae. vexans*, *Ae. vittatus* and *Ae. jamesi* were different from one another, indicating the interspecific and intrageneric variations. The *Ae. aegypti* showed uniform pattern of distribution because it was occurred in most of the study sites during the study period. *Ae. albopictus* and *Ae. vittatus* were distributed discontinuously by occurring in half of the study area. The other species of *Aedes* showed restricted pattern of distribution. Out of six species reported two species such as *Ae. albopictus* and *Ae. vittatus* exhibited discontinuous distribution (Fig. 9).

Among the anophelines, *An. subpictus* exhibited discontinuous pattern of distribution. *An. barbirostris*, *An. culicifacies*, *An. stephensi* and *An. vagus* showed restricted pattern of distribution (Figs 9). *Ar. subalbatus* showed uniform pattern of distribution, by occurring in selective sites where the suitable breeding habitats were available (Fig. 9). The distribution pattern of *Ma. uniformis* was a restricted one and the distribution was observed in the sites, where large stagnant water bodies with aquatic plants habitats were noticed (Fig. 9).

In *Culex* intrageneric variation was noticed in the distribution pattern of different species known as *Cx. infula*, *Cx. pseudovishnui*, *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus* exhibited uniform pattern of distribution. These species occurred in most of the study sites, which were associated with paddy cultivation and its fields with the availability of water enhances the larval
population. *Cx. vishnui* showed discontinuous distribution pattern. *Cx. bitaeniorhynchus*, *Cx. fuscocephalus* and *Cx. gelidus* showed restricted pattern of distribution. The adults of these species occurred only in low numbers compared with other *Culex*.

In urban situation, the distribution patterns exhibited by *Ae. aegypti* showed uniform pattern of distribution because it occurred in most of the study sites during the study period. *Ae. albopictus* and *Ae. vittatus* were distributed discontinuously by occurring in half of the study area. *Ae. lineotopennis*, *Ae. jamesi* and *Ae. vexans* showed restricted pattern of distribution (Fig. 10).

Among the anophelines, *An. subpictus*, *An. culicifacies* and *Anopheles stephensi* exhibited discontinuous pattern of distribution. *An. barbirostris*, and *An. vagus* showed restricted pattern of distribution (Fig. 10). *Ar. subalbatus* showed uniform pattern of distribution, by occurring in selective sites where the suitable breeding habitats were available (Fig. 10). The distribution pattern of *Ma. uniformis* was discontinuous one, where large stagnant water bodies with aquatic plants habitats were noticed such as ponds/pools.

In *Culex* an intrageneric variation was noticed in the distribution pattern of various species such as *Cx. infula*, *Cx. quinquefasciatus* and *Cx. gelidus* exhibited uniform pattern of distribution. These species occurred in most of the study sites, which were associated with agricultural practices and the fields with the availability of water that enhances the larval population. *Cx. bitaeniorhynchs*, *Cx. pseudovishnui*, and *Cx. vishnui* showed discontinuous
distribution pattern. *Cx. fuscocephalus* and *Cx.tritaeniorhynchus* showed restricted pattern of distribution. The adults of these species occurred only in low number in the study area (Fig 10).

**FEEDING AND BREEDING BEHAVIOUR OF MOSQUITOES**

Mosquitoes exhibit basically either zoophilic however adapted to anthropophilic feeding patterns. Depending upon the availability of single or multiple hosts, mosquitoes tend to change their feeding behaviour with reference to host selection pattern. In addition to human, mammalian hosts were available in adequate number in the study area (Plates 5). The analyses of blood meals of wild caught mosquitoes indicated that *Ae. aegypti* and *Ae. albopictus* exclusively preferred to feed on human indicating anthropophilic pattern. *Ar. subalbatus* exhibited a typical anthropophilic pattern. Eventhough *An. subpictus* and *Cx. quinquefasciatus* showed preference to human as well as animals, *An. subpictus* preferred to feed more on cattles than humans and *Cx. quinquefasciatus* showed predominantly anthropophilic pattern in domestic environment (Table 24 & 25). These feeding patterns were consistent because the patterns were more or less similar in both biting and resting collections during the study period in the selection sites of the study area.

Mosquitoes in the study area showed the temporal variation in their biting behaviour during the study period. Both rhythmic and arhythmic biting behaviour were recorded. Three types of rhythmic patterns such as diurnal, nocturnal and crepuscular were reported among the selected species. The
density of biting mosquitoes did not show much variation between the study area of rural and urban in all seasons. Minor variation was exhibited by *Ae. albopictus*, *Ae. vittatus*, *An. subpictus* and *Cx. vishnui*. The above four species showed higher degree of biting intensity in the northeast monsoon season than other seasons. The pattern of biting behaviour in the four seasons was shown in (Fig.11 to 32). The variation in the pattern was noticed in *Ae. aegypti*, *Ae. albopictus* and *An. subpictus*. However, the other species did not show variation in the biting pattern.

Arhythmic pattern was reported in *Ae. albopictus* (Fig.11 & 23). The crepuscular biting behaviour was exhibited by *Ar. subalbatus*, which showed two prominent peaks (dawn and dusk peaks) of biting activity (Fig.15 & 26). *Ae. aegypti* and *Ae. vittatus* exhibited typical diurnal biting behaviour (Fig.11&13 and 22 & 24). *An. subpictus*, *Cx. infula*, *Cx. pseudovishnui*, *Cx. vishnui*, *Cx. tritaeniorhynchus*, *Cx. quinquefasciatus* and *Ma. uniformis* exhibited nocturnal biting pattern (Fig.14 to 21 and 26 to 32). Though many species exhibited nocturnal activity, the peak of biting activity was observed at different time in the diurnal or nocturnal pattern.

The selected area had a wide variety of breeding habitats. These habitats were available on the ground and above the ground and this showed the presence of a high degree of mosquitogenic conditions, which were favourable to the mosquitoes to breed successfully at all time. The number of larvae collected from this selected study area showed a seasonal variation, indicating
the availability of suitable breeding ground. Some of the selected sites had perennial sources of water throughout the year indicating the occurrence of certain species at all seasons (Plates 2 to 5).

The chosen habitats of various mosquitoes were sewage water, paddy field and well categorized under earthen breeding habitats in the ground level (Plates 6 to 9) whereas cement tank, stone grinder, earthen pot, plastic bucket and plastic cup categorized under above the ground breeding habitats (Plate 8). Habitat selection behaviour of the mosquitoes was observed in the study area.

*Ae. aegypti*, *Ae. albopictus* and *Ae. vittatus* predominantly preferred to breed in containers. Stagnant pools were the preferred sites of *An. subpictus*. The larvae of *Ar. subalbatus*, *Cx. pseudovishnui* and *Cx. quinquefasciatus* were predominantly found more in sewage water than other habitats. *Cx. tritaeniorhynchus* was mainly noticed in paddy fields.

Among these two categories of breeding habitats reported in the study area, sewage water was the most predominant habitat that was preferred by *Armigeres, Culex* species than others. Among the container habitats, many of the containers such as coconut shell, plastic cup, tire etc., are preferred by *Aedes* species.
1.5 DISCUSSION

Mosquitoes are considered as serious nuisance pests and vectors of many dreadful diseases both in the urban and rural areas. The problem is more severe in the rural areas especially those are associated with a well irrigated agro ecosystem. In these areas, poor sanitation, several agricultural practices and lack of control measures enhance the diversity and density of the populations of mosquitoes and facilitate vector-borne diseases. In the present study, adult mosquitoes were collected by various sampling methods namely biting, resting and larval collections for a period 12 months and a total of 21,502 (rural) and 13030 (urban) mosquitoes belonging to five genera and 21 species were collected. The diversity of mosquitoes (21 species) was found to be higher in north-east monsoon season in both rural and urban. The reason for the maximum diversity was due to the occurrence of more larval habitats perturbations with regard to rice-cultivation. For successful implementation of vector management programme, adequate knowledge about the species composition, density and feeding behaviour is the most requirements as highlighted in various studies (Pandian et al., 1997, Thenmozhi et al., 2007, Devi and Jauhari, 2004 and Tubaki et al., 2004).

Muturi et al., (2006) also highlighted similar observation in Mwea, Kenya where the diversity was more during the cultivation season. In the present observation, the comparative study on the diversity of both the adult and larval population inferred that the northeast monsoon season facilitated the intergeneric and intrageneric diversity than the other three seasons. The main
reason for the predominant occurrence of more species was the availability of lentic and lotic water bodies, rain fall and the high percentage of land use for rice land agro ecosystem. The similar result was observed in the study undertaken in Kenya where the rainfall enhanced the diversity of mosquitoes and its larval form (Hutchings et al., 2005). The present study has showed that the diversity indices used to monitor changes in the diversity of organisms. These studies also used to monitor vector mosquito species at different sites in relation to type of habitat and land use. Databases were generated throughout the monitoring period to understand the effects of environmental changes on mosquito population.

A total of 21 species comprised 5 different genera recorded both in rural and urban study sites. Among 5 different genera, Aedes consists of 6 different species, Anopheles 5, Armigeres only one, Culex 8 and Mansonia only one species.

Out of 21 species most of them were collected both in resting as well as immature collections however very few species were obtained through adults collections both in rural and urban. Those species which are collected by adults alone include Ae. lineotopennis, Ae. vexans, Ae. jamesi, An. culicifacies, An. vagus, Cx. bitaeniorhynchus, Cx. gelidus, Cx. infula and Ma. annulifera. Similar records were reported from other studies carried out in different places (Pandian et al., 1997 and Thenmozhi et al., 2007).
Out of 6 *Aedes* species 3 species were obtained in both adult and immature collections. *Ae. aegypti*, *Ae. albopictus* and *Ae. vittatus* however, the other remaining species were obtained through adult collections. *Ae. lineotopennis* were obtained throughout the year except southwest monsoon. *Ae. jamesi* were obtained throughout the year except hot weather.

*Aedes* breeding habitats are well documented in tree holes, leaf axils, tree stems, rock holes etc., as natural habitats however, during sampling of various habitats, those 3 species were not obtained. This might be due to the contributions of adults from the inaccessible habitats which are located both in rural and urban environment.

Though the various habitats like cess pool, rain water pool, mud pool, tree hole etc., were available both in rural and urban, most of the habitats contributed mosquitoes throughout the year but very few species were contributed by certain seasons only. This is due to quantum of the availability of mosquito breeding habitats versus the density of mosquitoes obtained in different periods. Out of 6 different species of *Aedes* population *Ae. aegypti*, *Ae. albopictus* and *Ae. vittatus* were obtained in the entire year both in adult and immature collections.

Out of the total *Aedes* genera mosquitoes obtained both in rural and urban. 47.3% include urban whereas 52.7% from rural. Though *Aedes* mosquitoes were obtained from both the areas a narrow margin of difference 7% was recorded between urban and rural. *Ae. aegypti* was recorded 76.68%
whereas the remaining 5 different Aedes species consist of only 23.32%. The high percentage of Ae. aegypti obtained from all the study sites both in rural and urban showed that the contribution of various Aedes breeding habitats of water storage cement tank, cisterns, rain water holding habitats of grinding stone, refuse materials of bottles, tins and tyres etc, thereby chances for the outbreak of dengue/chikungunya is more vulnerable. Some of the pockets of the present study sites have already reported dengu e cases also. People must initiate precautionary measures to reduce the dengue vector Ae. aegypti by involving themselves through source reduction methods.

Ae. aegypti obtained in the urban areas stands as frequent (65.62%) occurrence pattern whereas all the remaining Aedes were under the pattern of sporadic with various percentages. The similar trend was also recorded in rural sites with frequent of Ae. aegypti (53.02%).

Three different species of Ae. aegypti, Ae. albopictus and Ae. vittatus were obtained through biting collections both in rural and urban areas. A total of 1927 Ae. aegypti were obtained in four different seasons from Sholavandan. The peak of biting activity showed slowly raising from (dawn) 18.00 hrs to 24.00 hrs and another peak raised from 2.00 hrs to 6.00 hrs (dusk). So the two clear distinct biting periodicities have indicated that Ae.aegypti is a diurnal mosquito and the biting activities of Ae.aegypti are very few or nil during night hours. A total of 73 Ae. albopictus and Ae. vittatus 22 were obtained through
biting collections carried out at Sholavandan. The peak of biting activity is similar to *Ae. aegypti*.

A total of *Ae. aegypti* (1108), *Ae. albopictus* (36) and *Ae. vittatus* (23) were obtained in four different seasons of biting collections carried out at Duraisamy nagar. The similar trend was noticed for the above stated all 3 different species and they were obtained through biting collections in urban areas.

The dominant *Ae.aegypti* mosquito is the important vectors for dengue and chikungunya. *Ae. albopictus* was the secondary vector of dengue in many places however this species act as primary vector for dengue in Kerala (Thenmozhi *et al.*, 2007). Chikungunya virus has maintained in ‘sylvatic cycle’ involving wild primates and forest dwelling *Aedes* mosquitoes (Mourya and Misra 2006).

Out of 5 *Anopheles* species 3 were obtained both adult and immature collections i.e., *An. barbirostris*, *An. stephensi* and *An.subpictus*. However, the other remaining species were obtained only through adult collections. *An.culicifacies* and *An. vagus* adults were collected throughout the year. *Anopheles* breeding habitats are well documented in mud pool, paddy field, pond etc., as natural habitats; however, during sampling of various habitats in the present study, *An.culicifacies* and *An. vagus* were not obtained.
Out of 5 different species of *Anopheles* population *An. barbirostris*, *An. stephensi* and *An. subpictus* were obtained throughout the year both in adult and immature collections. Out of the total *Anopheles* genera mosquitoes obtained from rural and urban areas, 50.88% include urban whereas 49.12% from rural. This showed that *Anopheles* mosquitoes were obtained from both the areas with a narrow margin difference of 2%. However, *An. subpictus* were recorded 60.81% whereas the remaining 4 different *Anopheles* species consist of 39.19% only. The presence of vector mosquitoes in both the areas has confirmed that the malaria incidence will be reported at different times. The main reason is migration/movement of people from these locations to malaria endemic regions for their professional/business purposes.

*An. subpictus* obtained in the urban areas stands as infrequent (33.12%) occurrence pattern whereas all the remaining *Anopheles* species in the pattern of sporadic with different percentages. The similar pattern was recorded with infrequent of *An. subpictus* (22.17%) in rural study sites.

*An. subpictus* was obtained through biting collections both in rural and urban areas. A total of 32 *An. subpictus* were obtained in four different seasons through biting collections carried out at Sholavandan. The peak of biting activity showed during night hours. The similar biting pattern was recorded in urban area also.

Out of 8 *Culex* species 4 species (*Culex quinquefasciatus*, *Culex tritaeniorhyncus*, *Culex vishnui* and *Culex pseudovishnui*) were obtained both
adult and immature collections. However, *Cx. bitaeniorhynchus*, *Cx. gelidus*, *Cx. infula* and *
Cx. fuscocephala* were the other remaining species obtained only through adult collections. *Cx. bitaeniorhynchus* and *Cx. infula* adults were obtained throughout the year, however *Cx. bitaeniorhynchus* was not found in south-west monsoon and *Cx. infula* was not found in cold dry weather. *Culex* breeding habitats are well documented as paddy field, irrigation channel, drains, canal, pits, pools etc. During sampling of various habitats in the present study those 4 species were not obtained from immature collections. This is due to the contributions of adults from various habitats, which are not sampled both in rural and urban.

Most of the habitats contributed mosquitoes perennial but very few species are contributed in certain seasons only. This might be due to quantum of the availability of mosquito breeding habitats versus the density of mosquitoes obtained in different season. Out of 8 different species of *culex* population *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, *Cx. vishnui* and *Cx. pseudovishnui* were obtained throughout the year both in adult and immature collections.

Out of the total *Culex* genera mosquitoes obtained in the study sites, 39.69% was from urban and 60.31% rural. This showed that *Culex* mosquitoes obtained from both the areas with the difference of 20%. However, *Cx. quinquefasciatus* is a ubiquitous mosquito found 77.43% of places whereas the remaining 7 different *Culex* species consist of 22.57% only. The high
percentage of *Cx. quinquefasciatus* obtained from all the study sites showed that the colossal loss of blood by the community is very high. In order to control *Cx. quinquefasciatus* breeding drains and canals need to be taken care of by the public health departments of the corporation and various other local departments to avoid breeding through various physical, chemical, biological and environmental methods.

*Cx. quinquefasciatus* obtained in the rural and urban areas stands as constant (100%) occurrence pattern whereas all the remaining *Culex* were under the pattern of sporadic with various percentages.

Five different species of *Cx. infula*, *Cx. pseudovishnui*, *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus* and *Cx. vishnui* were obtained through biting collections in rural areas. A total of 872 *Cx. infula* were obtained in four different seasons of biting collections carried out at Sholavandan. The peak of biting activity showed slowly raising from (dusk) 18.00 hrs to 24.00 hrs and another peak raising from 24.00 hrs to 2.00 hrs. So the two clear distinct biting periodicity indicated that *Cx. infula* is a nocturnal mosquito and the biting activity of *Cx. infula* is nil during day hours. Similar observations were recorded by Pandian *et al.*, 1997.

A total of 570 *Cx. pseudovishnui* were obtained in Sholavandan. The peak of biting activity showed slowly raising from (dusk) 18.00 hours to 22.00 hours and another peak raising from 24.00 hrs to 3.00 hrs. So the two clear distinct biting periodicity indicated that *Cx. pseudovishnui* is a nocturnal
mosquito. A total of 11248 *Cx. quinquefasciatus* were obtained in four different seasons of biting collections carried out at Sholavandan. The peak of biting activity showed slowly raising from (dusk) 18.00 hrs to 22.00 hrs and another peak raising from 23.00 hrs to 2.00 hrs. So two clear distinct biting periodicity indicated that *Cx. quinquefasciatus* is a nocturnal mosquito.

A total of 4275 *Cx. tritaeniorhynchus* were obtained in four different seasons of biting collections carried out at Sholavandan. The peak of biting activity showed slowly raising from (dusk) 20.00 hrs to 23.00 hrs and another peak raising from 24.00 hrs to 3.00 hrs. So two clear distinct biting periodicity indicated that *Cx. tritaeniorhynchus* is a nocturnal mosquito. A total of 85 *Cx. vishnui* were obtained in four different seasons of biting collections carried out at Sholavandan. The peak of biting activity showed slowly raising from (dusk) 20.00 hours to 23.00 hours and another peak raising from 24.00 hours to 3.00 hours. So two clear distinct biting periodicity indicated that *Cx. vishnui* is a nocturnal mosquito.

Five different species of *Cx. infula*, *Cx. pseudovishnui*, *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus* and *Cx. vishnui* were obtained through biting collections in urban areas. A total of *Cx. infula* 818, *Cx. pseudovishnui* 43, *Cx. quinquefasciatus* 6422, *Cx. tritaeniorhynchus* 2648 and *Cx. vishnui* 89 were obtained in four different seasons of biting collections carried out at Duraisamy nagar. All *Culex* species obtained from urban study sites were nocturnal and the 2 peaks of biting were noticed in all mosquitoes. JE vector
mosquitoes of *Cx. infula, Cx. pseudovishnui, Cx. quinquefasciatus, Cx. tritaeniorhynchus* and *Cx. vishnui* during early midnight biting collection periods was observed and second peak recorded before dawn hours.

*Ar. subalbatus* were obtained through both adult and immature collections. *Ar. subalbatus* breeding habitats are well documented from septic tank, ditches, manure pits etc., as habitats available both in rural and urban. Most of the habitats contributed for the perennial presence of mosquitoes in all seasons. *Ar. subalbatus* mosquitoes obtained from the study sites, 46.28% include urban whereas 53.72% from rural. This showed that *Ar. subalbatus* mosquitoes obtained from both the areas with a marginal difference of 7%.

*Ar. subalbatus* was obtained in moderate pattern both in rural (43.91%) and urban (54.38%) areas. *Ar. subalbatus* was obtained through biting collections both in rural (2300) and urban (1769) areas. The peak of biting activity showed between 10.00 - 11.00 hours and 5.00 – 6.00 hours. So the biting periodicity has indicated that *Ar. subalbatus* is a crepuscular biting activity.

*Ma. annulifera* were obtained throughout the year through immature collections except hot weather seasons. *Ma. annulifera* obtained in 53.33% rural and 46.67% from urban. This showed that *Ma. annulifera* mosquito obtained from both the areas with a marginal difference of 6%. *Ma. annulifera* obtained in the urban areas stands as sporadic (4.37%) pattern occurrence. The similar trend was also recorded in rural areas with sporadic pattern (3.47%).
A total of 20 *Ma. annulifera* was obtained through biting collections in rural and a total of 32 in urban areas carried out at Sholavandan. The peak of biting activity showed slowly raising from (dusk) 19.00 hrs to 23.00 hrs only in rural and 19.00 hrs to 24.00 hrs only in urban. So the biting periodicity indicated that *Ma. annulifera* is a nocturnal mosquito.

Species diversity and diversity of habitats are important contributing factors towards maintenance of ecological patterns of mankind. Though rapid environmental degradation results in the loss of unique habitats, manmade habitats also contribute to the growth of various species of mosquitoes. Five different genera of mosquitoes predominantly existing in the study sites of both in rural and urban clearly indicated that role of diversified feeding, resting and breeding behaviours are entirely unique. Coexistence of these mosquitoes in both the environment in various patterns is as follows. *Cx. quinquefasciatus* is a bancroftian filariasis that stands as a constant pattern in both the areas. *Ae. aegypti* is a dengue vector that includes frequent pattern. *Ar. subalbatus* is a nuisance mosquito which stands as moderate pattern. *An. subpictus* a malaria vector includes infrequent pattern. Most of the species exhibit sporadic pattern.

Vectors of dengue/chikungunya *Ae. aegypti, Ae. albopictus* of diurnal mosquitoes presented two clear biting peaks in both the areas. These observations have clearly shown a potential threat for epidemic of dengue/chikungunya and more vulnerable for outbreak during monsoon period.
JE vectors recorded in both the areas are more prevalent in the rainy months. This is a unique feature in every part of the world. Nuisance mosquito called Ar. subalbatus has shown crepuscular biting activity traced throughout the year.

Since the study as a whole, has reported the presence of vectors of lymphatic filariasis, malaria, JE and dengue/chikungunya it will help to adapt suitable and possible strategies to control those vector mosquitoes in order to reduce the diseases.
1.6 SUMMARY

In general, various kinds of mosquitoes cause the most dreadful diseases of human beings known as malaria, lymphatic filariasis, dengue, chikungunya and Japanese encephalitis and also harmful to domesticated animals. As the biological vectors, they transmit the pathogens from the infected person to healthy person and enhance the occurrence of vector-borne diseases. The mosquito-borne diseases are very common among people everywhere due to lack of awareness about the sanitation of their environment and creation of new breeding grounds regularly for the proliferation of mosquitogenic conditions. In order to reduce the problem of mosquitoes in a given area, it is essential to understand the diversity, density, distribution pattern and the behavioural expressions of the mosquitoes available in that particular area. In addition, to implement a proper management strategy, it is also necessary to have a better understanding of the above aspects of the mosquitoes. Under this context, the present investigation has been undertaken to study the mosquito fauna with reference to diversity, density, distribution pattern and behavioural expressions both in rural and urban areas of Madurai district, Tamil Nadu, India. This area is well known for the cultivation of rice and has many agro ecosystems, which are irrigated by the storage water from dams and wells. The study was undertaken for a period of one year from June 2010 to May 2011 in a systematic pattern.
DIVERSITY OF MOSQUITOES

The diversity of mosquitoes in the selected area in both rural and urban was reasonably high and twenty one species belonging to five genera viz. Aedes, Anopheles, Armigeres, Culex and Mansonia were recorded from five selected sites during the study period. The biodiversity index for the study area (rural and urban) was relatively high (0.8133 and 0.8260). The biodiversity indices for the southeast monsoon, northeast monsoon, cold dry weather and hot weather were 0.8139, 0.7978, 0.8209 and 0.8144 respectively in rural and 0.7853, 0.8474, 0.8246 and 0.8169 respectively in urban area which showed in the occurrence of the species not much varied in all the study areas. The variations in the biodiversity indices in many of the collection sites were higher during wet season than the dry.

Five different species were recorded, which were based on the percentage of relative occurrence. The number of constant species, frequent species, moderate species, infrequent species and sporadic species were 1, 1, 1, 1 and 17 respectively in both rural and urban areas. Interspecific variation was also noticed invariably in those selected rural and urban area. Cx. quinquefasciatus exhibited constant occurrence, Ae. aegypti exhibited frequent occurrence. The moderate occurrence was found in Ar.subalbatus. The pattern of mosquito diversity recorded in those typically rural areas, where agricultural practices were associated continuously.
DENSITY OF MOSQUITOES

The density of mosquitoes showed a seasonal variation i.e. the density of many of the mosquito species was high during the wet season whereas the density was moderate during dry season. Among the twenty one species recorded in rural area *Cx. quinquefasciatus* exhibited the highest density and this was followed by *Cx. tritaeniorhynchus*, *Ar. subalbatus* and *Ae. aegypti*, other species showed a moderate or less density. Among the twenty one species recorded in urban area *Cx. quinquefasciatus* exhibited the highest density followed by *Cx. gelidus*, *Ar. subalbatus*, *Ae. aegypti* and *Cx. infula*. All other species showed a moderate or less density. The rainfall and the irrigation of the agroecosystem were considered as the main factors that promote the density. However *Ae. aegypti*, *An. subpictus* and *Ma. uniformis* were dominant during summer because of the presence of their breeding habitat i.e. the availability of stagnant water either in the small pond or in the natural and artificial containers. The density of these mosquitoes was predominantly coinciding with regular like paddy cultivation the agricultural practices therefore the rural identity was again confirmed. The number of dominant, subdominant and satellite species was four, two and fifteen respectively in rural and four, one and sixteen respectively in urban area. Further, spatial variation was also been recorded with reference to larval and adult mosquitoes among the five selected sites in the four different seasons.
SEASONAL INFLUENCE OF MOSQUITO DENSITY

The density of the mosquitoes recorded in rural areas is relatively higher than urban areas due to the increase in mosquito breeding sources during the rainy days. The percentage of mosquitoes obtained both in rural and urban areas in four different seasons narrowly is lesser in urban areas. During northeast monsoon (November – December) the percentage of mosquito density in rural (39.79%) and urban (38.97%) was found to be the highest in both the areas compared to other seasons.

DISTRIBUTION PATTERN OF MOSQUITO

Studies on the distribution pattern of mosquitoes are more useful for a better understanding of the availability of mosquitoes in various locations and their diversity in the study area. Different mosquito species exhibited various patterns of distribution. Three types of distribution patterns were noticed, i.e. uniform, discontinuous and restricted. In rural area, *Ae. aegypti*, *Ar. subalbatus*, *Cx. infula*, *Cx. quinquefasciatus*, *Cx. pseudovishnui* and *Cx. tritaeniorhynchus* showed uniform distribution pattern. The other species such as *Ae. albopictus*, *Ae. vittatus*, *An. subpictus* and *Cx. vishnui* showed discontinuous distribution. Restricted pattern of distribution was observed in *Ae. lineotopennis*, *Ae. vexans*, *Ae. Jamesi*, *An. culicifacies*, *An. barbirostris*, *An. Stephensi*, *An. vagus*, *Cx. bitaeniorhynchus*, *Cx. fuscocephalus* and *Cx. gelidus*. In urban area, *Ae. aegypti*, *Ar. subalbatus*, *Cx. infula*, *Cx. quinquefasciatus*, and *Cx. gelidus* showed uniform distribution pattern. The other species such as *Ae. albopictus*, *Ae. vittatus*, *An. subpictus*, *An. culicifacies*, *An. stephensi*, *Cx. bitaeniorhynchus*, *Cx. vishnui* and *An. Stephensi* showed discontinuous distribution.
*Cx. pseudovishnui, Cx. vishnui* and *Ma. annulifera* showed discontinuous distribution. Restricted pattern of distribution was observed in *Ae. lineotopennis, Ae. vexans, Ae. jamesi, An. barbirostris, An. vagus, Cx. tritaeniorhynchus* and *Cx. fuscocephalus*. Availability of adequate breeding grounds and appropriate hosts were the probable reasons for the existence of variation in various collection sites in the study areas of both rural and urban.

**BEHAVIOURAL EXPRESSIONS**

The proliferation of the mosquitoes was dependent mainly on the behavioural expressions of the mosquitoes. The host selection behaviour, temporal pattern of feeding behaviour and preferential habitat selection of the mosquitoes were quite different in various places. Each area had its unique pattern, which could be modulated by the ambient conditions i.e. both biotic and abiotic factors.

Study on the feeding behaviour of mosquito provides more information on the nature of the hosts mostly preferred and on the diversification in the host selection behaviour. Most of the species exhibited anthropophilic pattern in rural and urban area because all the twenty one species were recorded in the man-landing collection only. *Ae. aegypti, Ae. albopictus, Ae. vittatus, Ae. lineotopennis* and *Ar. subalbatus*, many of species of *Culex* and *Ma. uniformis* showed a preference to human host. *An. subpictus* mainly preferred to feed on buffalo and cow rather than human whereas *Cx. quinquefasciatus* fed predominantly on the human host but also on the other vertebrate hosts too.
Both the rhythmic and arhythmic patterns of biting behaviour were recorded among the collected species in both the rural and urban areas. Temporal variation in the biting behaviour was observed among the different species of mosquitoes. The mosquitoes showed either crepuscular pattern or diurnal or nocturnal pattern in their blood feeding behaviour. *Ae. aegypti* and *Ae. vittatus* exhibited diurnal pattern of biting behaviour but *Ae. albopictus* exhibited arhythmic pattern. Biting behaviour of *Ar. subalbatus* was seen exclusively during the dusk and dawn periods, indicating the crepuscular biting pattern. Most of the *Culex* mosquitoes showed nocturnal biting behaviour. *Cx. quinquefasciatus* and *Cx. vishnui* showed midnight peak and on the other hand *Cx. infula, Cx. pseudovshnui, Cx. tritaeniorhynchus* and *Ma. uniformis* exhibited a typical biting activity peak before the midnight hours. Rhythmic pattern of biting pattern was observed in many of the species. However, *Ae. albopictus* showed arrhythmic biting pattern by feeding both during the light and dark phase of the day.

The breeding behaviour had a paramount influence on the successful existence and co-existence of mosquitoes in the rural and urban areas. Analysis of larval breeding grounds in the study area was considered as the key factor to measure the mosquitogenic conditions. Existence of perennial water bodies, temporary or stagnant, shallow or artificial sources attracted the mosquitoes to select the breeding grounds. Different larval habitats of the study area were the cement tank, grinding stone, unused utensils, plastic cups etc. These container habitats favoured predominantly the breeding of *Ae. aegypti, Ae. vittatus* and
Ae. albopictus, Cx. quinquefasciatus and Cx. pseudovishnui showed a preference to breed in perennial in various types of stagnant water bodies. Clean water bodies on the shallow regions and polluted sewage water were the favourable breeding medium for An. subpictus and Ar. subalbatus respectively.

Ongoing agricultural practices in the study area favoured the formation of suitable breeding habitats for Cx. pseudovishnui, Cx. tritaeniorhynchus and Cx. vishnui. Cultivation methods including the short-term yielding cultivation and multicropping pattern enhanced the formation of more larval habitats and the availability of different mosquito species. Existence of storage water practices by people during dry season accelerated the density of larval forms of Aedes spp. It was an interesting point to note that the larvae of Ae. aegypti were recorded in the stagnant water, in various containers and well. The breeding of Ar. subalbatus, Cx. pseudovishnui, Cx. quinquefasciatus and Cx. tritaeniorhynchus was more in wet season. Seasonality in the breeding behaviour of the mosquito was observed very distinctly.

The various findings from this study showed that the rich diversity of species, reasonable density of mosquitoes and distribution pattern the mosquitoes were similar to that of the typical rural and urban fauna. Temporal variation in the biting behaviour of the mosquitoes was observed, which was an adaptive feature for these mosquitoes to share the hosts either in the diurnal or nocturnal cycle and the host selection behaviour of mosquitoes was flexible by feeding either animal or human. The agricultural practices and anthropogenic
factors promoted the proliferation and successful breeding of the mosquitoes by providing suitable and adequate breeding habitats in study area. Based on these findings, suitable strategy could be evolved and executed to manage the mosquito problem in the agro-ecosystem based rural and unmanaged urban areas.