Chapter 4

Discussion

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DISCUSSION

During the present research work on the Profile of Mosquitoes prevalent in the districts of Thiruvananthapuram and Kottayam of Kerala State, several observations were made on the distribution, sex, species composition, resting and host landing habits exhibited. The density status and diversity indices of mosquitoes were determined for three terrain land areas and urban-rural settings. Moreover the population status of major disease vectors was assessed on a longitudinal basis for five years covering twelve months. Climatic factors of the study area were analysed and correlated with various diversity indices. The profile of major vector mosquitoes prevalent in the districts was also elicited to bring out a complete understanding of the mosquito fauna.

It was for the first time that a longitudinal study designed for a multi-stage random sampling method and carried out for five years could reveal information on nearly three dozens of species of mosquitoes by covering areas of urban and rural wards from low, mid and high land terrains in the two districts of Kerala State. Several previous studies on mosquitoes had focused only on the taluk or city area or certain wards or localities of Thiruvananthapuram district in connection with investigation of outbreaks or epidemics of diseases. Many of these studies had reported about several species of mosquitoes belonging to *Anopheles, Aedes, Culex, Armigeres, Mimomyia, Ficalbia* and *Toxorhynchites* (Iyengar 1938, Menon 1944, Menon and Thampi 1959, Ayyachami Daniel et al 1986, Rajendran and Prasad 1992 & 1994 and Rajendran 1996). The number of species reported by earlier researchers included mainly from either Thiruvananthapuram Taluk (twenty two species by Iyengar in 1938 and twenty three species by Menon M.A.U during 1944-1962) or from Thiruvananthapuram city (twelve species by Ayyachami Daniel et al during 1986 and eleven
species by Rajendran and Prasad during 1985-1994 and nine more species by Rajendran during 1996). Many of these reports were overlapping of once-reported species and some were new additions. Over the six decades time since 1938, the earlier researchers have reported about ten species from *Anopheles*, four from *Aedes*, ten from *Culex*, one each from *Armigeres*, *Malaya* and *Toxorhynchites*, three from *Mimomyia* and two species from *Mansonia* genera. Thereafter reports came again from Thiruvananthapuram city based on observations between 1999 and 2002 (Dilipkumar 2006) which mentioned about several other species from the above said genera. These included *A. peditaeniatus*, *C. pluvialis*, *Coquillettidia crassipes*, *Ficalbia minima* and a species of *Uranotaenia* as new addition to the mosquito species from the city area of Thiruvananthapuram. Similar studies were lacking in the district of Kottayam. In this background, the species composition and distribution of mosquitoes of Thiruvananthapuram and Kottayam districts, as revealed by the present study is discussed.

4.1 **Species Composition and Distribution of Mosquitoes**

The present research work has brought to light the prevalence of thirty three species of mosquitoes from Thiruvananthapuram and twenty six species from Kottayam districts. The species configuration of the study area appeared to be very peculiar that all the thirty three species of mosquitoes belonged to one or other of eight genera namely *Aedes*, *Anopheles*, *Armigeres*, *Coquillettidia*, *Culex*, *Mansonia*, *Mimomyia* and *Toxorhynchites*.

Of the thirty three mosquito species recognized from the present study area, *Ae aegypti* was the species which appeared in the early report of Linnaeus (1762) from Egypt, which was subsequently reported by Poiret (1787) from Barbary, Fabricius (1805) from West Indies, Meigen (1818) from Portugal, Theobald (1901) form Demerara of South America and South Queensland of Australia and by Edwards (1920) from Accra of West Africa. *An roperi*
found from the study area was the mosquito species that appeared in the latest literature (Reid 1950) which was reported to occur in the locality of Kuala Kubu, Selangor, Malaysia. From these mentioned very early reports it was understood how antique are these referred mosquito species.

For the all the thirty three mosquito species found out from the present study area, the first reported year (Table-5) shown against each species name gave the evidence of the original appearance in the localities. In the present study, out of the thirty three mosquito species identified, only An roperi (Reid 1950) was the pretty new species reported. All the remaining thirty two species belonged to those reported records of eighteenth to twentieth century from the various countries of the world (Linnaeus 1762; Wiedemann 1819, 1820 &1828; Meigen 1830; Bigot 1861; Van der Wulp 1884 & 1892; Skuse 1894; Coquillett 1898; Grassi 1899; Giles 1900, 1901, 1902 & 1904; Liston 1901; Theobald 1901 & 1907; Donitz 1902; Leicester 1908; Iyengar 1924; Edwards 1930 and Reid 1950). Hence it is also assumed that for thousands of years these reported mosquito species had been surviving through their generations (LeFroy 1909).

Several researchers had given the descriptions on the geographical distribution and taxonomy of many mosquito species including from the Indian Subcontinent (James 1900 & 1910, Theobald 1901, Edwards 1930, Christophers 1933, Barraud 1934, Ramachandra Rao 1964 & 1984, Knight & Stone 1977 and Nagpal & Sharma 1995). Many of the mosquitoes now known to the world are found distributed in far and wide places by different means (Reiter & Darsie 1984 and Reiter & Sprenger 1987). Mosquito species of An aconitus, An gigas, An roperi, An turkhudi, Cx fuscocephalus, Cx whitmorei, Cx pseudovishnui and Cx univittatus which were recognized as new from the present study area were also found in the localities of several States of India (James 1900, Roy & Brown 1970, Reuben et al 1972 and Nagpal & Sharma 1995) and many localities of other countries (Knight & Stone 1977).
Anopheles fauna of India and its relationship with those of neighbouring countries had been investigated by Christophers (1933) based on the geographical distribution of Oriental species from east to west of the country. Ramachandra Rao (1984) had given an account of anopheline distribution based on three main categories of regions the species found. Almost all the mosquito species reported in the present study has been noticed in various localities of India. The eleven anopheline species found in the present study could be recognized in the three categories of classification given by Christophers. Thus, *An culicifacies*, *An (hy) nigerrimus* and *An subpictus* were found to have wide occurrence in India with extension of distribution to both the west and east. *An stephensi* and *An turkhudi* were found widely distributed in India, but mainly to the west. *An vagus* was found widely distributed, but extending towards east. *An varuna* was reported to widely, and prominently or exclusively as Indian species. The *An gigas* was reported as localized species. These eight anopheline species seemed to have the main range of distribution in India. *An aconitus*, *An barbirostris* and *An roperi* were reported to be South-east Asian elements occurring in India.

The state-wise distribution of these reported anophelines of the present study was understood from the observations of Wattal et al (1960) who had examined the anopheline collections at the Malaria Institute of India (MII), to study variations or abnormalities. They observed that *An aconitus* Donitz 1902 was recorded from localities of Saidpur, Hyderabad in March 1929; Hiriyur, Mysore in May 1931; Madhubani, Dharbanga in March 1933 and from Rampoti, Hyderabad in May 1931. They further accounted that *An culicifacies* Giles 1901 was reported from Belgaum in August 1921; Bombay, Andhra Valley and Punjab in July 1923 and from Delhi in 1958. *An hyrcanus* var. nigerrimus Giles 1900 was reported from Thana, Bombay in November 1959; Nelligere, Mysore in October 1957 and from Tripura in October 1958.
Wattal et al (1960) had also observed from the collection of MII that, *An subpictus* Grassi 1899 was reported from Arthala (Uttar Pradesh) in July 1958 and March 1959, from Kanpur (U.P) in January 1959, from Bellaryard (U.P) in May 1958 and from Hissar (Punjab) in November 1958. They had also noticed the reporting of *An turkhudi* Liston 1901 from Kasauli (Simla Hills), *An vagus* Donitz 1902 from Hissar (Punjab) in November 1958 and from Paraganas (West Bengal) and *An varuna* Iyengar 1924, from Hyderabad (Andhra Pradesh) in November 1959. Nagpal and Sharma (1995) reported the presence of *An varuna* in all the states of South India and also from Lakshadweep and Andaman Islands. Similarly they reported the distribution of *An vagus* throughout the country except Delhi, Himachal Pradesh and Punjab.

*An stephensi* Liston 1901 was originally reported in locality, Ellichpur, Berars, Deccan of India and subsequently from almost all the states in India, especially from the town areas of Bombay, Madras, Lucknow, Mysore, Ahmedbad, Alwar, Culcatta, Delhi, Goa, Vizagapatnam, Bellay, Bapur, Burdwan, Broan Town, Salem and Arthala (Bently 1911, Covell 1927, Sweet and Rao 1937, Singh and Jacob 1943, Senior White and Rao 1943, Bhaskar Rao et al 1946, Godbole et al 1948, Nair and Samnotra 1967, Sharma et al 1982, GoI 1983 and Choudhary & Sen 1987).

*An barbirostris* Van der Wulp 1884 was reported to be present throughout the country in India in high elevations (Puri 1948 and Issaris et al 1953). *An gigas* Giles 1901 had been reported from Indian states of northern and western sides, and from the southern side from Coonor, Nilgiri Hills of Tamil Nadu. It was also reported from Mahasu near Simla and Garhwal of Western Himalayas (James and Liston 1911).

About *An roperi* Reid 1950, in India Harrison and Scanlon (1975) stated that it was known from Assam only. The distribution of this species was documented by Stone and
Delfinado (1973) and Reid (1968). Harrison and Scanlon (1975) felt that many *An umbrosus* previously identified in Assam could actually have been *An roperi*.


Reports about the appearance of Culicinae species (of *Aedes*, *Armigeres*, *Culex*, *Mansonia* and *Mimomyia* and of the Toxorhynchitinae species from various states in India were seen in the early publications of James (1900, 1910 and James & Liston 1911); Theobald (1901); Edwards (1930) and Barraud (1934). In the contexts of a five year prospective epidemiological study of filariasis, the prevalence of *Cx quinquefasciatus*, *Cx vishnui*, *Cx tritaeniorhynchus*, *Cx pseudovishnui*, *Cx gelidus*, *Ae aegypti*, *Ma annulifera*, *An subpictus*, *An varuna* and *An hyrcanus* was established in East Godavari District of Andhra Pradesh (Krishna Rao et al 1981). Similarly in Kancharapara area (De & Chandra 1994) and in the Bankura District of West Bengal with tribal and non-tribal settlements (Chandra et al 2003) too, the prevalence of the same species was noticed.

Menon and Rajagopalan (1975) had studied on *Cx tritaeniorhynchus* in villages near Delhi, India and Reuben (1971), on the mosquitoes of North Arcort District, Madras State, India. Seasonal prevalence of the *Cx vishnui* group of species (*Cx vishnui*, *Cx tritaeniorhynchus* and *Cx pseudovishnui*) was also studied by Reuben (1971).

*Armigeres subalbatus* reported in the areas of the present study was found in the literature of Giles (1902) and Barraud (1934), and this species was reported to be distributed from Punjab to Assam and throughout the Peninsular India to Ceylon. Samuel et al (2004), in their study on host feeding pattern of *Cx quinquefasciatus* and *Ma annulifera* had established the distribution of major vectors of filariasis in rural area of South India. Similarly, the prevalence of Aedes mosquitoes (*Ae aegypti* and *Ae albopictus*) had been further established in rural area in South India by Tewari et al (2004). Recently, the occurrence of sixteen species of mosquitoes including *Ae aegypti*, *Ae albopictus*, *Ae vexans*, *Ae vittatus*, *An stephensi*, *An subpictus*, *An vagus*, *Ar subalbatus*, *Cx bitaeniorhynchus*, *Cx fuscocephalus*, *Cx gelidus*, *Cx pseudovishnui*, *Cx quinquefasciatus*, *Cx tritaeniorhynchus*, *Cx vishnui* and *Ma uniformis* from the reserve forest, rural village and urban town in Natham Taluk of Tamil Nadu was reported by Thenmozhi and Pandian (2009).

Sudharmini et al (2008) found the occurrence of *Ae albopictus* in Chadayamangalam area of Kollam and Vellanad area of Thiruvananthapuram districts. Farook et al (2008) reported the occurrence of *Ae aegypti*, *Ae albopictus* and *Ae vittatus* from Pathanamthitta, Kottayam, Kollam and Thiruvananthapuram districts. From the city area of the district of Thiruvananthapuram, *An subpictus* (Beenarani et al 2008), *Ae albopictus* and *Ae vittatus* (Sreevidya et al 2008) were reported. As per the reports of these researchers, the total number of mosquito species prevalent in Thiruvananthapuram was counted to the thirty seven numbers (Table-5a).

The species configuration of mosquitoes in the study area of the present research work appeared to be diverse. The present study revealed eleven species of anopheline mosquitoes. Of these, *An aconitus*, *An roperi*, *An gigas* and *An turkhudi* were not reported by earlier researchers. These four anopheline species were exclusively obtained from the indoor sites in the district of Thiruvananthapuram. Similarly the present study reported *An culicifacies* which was not reported by previous researchers exempting that of Iyengar in 1938. There was also disagreement with the observation of Dilipkumar (2006) in the availability of *An hyrcanus* var. *nigerrimus*, which appeared in the present study. But this finding was in agreement with reports of six decades before (Iyengar 1938, Menon 1944, Ayyachami Daniel et al 1986 and Rajendran et al 1992 and 1994). *An philippinensis* reported as early in 1938 (Iyengar) could not be traced during the period of present study after the gap of very long spell of time. Likewise, *An jamesii*, *An peditaeniatus* and *An tessellatus* which were reported earlier, also could not be collected during the present study.

Out of the fifty eight species of anophelines reported from India (Nagpal and Sharma 1995), the present study could reveal eleven numbers of species from the study area. Thiruvananthapuram district could alone claim to have four anophelines like *An aconitus*, *An
An *gigas*, *An roperi* and *An turkhudi* reported for the first time, to be included in the map of Anophelines of Kerala.

Among the Aedes mosquitoes, the four species reported in some of earlier studies mentioned were also found in the present study. So was the case with *Cq crassipes*, *Cx bitaeniorhynchus*, *Cx tritaeniorhynchus*, *Cx fuscanus*, *Fi minima*, *Mi hybrida* and *Tx splendens* species of mosquitoes which appeared in the areas of Thiruvananthapuram and Kottayam districts in the present study.

The mosquitoes reported from the city area and taluk area of Thiruvananthapuram by earlier researchers and still found prevalent in the districts of Thiruvananthapuram and Kottayam according to present research work include *An barbirostris*, *An vagus*, *Ar.subalbatus*, *Cx gelidus*, *Cx quinquefasciatus*, *Cx sitiens*, *Ma annulifera* and *Ma uniformis*. In comparison to the earlier studies, the present study could make eight new additions to the species configuration of mosquitoes from Thiruvananthapuram district. These consisted of four species from *Anopheles* and four from *Culex* genera. The new addition of species reported in the present study from Thiruvananthapuram District area include *An aconitus*, *An gigas*, *An roperi*, *An turkhudi*, *Cx pseudovishnui*, *Cx univittatus* and *Cx whitmorei*. These species did not appear in the reports of earlier researchers. So the present study could add eight more species to the mosquito fauna of the district of Thiruvananthapuram, so as to update the number of reported mosquito species from the district. The present study has revealed the scenario of mosquito fauna of Kottayam district too, from where similar studies were almost lacking. Twenty six species of mosquitoes were recognized from the district of Kottayam. All of these species were found distributed in the district of Thiruvananthapuram.
4.1.1 Sex composition of Mosquitoes of the Study Area

The reproductive potential of an insect species is its ability to multiply in a given time when relieved of all environmental resistance. The reproductive potential depends upon the female’s fecundity, the length of developmental period, and the sex ratio (Chapman 1925). Of these, sex ratio is an important factor determining the reproductive potential of a species. The proportion of males and females is characteristic for any species. Usually the females predominate in parthenogenetic species. Frequently sex-ratio indicates the ratio of males to females and sometimes it is expressed as the ratio between females and the total population. Then it is called the sex factor, which plays an important part in determining the reproductive potential of a species; because it expresses the numbers of individuals in each generation of a species that are capable of producing new individuals (Thompson 1922). Significance of high proportion of females among insect populations seemed to help in maintaining the generations (Thompson 1922 and Chapman 1925), is an established fact.

Among mosquitoes too several species of Culex and Aedes were reported to show variations in their sex-wise proportions (Christophers 1960, Roy and Brown 1970, Suguna & Curtis 1974). Gordon (1922) claimed in Brazil during a study on bionomics, that Aedes (Stegomyia) calopus Meig (Aedes aegypti Linn.) males were found not only in excess but they hatched out first, a day quicker in development than the females. Christophers (1947) observed during 1943-44 period while setting out standardized test in connection with work on repellents and Ae aegypti mosquitoes, that throughout the study counts recorded males consistently more numerous than females. The males seemed to predominate to the extent of approximately from 51.1% to 60.5%. He further observed that though the males were more numerous than the females, the percentage of males was not as high as counts noted by several others (Teesdale 1955 and Mattingly 1956).
Christopher (1947) and Suguna & Curtis (1974) had also noticed that the preponderance of males in *Ae aegypti* mosquitoes has considerable interest from genetic point of view, as the sex distorter strains of female species can be utilized in controlling the species genetically. Among *Culex* genus (*Cx fatigans* Wied.), Qutubuddin (1952) observed that out of a total of 4353 laboratory-bred mosquitoes, 55.8% (2427) were males and 44.2% (1926) were females.

Gakhar and Vandana (1996) had observed in a two year successive study in Rohtak in Haryana State, that the female and male mosquitoes of culicines contributed about 64% and 46% respectively, the ratio being 1.15:1, which was quite low as compared to anophelines, (3:13). The highest female: male ratio had been noted by them in *Cx vishnui* (7:1) and lowest in *Cx quinquefasciatus* (1.1:1), which suggested the different population structure as also the life expectancy of the two sexes for different species.

In the present study, sex composition of mosquitoes (Table-3) collected showed that females constituted about 81%. But among the eight different genera (Table-3), the proportions of males and females varied. In all the genera, female mosquitoes were found to the more than the males. Among different genera, males of *Coquillettidia, Mimomyia* and *Toxorhynchites* predominated. Very low proportion of males was noticed among *Mansonii*, *Culex, Aedes, Anopheles* and *Armigeres*. But the species-wise distribution of male and female mosquitoes showed a heterogeneous picture (Table-7). Among Aedes species, *Ae aegypti, Ae albopictus, Ae vexans* and *Ae vittatus* showed dominance of males. All the Aedes species mosquitoes could be found in agreement with the finding of earlier researchers regarding male dominance.

Among anopheline species male dominance was noticed in *An subpictus* and *An varuna*. This finding was similar to that of anophelines in the study of Gakhar and Vandana
Ar subalbatus had a very clear predominance of the male populations. This finding was also in conformity with that of Beena and Ramakrishna (1996) who studied Ar subalbatus from various sites of Kozhikode and Malappuram Districts in Kerala. Among Culex species, Cx gelidus, Cx vishnui, Cx fuscocephalus and Cx sitiens showed male domination. Similar observation was also noticed in the study of Gakhar and Vandana (1996). Cx quinquefasciatus and Cx tritaeniorhynchus showed the female predominance in the present study. This observation on Culex quinquefasciatus was disagreeing with that of Qutubuddin (1952) among laboratory bred Culex fatigans Wied., but fully agreeing with Gakhar and Vandana (1996).

4.1.2 Mosquito species from Indoor and Outdoor Resting sites of the Study Area

Proportions of individual mosquito species from indoor and outdoor sites can give the idea of the habits or behavior related to resting and feeding activities. Krishna Rao et al (1981) observed ten species of mosquitoes from both indoor and outdoor sites in areas of East Godavari in Andhara Pradesh during June 1975 to April 1978, which included An subpictus, An vagus, An hyrcanus, Cx quinquefasciatus, Cx vishnui, Cx tritaeniorhynchus, Cx pseudovishnui, Cx gelidus, Ae aegypti and Ma annulifera. Very high proportion of Cx quinquefasciatus was observed by them in indoor and outdoor sites throughout the study period. Observations of Pal et al (1960) on the bionomics of vectors of human filariasis in Ernakulam (Kerala), India also did not show much difference in resting densities.

Kareem et al (1985), during a systematic study undertaken in Boko of Kamrup district situated on Assam/Meghalaya border during 1981 and 1982 observed that there appeared twenty one species of anopheline mosquitoes both in indoor (human dwellings and cattle shed) and outdoor sites. The species encountered were An aconitus, An aitkeni, An annularis, An balbacinus, An barbirostris, An culicifacies, An hyrcanus group, An jamesii, An
jeyporiensis, An karvari, An kochi, An maculatus, An majidi, An minimus, An philippinensis, An ramsayi, An splendidus, An tessellatus, An theobaldi, An vagus and An varuna. This observation was very significant that the researchers could collect the mosquitoes from the malaria endemic area. Among the twenty one species, An culicifacies showed high proportions from human dwellings (21.1%) and cattle sheds (47.4%) than the outdoor sites (10.5%).

The report of ICMR (1991) recorded a wide range of density (zero to 650) of Cx vishnui group of mosquitoes in resting collections from cattle sheds in the Madurai area of Tamil Nadu during 1986 to 1987. Hasegawa et al (2008) reported that in Hanoi, Vietnam among the JE vectors collected, the most dominant species found indoors was Cx quinquefasciatus, Cx vishnui group and Cx gelidus. On the other hand, Cx gelidus was the dominant species found outdoors, followed by Cx vishnui group.

In the present study also, all the thirty three species of mosquitoes recognized could be collected from indoor sites whereas only thirty species could be obtained from outdoor sites (Table-8). This observation was almost agreeing with that of Krishna Rao et al (1981) and Kareem et al (1985), suggesting the homogeneity in resting behavior of mosquitoes. In the district-wise analysis (Tables-9&10), Kottayam district showed more number of mosquitoes (57.91%) in the indoor collections, but with only twenty four species than the district of Thiruvananthapuram. In Kottayam district (Table-10), outdoor collected mosquitoes included twenty six species. But collections from Thiruvananthapuram district were rich with thirty two species from indoor sites (42.09%) and twenty nine species from outdoor sites (39.90%). The proportions of different individual species of mosquitoes varied with respect to indoor and outdoor collections in both the districts. This suggests heterogeneity in resting habit of mosquitoes in the two districts of the study.
4.1.3 Bait-collected Mosquitoes of the Study Area

Blood-sucking insects feed from a range of different host animals, exploiting mammals, birds, reptiles, amphibians, fish and even insects, arachnids and annelids (Hocking 1971). Insects often choose to feed on particular individuals from among the preferred species, which may well have implications for disease transmission (Burkot 1988). *Culex salinarius* was found to have a wide range of potential hosts which includes birds, equines and canines (Cupp & Stokes 1976). Morphological characteristics of the host are also important in determining host choice. Considering this fact, the mosquito species obtained from collections taken directly that landed on human and animal hosts are discussed.

Samarawickrema (1967) recorded that *Cx pipiens fatigans* Wiedemann was present throughout the night hourly collections taken from human bait during a study in Sri Lanka, to determine the age-composition of that species. Kareem et al (1985) had reported that in Malaria endemic areas of Kamrup district in Assam, 82% of (2183) bait collected mosquitoes were obtained from human bait and only 18% were found from outdoor animal bait. Amongst human bait collection, important species found were *An minimus, An annularis, An philippinensis, An karwari, An kochi* and *An maculatus*, of which *An philippinensis* was the most prominent species. The predominant species of animal bait-collected mosquitoes in the study of Kareem et al (1985) were *An kochi, An philippinensis* and *An karwari*.

In the present study area, twenty different species were collected overnight from human and animal baits (Table-11). These species were obtained from both human and animal baits. About 54% of mosquitoes were collected from animal baits which indicate affinity of mosquitoes to animal hosts. Predominance of *Ae aegypti, An babirostris, Cx pseudodvishnui* and *Ma annulifera* in human baited collection shows their inclination to be more anthropophilic in host selection. Thiruvananthapuram district (Table-12) contributed to
53.56% of the bait-trap collection with nineteen species. But only 17 species were obtained from the human and animal baits in Kottayam district. The host-affinity shown by *Cx quinquefasciatus* in the present study was agreeing with that of Samarawickrema (1967).

### 4.1.4 Mosquitoes from Different Terrains of the Study Area

An important factor influencing the prevalence of a mosquito species in particular localities and even in the major features of the world distribution is altitude (Christophers 1960). In general, an elevation of 6000-8000 feet is likely to limit the distribution of *Aedes aegypti*. The highest altitude recorded would appear to be that of Mara (1946) for presence of *Aedes aegypti* at an altitude of 7800 feet.

Although *Anopheles* mosquitoes are most frequent in tropical or sub-tropical regions they are found in temperate climates and even in the Arctic during the summer. As a rule *Anopheles* are not found at altitudes above 2000-2500 meters (Bruce-Chwatt 1980). But however, Bhatt (1975b) had reported that *An gigas* var sinensis has been found at Kedarnath in U.P. Himalayas at an altitude of 3530 metres. Christophers (1933) had quoted Dr.Strickland’s finding (1925) of a variety of *An gigas* at an altitude of 11,000 feet (3,350 metres) near Indo-Tibetan border. Azeez (1965) recorded *An annularis* and *An vagus* at depths of 300 to 600 feet (92-184 metres) and *An culicifacies, An nigerimus, An stephensi* and *An subpictus* at depths of 300 feet (92 metres) in the coal mines of Bihar. *Culex fatigans* was found breeding at 600 feet (184 metres) below ground level. Ramachandra Rao (1984) stated that the number of species at the sea coast or in the plains is smaller than in the hills and foothills but the abundance of common species is high. *An stephensi* was found to breed in over-head water cisterns in tall buildings of six or seven storeys high in Bombay city (Ramachandra Rao 1984).
The study area of present research work was recognized to fall under three physiographic zones according to the terrain determinants in Kerala (Haigh 1987). The terrain-wise study of mosquito fauna (Table-13) was analysed for lowland (coastal area and adjoining lowlands of < 20 metres of the sea level), midland (undulating midland terrain of 20-100 metres of the sea level) and highland terrains (upland regions of 100-300 metres of sea level) areas. Terrain-wise analysis of present study (Table-13) showed that lowland terrain contributed more number of mosquitoes (39.1%) followed by midland terrain (30.6%) and highland terrain (30.3%) areas. District-wise study also showed that lowland terrain contributed to more number of mosquitoes. Different species of mosquitoes available in each terrain also varied considerably (Table-14).

As stated by Ramachandra Rao (1984), the lowland terrain regions of the study area also contributed to major populations of mosquitoes and the different species of mosquitoes available in each terrain also varied considerably (Table-14). All the four species of Aedes mosquitoes were found in the three terrains. The lowland terrain supported the distribution of An aconitus, An gigas, An roperi and An turkhudi, unlike the observations of Bhatt (1975b) and Christophers (1933). Culex gelidus and Cx quinquefasciatus were abundantly present in all three terrain areas. The total absence of Mansonia species, Mimomyia and Toxorhynchites noticed in the highland terrain areas could be due to an ecological peculiarity.

4.1.5 Mosquitoes of Rural-Urban Settings of the Study Area

Peculiarities of different ecological niche are found to influence the flora and fauna of any environment. Mitchell and Chen (1973) had thoroughly studied the distribution of mosquito vectors of Japanese Encephelitis in Province of Taiwan in China (Becking 1978). Human encounters like deforestation and development of human settlements in the cleared forests also lead to the invasion of feral species of blood sucking insects especially
mosquitoes (Gubler 1997). Ecological changes are evidently noticed as transformations of rural areas to urban nature due to population growth, relative density of dwellings, trade and historic association of places with facilities for higher education, public utility services, local body administration, urban diversions and recreations (GoI 2001).

In India, the spread of Culex fatigans mosquitoes and bancroftian filariasis had been related with rapid changes in rural settings of many states (ICMR 1961, Singh 1962 and 1967). Reuben (1971) had studied on the spread of Culex species of mosquitoes and the spread of viral disease Japanese Encephalitis; and Thenmozhi and Pandian (2009) had recently studied on the prevalence of mosquitoes in forest, rural village and urban town in Natham Taluk in Tamil Nadu State. The studies of the above researchers had given ample evidence of spread of various mosquitoes in the rural-urban settings of various Indian states.

The rural areas of present study (Table-15) contributed to slightly more number of mosquitoes (51.75%). In Kottayam district rural areas contributed to 53.42% of mosquitoes whereas in Thiruvananthapuram district, rural areas contributed to only 49.35%. The urban settings stood first with thirty three species of mosquitoes (Table-16). Mosquito species were found rather less in rural settings. Among various species, Cx quinquefasciatus was prevalent widely in both urban and rural settings. Predominance of Ma uniformis and Ar subalbatus also was noticed in urban areas. But in rural settings, a similar observation was noticed among Ae albopictus, Ae vittatus, Cx gelidus and Cx tritaeniorhynchus.

Regarding the spread of Cx quinquefasciatus and the vector mosquitoes of JE, the present study was found to agree with the above researchers, but disagree with Thenmozhi and Pandian (2009), to the extent that in the rural and urban settings, the present study (Table-16) noticed twenty five and thirty three species of mosquitoes respectively as against nineteen and nine species in their study.
4.1.6 Year-wise Distribution of Mosquitoes in the Study Area


In the present study the number of mosquito species collected during the different years of study period varied much. During the first year of study the number of species obtained was twenty nine. During the second year, twenty five species were obtained. The third year reported twenty species and the fourth year, twenty seven species and the last year the number of species obtained were twenty eight (Table-17). Certain species that were collected in the first year of study could be collected again only after two to three or four years and some others could be collected only during certain years of the study. This kind of appearance, absence and reappearance of certain species contribute to species richness of the mosquito fauna.

Unlike the observations of the previous researchers during their longitudinal studies, the present study (Table-17) could reveal about the year-wise variations of thirty three species of mosquitoes prevailed in the different places of Thiruvananthapuram and Kottayam districts in Kerala during the period of September 2002 to August 2007.
4.1.7 Designated Vector Status of Mosquitoes

4.1.7.1 Established Vectors

The historical evidence of attributing the vector role of many mosquito species (Anopheles, Aedes and Culex) had appeared in the writings of Beauperthuy (1854), Finlay (1886), Ross (1898), Reed et al (1900) and Low (1900) in relation to yellow fever, malaria and filariasis. The role of several mosquitoes (species of Culex and Mansonia) had been established in the transmission of Japanese Encephalitis viral infection in different parts of the world by Wang et al (1962a & 1962b), Detels et al (1970), Reuben (1971), Okuno et al (1973) and Mitchell and Chen (1973). In the transmission of Dengue fever and Chikungunya infection, the role of several species of Aedes mosquitoes (Aedes aegypti and Ae albopictus) had been attributed by Tesh et al (1976), Reiter and Darsie (1984), Reiter and Sprenger (1987), Zytoom et al (1993), Gubler 1997 and Diallo et al (1999).

From various districts of Kerala state, the distribution and prevalence of vector mosquitoes of malaria had been reported in the early years by Iyengar (1934) from Travancore, Covell and Harbhagwan (1939) from Wayanad and by Mathew (1939) from south Travancore. These authors reported about *An culicifacies* and *An fluvialitis* as the main malaria vectors respectively from rural areas and foot-hill places in Kerala. Mentions about the urban malaria vector, *An stephensi* was noticed in 1992 (Mariappan et al) from Cochin of Ernakulam district. Presence of *An varuna* in Kerala was found reported in “Indian Anophelines” of Nagpal and Sharma (1995). *An varuna* is recognized as an efficient local vector for malaria. The vector status had been attributed to these said mosquito species of anophelines based on the observations of the incrimination studies by earlier researchers.

The incriminated and established vectors of filariasis in Kerala as appeared in the reports of Iyengar (1932 & 1938) in Thiruvananthapuram area were *Cx quinquefasciatus, Ma annulifera, Ma uniformis* and *Ma indiana*. It was also found in the report of Singh et al (1956). Subsequent study (Raghavan 1969) also revealed the relative role of these vectors in disease transmission in Shertallai taluk in Alappuzha district. Sabesan et al (1991) had further established the vector capacity of these mosquitoes in Shertallai, Kerala State. Arunachalam et al (1996) reported about the presence of vectors of filariasis, (*Cx quinquefasciatus and Ma annulifera*), vectors of dengue and Chikungunya fever (*Ae aegypti* and *Ae albopictus*) and vector of malaria (*An stephensi*) in Mattancherry, the urban agglomeration in Ernakulam district, Kerala.

Vectors of JE, (*Cx vishnui, Cx triteniorhynchus, Ma annulifera* and *Ma uniformis*) were reported to be present in Kerala in varying proportions (Arunachalam et al 2004 and Philip et al 2004). The vector (*Ae albopictus*) of DF and Chikungunya viral infections were reported from Ernakulam city (Hiriyan et al 2003), from Kannur and Wayanad district (Sumodan 2003), from Alappuzha district (Thangaratham et al 2006) and from certain
localities of Kottayam, Ernakulam, Alappuzha, Coastal Thrissur and Thiruvananthapuram districts (Thenmozhi et al 2007).

4.1.7.1.1 Established Vectors of the Study Area

The established vector mosquitoes of major diseases like *Malaria, Filariasis, Japanese Encephalitis, Dengue* and *Chikungunya* viral infections were found to be prevalent in some of the districts in Kerala as per the observations of the earlier researchers. In this circumstance, an overview of the established vector mosquitoes prevalent in the present study area were made among the mosquito species collected. The mosquitoes collected from the study area were classified according to the existing designated vector status into established vectors, suspected vectors and non-vectors (Table-18). Of the total collected mosquitoes, 66.8% were established vectors, 18.32% were suspected vectors and the remaining 14.88% were non-vectors. The mosquitoes of established vectors recognized (Table-19) from the study area included that for major diseases like *Malaria, Filariasis, Japanese Encephalitis, Dengue* and *Chikungunya* viral infections.

In comparison to the findings of studies from states other than Kerala, the established vectors of malaria found out from the study area were only three species namely *An culicifacies, An stephensi* and *An varuna*. But the present study almost agreed with the prevalence of vectors of urban and rural filariasis as well as Japanese Encephalitis noticed by earlier researchers. The present study also agreed with Arunachalam et al (1996) regarding the presence of established vectors, *An stephensi, Cx quinquefasciatus, Ma annulifera, Ae aegypti* and *Ae albopictus* found in urban Mattancherry of Ernakulam. But other researchers from Kerala could reveal the status of only *Ae albopictus* during their studies. Moreover, none of these researchers from Kerala reported about *Cx pseudovishnui*. The present study could thus bring to light the prevalence of eleven species of established vector mosquitoes
(Tables-18&19) of major diseases like Malaria, Filariasis, Japanese Encephalitis, Dengue and Chikungunya infections from the study areas of Thiruvananthapuram and Kottayam districts in Kerala State.

### 4.1.7.2 Suspected Vectors

Several mosquito species coming under *Anopheles, Culex, Coquillettidia* and *Mansonix* genere were considered as capable of, and suspected as probable vectors for the transmission of malaria, filariasis and Japanese Encephalitis in several countries (Knight and Stone 1977, Harrison and Klein 1975 and Harinasuta et al 1970); as well as in India (Ramachandra Rao and Rajagopalan 1957, Reuben 1971, Sabesan et al 1991, Shukla et al 2002, and Arunachalam et al 2002 and 2004). These researchers had found out the abundance and high density of several mosquito species during their studies. Moreover, some of the species (*An aconitus, An (hy) nigerrinus* and *An subpictus* were found harbouring the sporozoites of *plasmodium* parasites, (Ramachandra Rao 1984) or the growing stages of microfilaria in the thoracic muscles (*Ma indiana, An barbirostris* and *Cq crassipes* (Park 2002). Some mosquitoes showed positivity for viraemia of Dengue or JE, (*An barbirostris, An (hy) nigerrimus* and *An subpictus* (Dandawate et al 1969 and Chakravarty et al 1975). *Cx gelidus, Cx bitaeniorhyuchus, Cx fuscanus* and *Cx whitmorei* were reported to harbour JE virus (Rahman et al 1989 and CBHE 1981). These mosquito species were classified accordingly as suspected vectors considering their abundant availability, high density and infection status.

#### 4.1.7.2.1 Suspected Vectors of the Study Area

Among the mosquitoes collected from the study area (Table-20), the suspected vectors recognized were those of Japanese encephalitis, Malaria and Filariasis. This shows an added threat to the study area that the mosquito fauna consisted of ten species of suspected
vectors, in addition to the presence of eleven species of established vectors of major mosquito-borne diseases.

4.1.7.3 Non-vector Mosquitoes

Among mosquitoes of different genera, various species show susceptibility to infection. Some species are easily infected, while others are not. This phenomenon had been studied and established by several scientists (Boyd and Kitchen 1936, Wattal 1961b and Horsfall 1972). Likewise, density of the vector species at a given time is one of the most important factors in determining vectorial efficiency. No mosquito species should be eliminated as a vector until very large specimens of them have been subjected to studies, to determine the infection status (Ramachandra Rao 1984 and Jupp & McIntosh 1990). These facts seemed to be very true with regard to several mosquito species which are not yet incriminated and attributed vectorial capacity. There are innumerable mosquito species which are to be included as Non-vectors.

4.1.7.3.1 Non-vector Mosquitoes of the Study Area

From the study area, twelve species of mosquitoes could be considered as non-vectors, due to lack of incrimination studies and infectivity studies. The mosquitoes classified as non-vectors included species of *Anopheles, Culex, Aedes, Armigeres, Mimomyia* and *Toxorhynchites* (Table-21).

District-wise distribution (Table-22) also showed that the proportions of established, suspected and non-vectors did not show much difference. Terrain-wise study showed that in all three types of (low, mid and high-land) terrains (Table-23), established vectors were the most prevalent, followed by the suspected vectors and the non-vectors. Rural and urban setting-wise study also showed (Table-24) that established vectors were in much larger
proportion in both settings, than that of suspected and non-vectors. Comparison of vectorial status of mosquitoes for the five years of study (Table-25) showed that the established vector species were more prevalent during all the five years, followed by suspected vectors.

Distribution of mosquitoes of different vector status was appeared to be heterogenous but with predominance for major established vectors in the three types of terrains, rural and urban eco-regions during the five years period of study.

### 4.2 Density Status and Pattern of Fluctuation of Mosquito Populations

The population status or density pattern of mosquito species gives a quantitative assessment which can be used to estimate the critical density of a vector (Ross 1911, Rahman et al 1989). Density variations occur according to climatic conditions of temperature, humidity and rainfall (Mani 1970 and Odum 1971). Habitat variations and host availability also influence the density patterns of mosquitoes (Lehane 1991).

The density pattern and fluctuation of the mosquitoes of the study area were revealed through total man-hour density. The district-wise MHTD of mosquitoes (Table-26) during each month from September to August was found to be significantly fluctuating. Marked seasonal fluctuation was noticed in the MHTD of mosquitoes from the low-mid and highland terrains (Table-27). Like district-wise variation noticed in MHTD, significant variation was noticed in the MHTD of mosquitoes from urban and rural settings (Table-28). Post-monsoon periods showed significant fall of MHTD during all the five years (Table-29). Another significant observation was that year-wise MHTD was found to be continuously increasing from year-1 to year-5. The MHTD of mosquitoes among established, suspected and non-vector groups also was found to have seasonally fluctuating pattern with peaks during the south-west and north-east monsoon periods (Table-30). This seasonal pattern of abundance
in density of these three groups of mosquitoes can be compared with the observations made by Gakhar and Vandana (1996) during October 1988 to September 1990.

The density status of individual species among the established vectors, suspected vectors and non-vector mosquitoes was assessed. The MHD of each established vector species of the two districts did not show significant variation (Table-31). But between two individual species of established vectors from each district of study, there existed statistically significant difference. Similar were the observations with regard to the MHD of suspected vectors (Table-32) and non-vector mosquitoes (Table-33).

The terrain-wise observations of the established vectors showed that their MHD values significantly varied within each terrain but there existed no significant difference among them hailing from lowland, midland and highland terrain areas (Table-34). The suspected vectors found out from lowland, midland and highland terrain areas (Table-35) had very significantly varying man-hour densities. Similar variation was noticed in their densities calculated for each terrain. The non-vector mosquitoes too showed the same pattern of variations in MHD, when the three terrains were considered (Table-36).

The density of established vector mosquitoes from urban and rural eco-settings (Table-37) was found to be significantly differing. But the status of MHD of suspected vectors (Table-38) and non-vector mosquitoes (Table-39) did not seem to do so in the urban-rural settings, although the individual species of them differ considerably within each ecosystem. The year-wise comparison of the MHD of established vectors (Table-40), suspected vectors (Table-41) and non-vector mosquitoes (Table-42) appeared to be outstandingly differing from year-1 to year-5 of the study period. These differences were statistically highly significant.
4.3 **Biodiversity Indices of Mosquito fauna of the Study Area**

Biodiversity of flora and fauna is an indicator of an ecosystem. From the estimations of the diversity indices like Species Richness (Margalef 1958 and Pielou 1960), Evenness Index (Odum 1971 & Brower et al 1998), Man-hour total density (Service 1980 & 1993 and Rahman et al 1989), Absolute frequency (Onori & Grab 1980 and Brower et al 1998) and Abundance (Pielou 1960 and Odum 1971), the extent of flourishing of an area with the living organism can be well understood.

In the light of the definitions and descriptions of various authors, biodiversity indices found out for the mosquito fauna of the study area were over viewed. The present study revealed that the district of Thiruvananthapuram was highly rich enough with thirty three species of mosquitoes, the species richness (SR) value being 21.07. The Kottayam district had the SR value of 16.46 and was reported to have only twenty six species of mosquitoes. The difference in SR values of the two districts and over the months of the study period was statistically very much significant (Table-43). A similar condition was observed for the richness status of the mosquito fauna of the three different terrains (Table-44) and urban-rural eco settings (Table-45) of the study area. But over the period of five years of study, the species richness did not change significantly (Table-46) unlike the significant fluctuations noticed over the twelve months in each year of study.

The over all evenness in the distribution of different species of mosquitoes of the study area (Table-47) ranged between 0.688 (January) to 0.84 (May). This means that during January (post-monsoon month), most of the individual mosquitoes distributed belonged to one or a few species, whereas during May (pre-monsoon month) none of the various species distributed were dominant over the others. The evenness of mosquitoes of the two study districts did not vary significantly. But it appeared uneven over the months in each district.
Terrain-wise evenness was found to be significantly varying and very high showing the influence of type of terrain in determining the equitability of species distribution (Table-48). In the urban and rural settings too the evenness indices varied much with high significance (Table-49). The evenness index values of the mosquito species distributed over the years from year-1 to year-5 (Table-50) varied significantly and were found to be nearer to the upper limit of its range (zero to one). Through out the period of study the mosquitoes were evenly distributed with equal dominance for individual species. Month-wise observations also showed similar picture of evenness in the distribution of mosquito species inspite of seasonal fluctuations in the study area.

The over-all absolute frequency of appearance of mosquito species in the study area was 45.63% (Table-51). The frequency of appearing the mosquito species in the sample sites of Thiruvananthapuram district was 48.08%. There was remarkable and significant difference in the absolute frequency with which mosquito species appeared in the two districts of study. Among individual species, *Culex quinquefasciatus* and *Culex tritaeniorhynchus* appeared in more than 50% of sites of both the districts. Though nine species of mosquitoes not at all appeared in the sites of Kottayam district, thirty three species of mosquitoes in Thiruvananthapuram district showed their presence in varying frequencies.

Among the three terrains, sites of lowland terrain showed the highest (48.7%) absolute frequency which was followed by that of highland (43.8%) and midland (43.26%) terrain areas (Table-52). Significant variations in the frequency of appearance among individual species of mosquitoes were also noticed. *Cx quinquefasciatus* appeared most frequently in lowland and highland terrain sites where as *Cx pseudovishnui* was doing so in the sites of midland terrain. Several other species had not appeared in the sites of lowland, midland or highland terrains.
Sample sites of rural settings (Table-53) appeared to have greater absolute frequency (46.59\%) than that of the urban settings (44.66\%). The variations noticed among the frequency of various species within each eco-setting were not of much significance. The year-wise analysis of absolute frequency (Table-54) of mosquito species showed that the time factor had affected their appearance and dispersal. It significantly varied from year-1 to year-5 and also among the species within the period of each year. The month-wise absolute frequency (\%) of all the thirty three mosquito species (Table-55) found in the present study also showed significant variations. Six species depicted continuous appearance through out the months of study period. A positive seasonal fluctuation was noticed in the increased frequency of appearance among several of the thirty three mosquito species except during the post-monsoon and pre-monsoon months.

Kottayam district appeared to be peculiar with significant status for abundance of mosquito species (Table-56) like *Aedes albopictus, Ae vexans, Ae vittatus, An culicifacies, Ar subalbatus, Cx gelidus, Cx fuscocephalus, Cx fuscanus, Cx quinquefasciatus, Cx tritaeniorhynchus, Cx univittatus, Cx vishnui, Cx whitmorei* and *Ma uniformis*. Among the three terrains, midland areas appeared to be more abundant (Table-57) with more numbers of mosquito species than the low and high land places. Urban settings of study area supported for the abundant distribution (Table-58) of eleven species and only six species were significantly abundant in rural settings. There were ten species of mosquitoes found abundantly distributed in both the settings. Fourteen mosquito species were found to be abundantly distributed through out the five years period of study from September 2002 to August 2007 with significant variations (Table-59). Many of the abundant species were also recognized to be established vectors of major diseases. Seasonal fluctuation too was noticed in the abundance level of twenty seven species of mosquitoes from the study area during the month-wise observation (Table-60).
4.4 Resting and Host-seeking Behaviour of mosquitoes in the Study Area

Selection of resting places and hosts for feeding are two important aspects noticed among several haematophagic insects. The choice of resting places and hosts may be determined by a large number of factors including behavioural, physiological, morphological, ecological, geographical, temporal and genetic considerations (Lehane 1991). Many mosquito species have been noticed to rest indoors (endophilic) and several others rest outdoors (exophilic). Feeding behavior may also make changes in the resting habit. Some of the species show a combination of these habits while selecting resting places or hosts to feed.

Christophers (1960) had worked out on resting and host-landing aspects of *Ae aegypti*. Bruce-Chawatt et al (1966) made a distinction between host selection and host preference. According to him, host selection indicated the host was actually fed upon, and host preference indicated the innate habit of exercising choice of a host or hosts. Shalaby (1971), Sharma et al (1986) and Bhatt et al (1989) had investigated on resting behavior of anopheline and culicine mosquitoes. Host-landing and resting preferences of several anopheline mosquitoes had been reported by Kareem et al (1985) in malaria endemic areas in Assam district.

4.4.1 Resting Preference of Mosquitoes of the Study Area

The resting preference of mosquitoes was studied by analyzing the data on collections taken from indoor and outdoor sites of human and animal dwellings of different terrain areas, rural and urban settings, and during various months of the five years period of study. In the lowland, midland and highland terrains the indoor and outdoor resting density (Table-61) of mosquitoes varied much. But within each terrain no significant difference was noticed in the density of indoor and outdoor resting mosquitoes. In the rural and urban areas, the mosquitoes did not show significant shift in the resting behavior (Table-62). From year 1 to
year 5, gradual increase in the density of indoor and outdoor resting mosquitoes was observed (Table-63). During the dry months, both indoor and outdoor resting mosquitoes appeared in very low density. From the onset of pre-monsoon month (March) onwards a trend of increase in resting populations was noticed in indoor and outdoor sites. During monsoon times, indoor resting behavior was prominent, especially in the months of August and October. Outdoor resting behavior reached peaks during July and October. Seasonal influence had reflected in the resting behavior of the mosquitoes (Table-64 & Figure-8). This finding was very much in agreement with that of Bhatt et al (1989).

4.4.2 Host Seeking Preference of Mosquitoes of the Study Area

The host seeking behavior of the mosquitoes also appeared to be of the similar pattern of resting habits expressed (Table-65). In addition to the seasonal fluctuations in the landing densities, the over-all animal and human-host attracted densities of mosquitoes significantly varied to show the predominance of zoophilism among them (Fig.9). The frequency of host-landing behavior of mosquitoes (Table-66) during the twelve hours between dusk to dawn showed that the average landing density was highest during the early first hour of dusk time on both human and animal baits. The second peek of host landing density was noticed between 1.00 a.m. and 6.00 a.m. Frequency was the lowest between 9.00 p.m. and 11.00 p.m. Moreover animal host-landing density seemed to be higher than that of human-host landed density. The predominance of animal host attracted mosquitoes noticed in the present study was almost similar to the finding of Kareem et al (1985) in areas of Kamrup district of Assam.

4.4.3 Nocturnal Host-Landing Preference of Mosquitoes of the Study Area

Kareem et al (1985) reported that in Kamrup district of Assam, the malaria established vectors of 50%) preferred to land on hosts mostly during the first quarter of the
night and over 40% in the second quarter. During third and fourth quarters, 7.4% and 1.2 percent were found landing respectively. The host landed mosquito collections also consisted of established vectors. The host landing density of them was high between 6 p.m. and 7 p.m. (Table-67). The human host landed density of established vectors (MHTD 258) was higher than that of animal host landed ones (MHTD 225). After an interval of six hours, mosquitoes showed the propensity of host-landing more on animal bait (MHTD 95.42) especially from 1.00 a.m. till the dawn. The established vectors recognized from bait-collections showed more anthropophilic behavior (MHTD 258) during the very early hour of dusk than their counterparts (MHTD 88) during late hours of night till the early morning.

Similar to the observations of Kareem et al (1985) in Assam, in the present study area too, established vector mosquitoes collectively showed an attraction to feed from human host thereby showing the anthropophilic behavior in host selection. Epidemiologically speaking, this observation from the study area is an important behavior among established vector mosquitoes, from which the anthropophilic index, the actual frequency of human-mosquito contact and the measure of probable transmission of disease could be derived, as interpreted by Bruce-Chawatt (1966).

4.5 Abiotic Parameters and Relation to Mosquito Fauna in Study Area

Effects of heat and cold conditions of environment not only act on insects directly in a variety of ways but affect indirectly also on other ecological factors like humidity rainfall, atmospheric pressure, wind currents, food etc. Temperature is also the most important single factor that determines the climate of a region, which inturn affects the insect life (Mani 1970). The effects of external temperature on the physiological activities of many insects had been studied by several researchers (Uvarov 1931, Headlee 1940 and Christophers 1960) and
they had stressed the impact of zone of effective temperatures: minimum effective and maximum effective temperature.

The moisture content of the atmosphere (humidity and rainfall) profoundly influences the distribution and abundance of insects. Humidity and temperature are interdependent and also vary nearly reciprocally. Besides temperature and humidity, the rainfall is another important abiotic factor that influences insects. It modifies temperature and relative humidity and increases the surface area for mosquito breeding. Tropical zones of the world having monsoon rains are the usual habitat of Ae aegypti (SEARO 1999). The breeding of Ae aegypti is highest during pre and post-monsoon period (Ynus 2000). A major contributory factor to this increase of Aedes vectors is attributed to excessive rainfall and related changes in weather pattern such as El-Nino Phenomenon (WPRO 1998). A detailed enquiry of these abiotic factors relating to the study area was made through the meteorological data.

The meteorological picture of the study area (Tables-68, 69, 70, 71, 72, 73, & 74) showed that the mean maximum temperature ranged from 28.7°C (July) to 35.3°C (March) and the mean minimum temperature ranged from 19.9°C (December) to 25.6°C (May). No much variation was noticed in the relative humidity of the study area over the years. Though heavy rainfall was available in the districts of study, Kottayam district appeared to have received remarkably very heavy showers during the south-west monsoon months throughout the study period. In the study area too, not only temperature, humidity, and rainfall, were individually found to affect the distribution and abundance of insects but also climate as a whole.

The climatic parameters like temperature, relative humidity and rainfall pertaining to the study area were considered to correlate with the density and diversity indices (Table-75). The maximum temperature levels of the area seemed to have negatively influenced the
density and species richness of the mosquitoes. The minimum temperature appeared to have positively influenced their density, species richness and evenness in distribution. Density and species richness also showed positive correlation with relative humidity and rainfall. The meteorological conditions of the study area were found to have produced profound influence on mosquito fauna of the area and the scenario was agreeing with the observations and statements made by several researchers (Uvarav 1931, Headlee 1940, Christophers 1960 and Mani 1970).

### 4.6 Influence of Biotic Factors on Mosquito fauna of the Study Area

The biotic factors emanate from the living environment namely flora and fauna of a particular area. The biotic factors are also found to play a vital role in determining the prevalence of many vector-borne diseases, as the flora and fauna provide aboard and hosts for the blood sucking mosquitoes and similar insects. The distribution of vector mosquitoes is influenced by the presence or absence of a particular type of flora in and around mosquito habitat (Rahman et al 1989). The breeding and distribution of several anopheline vectors (An culicifacies, An stephensi, An varuan, An philippinesis, An fluvatilis, An minimus and An balbacensis) had been associated with the presence of visible vegetations and very smaller plants (Spirogyra, Chlorella, Chlamydomas) and certain planktons (Volvox, Euglena etc.) found in temporary and permanent water collections, wells, rice fields and ponds (Rahman et al 1989).

Distribution and breeding of Mansonia species (Ma annulifera, Ma uniformis, Ma indiana and Ma longipalpis), Cq crassipes and Cx vishnui group of mosquitoes had been related with water habitats having floating vegetations (Nelumbium, Eichornia, Pistia and Lemma species) and submerged plants (Vallisneria, Hydrilla, Azolla and Mimosa species) by many researchers in India and abroad (Rajendran et al 1989 and 1993, Chang 2002, Ferreria...

Due to the changed agricultural practices adopted in many countries, extensive land area come under cultivation of trees of cash crop items like teakwood and rubber. The resultant plantations act as favourable breeding habitat (during rainy season) of mosquitoes as observed by Sumodan (2003) in Kannur and Wayanad districts in Kerala State. *Aedes albopictus* was found to breed in the artificial containers kept to collect rubber sap, in the plantations of Kannur and Wyanad areas. This observation of Sumodan is an example of influence of a biotic factor on mosquito breeding. Bhatt et al (1989) also reported about *An culicifacies, An annularis, An stephensi* and *An aconitus* found in good numbers in the villages of Kheda district, Gujrat, because of rice cultivation and water logging due to canal irrigation.

The floral composition of the study area was found to provide good habitat for larval breeding and resting places of adult mosquitoes. Highland area was noticed to have plantations with trees of cash crop variety, timber trees and also palm trees. In the midland terrain lands, an exclusive collection of trees like coconut, cashew, jack fruit, mango, *Azadirakta indica*, paddy, tapioca, plantain and different kinds of vegetables were noticed. In lowland areas in addition to floating and submerged plants found in aquatic areas, the terrestrial area was found to have growth of a variety of trees, perennial crop plants and medicinal and ornamental plants.

While considering floral composition, Kottayam district was found have the largest area (109,582 hectares) under rubber cultivation (GoK 2003) in the state, in comparison to Thiruvananthapuram, where rubber cultivation was confined to about 26,999 hectares of
plantation area (GoK 2004) in Nedumangad Taluk. These plantations might have contributed to increased breeding in latex collecting cups by the container breeding mosquitoes like *Aedes* species, during monsoon periods when rubber tapping is temporarily suspended, as observed in North Kerala (Sumodan 2003).

The two districts have admixture of urban, sub-urban and rural situations which often remain indistinguishable in different terrains of high, mid and lowlands. Midlands and low wetlands of the districts might have supported in building up of mosquito density during different seasons. Conducive environments for mosquito breeding and resting were also noticed to be contributed by developmental activities resulting from industries, agriculture, live-stock and poultry maintenance, fisheries and the like practiced in the study area. The population of these two districts has been changing since 1901. In 1901 census (Nagam Aiya 1906) the populations of Thiruvananthapuram and Kottayam were 1,34,196 and 94,327 respectively. According to the 2001 census, Thiruvananthapuram district had a total population of 32,34,356 and Kottayam district had the total population of 19,52,901. These formed respectively 10.16% and 6.13% of the population of the state (Kerala). The human population growth might also have positively influenced the mosquito breeding and distribution (WHO 1999).

Taking into consideration of the biotic elements and the species composition of mosquitoes of the study area, it was understood that definitely the flora and fauna had influenced the breeding, feeding, resting and the prevalence of mosquitoes. These observations on biotic factors of the study area were found to be similar to those of earlier studies (Kumar et al 1989, Rajendran et al 1989 and 1993, Murthy et al 1999, Chang 2002, Ferreria et al 2003 and Goutam et al 2006 and Chamnarn et al 2006). The flora of the study area appeared to be very much flourishing, conducive and eco-friendly to various animals and
provide breeding, feeding and resting habitat. The biotic environment of the study area had a mosquitogenic atmosphere that was created by the combined effect of flora and fauna.

4.7 Prevalence of Mosquito Fauna of the Study Area


But on the contrary, the present research work was carried out as five-year longitudinal prospective study, so as to draw information on temporal and spacial profile of mosquitoes from the study area. The profile of mosquitoes of the study area appeared to have seasonal fluctuations (Table-76) within the year with bimodal peak during the entire study period. Peaks of prevalence were occurred during June, July, August and October months. The lowest prevalence was noticed during December, January and February months (Fig.14). The present study revealed the varying distribution of mosquito species mainly from genera of Aedes, Anopheles, Culex and Mansonia. Several species of these genera could be recognized as established vectors of major diseases like Malaria, Filariasis, Japanese Encephalitis, Dengue and Chikungunya fever.
The prevalence of vector mosquitoes of major diseases found in the study area (Table-77) showed that, vectors of malaria (Table-77) were totally absent during February months of years-1 to year-5. During all other months of the entire study period malaria vectors made their appearance but in small numbers. Vectors of filariasis (Table-77) were the most appeared ones with 34426 numbers involving Cx quinquefasciatus, Ma uniformis and Ma annulifera. These showed an increase in number from year-1 to year-5. Vectors of Japanese Encephalitis (Table-77) formed the second largest group of established vectors which was immediately followed by vectors of Dengue and Chikungunya fever (Table-77). The studies on virus isolation from field collected Ae albopictus mosquitoes of certain areas in Kottayam and Thiruvananthapuram districts (Thenmozhi et al 2007) was also found to be supportive of the wide distribution of vectors of Dengue and Chikungunya fever, observed in the present study. In the study area, the prevalence of the major disease vectors too showed seasonal fluctuation with bimodal peaks during the monsoon times (Fig.16).

The pattern of prevalence of vector mosquitoes of the study area (Table-78 and Fig.17) also showed a seasonal variation with bimodal peaking up during the periods of south-west and north-east monsoon months. A trend of increase in mosquito populations was noticed during the monsoon months throughout the period of study (Table-76 & Figure-15). This was also found reflected in the case of established vectors of major diseases (Tables-77 & 78 and Figures 16 & 17). These observations, especially on the status of vectors of DF and Chikungunya, appeared to be fully in agreement with the observations of WPRO (1998) and SEARO (1999) of World Health Organization. Thus in the study area also, the mosquito fauna was found influenced by the changes in weather pattern such as El-Nino Phenomenon.