Chapter 1

Introduction

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INTRODUCTION

Insects flourish in conditions of heat and humidity, poverty and overcrowding and they spread disabling diseases among almost half of the world’s population. Of all the insects that transmit disease, the mosquito represents by far, the greatest menace. It remains mankind’s most indomitable foe, resisting costly efforts to eradicate or even control it. Today, the mosquito is literally spreading its wings as a carrier of disease and setting in new areas far from its original geographical boundaries. Both developing and developed countries now experience the problem due to emerging and re-emerging mosquito-borne diseases and viral infections (WHO 1996).

The role of different mosquitoes in the transmission of these diseases has been established as early as century ago. The epoch making events in this connection were attributed to four great leaders: Sir Patrick Manson for the role of mosquitoes in the transmission of filariasis, Sir Ronald Ross for malaria and Major Walter Reed and Carlos Juan Finlay for yellow fever (Robert 1950).

1.1 Global Scenario of Mosquito-borne Diseases

Of the various mosquito transmitted diseases, Malaria is a major public health problem in tropical developing world. More than 2.4 billion of the world’s populations are still at risk. The global incidence is estimated to be 300-500 million clinical cases each year with mortality ranging from 1.1 to 2.7 million per year (WHO 2000). According to the United Nations Development Programme (UNDP 2003), an estimated 1.3 billion people of South East Asian Region (SEAR) are at risk of malaria, 30 per cent of this population lives in areas with moderate to high risk of malaria, mainly in India, Myanmar and Thailand. Human malaria is transmitted only by Anopheles mosquitoes (Bruce-Chwatt, 1980). Though there
are over four hundred and thirty (430) species under the genus Anopheles, only about seventy are malaria vectors, out of which forty are important malaria vectors (Service 2004).

Lymphatic Filariasis (LF) is a disabling and disfiguring disease affecting mankind since antiquity. It is a global problem and is a major social and economic scourge in the tropics and subtropics of Africa, Asia, Western Pacific and parts of the Americas, affecting over 120 million people in eighty countries. More than 1.1 billion people live in areas where there is a risk of infection (WHO 1998). The disease is caused by one of the parasites, Wuchereria bancrofti, Brugia malayi or Brugia timori. The mosquito vectors involved in filariasis transmission include different species of Culex, Aedes, Mansonia and Anopheles in the world (Sasa 1976).

The first outbreaks of a disease compatible with classic dengue fever (DF) occurred in the French West Indies in 1635 and in Panama in 1699, 144 years before the 1779 epidemic of a dengue-like illness that is often reported as the first (Ehrenkran et al 1971 and Mc Sherry 1982). The first definite clinical report of dengue is attributed to Benjamin Rush in 1789. Viral etiology and mode of transmission by mosquito was established in early 20th century. In 1979, dengue viruses paved girdle to the globe in the tropical zone (Halstead 1980). Over half of the worlds’ population lives in areas at risk of infection caused by the four serotypes of dengue virus, (DEN 1, 2, 3 and 4) which are closely related antigenically (Banerjee 1996 and Sharma et al 2000).

A prevalence of Aedes aegypti and Ae albopictus together with the circulation of dengue virus of more than one serotype in any particular area tends to be associated with outbreaks (WHO 1993) of Dengue Haemorrhagic Fever (DHF) /Dengue Shock Syndrome (DSS). DF and DHF have steadily increased in both incidence and distribution over the years since 1956; and in 1996, 2.5 - 3 billion people lived in areas potentially at risk for dengue
virus transmission. Annually it is estimated that there are 20 million cases of dengue infection resulting in around 24000 deaths (WHO 1997).

Acute epidemic encephalitis has been recognized in Japan as a recurring clinical entity since the 19th century and definitely since 1920. The disease Japanese Encephalitis (JE) was shown to be due to the group B arbovirus (Flavi virus) in 1935. In addition to its occurrence in Japan, JE virus activity had been detected in many areas of East and Southeast Asia, including Taiwan, the Philippines, Indonesia, Korea, China, Siberia, Thailand and Malaysia (Miler 1960 and Carey et al 1969). During 1970s it has spread widely in South East Asia, with outbreaks in Thailand, Indonesia, Vietnam, India, Myanmar and Sri Lanka (Okuno 1978). An estimated 43,000 cases of JE occur globally each year, with 11,000 deaths and nearly 9000 disabled. About three-quarters of the cases occur in the Western Pacific countries and the remainder in South-East Asia, especially India (WHO 1996). The involvement of mosquitoes like Culex tritaeniorhynchus Giles and Culex pipiens Pallens in the transmission of JE virus had been claimed (Hammon et al 1949) in Tokyo.

Chikungunya (CHIK) is a relatively rare form of viral fever caused by an alpha virus and spread by the bite of infected mosquitoes of Aedes aegypti species. The disease resembles dengue fever and is characterized by severe joint pain (arthritis) as well as fever and rash. The disease was first described by Marion Robinson following an outbreak in Makonde Plateau, along the border between Tanganyika and Mozambique in 1952-53 (Robinson 1955). The Chikungunya virus was first isolated between 1952-1953 from both man and mosquitoes during the epidemic of fever in Tanzania.

Chikungunya virus (CHIKV) is enzootic in many countries in Asia and throughout tropical Africa. In Asia the virus is transmitted from primates to humans almost exclusively
by Aedes aegypti, while various aedine mosquito species are responsible for human infections in Africa (Pfeffer et al 2002).

In Asia, virus strains have been isolated from Bangkok in 1960s; India in 1964; Sri Lanka in 1969; Vietnam and Myanmar in 1975 and from Indonesia in 1982. Outbreaks have occurred in Philippines in 1968, 1969 and 1996 (Joselito et al 1998) and in Malaysia in 1999. Among many of these outbreaks and epidemics, the role of Aedes species mosquitoes (Ae aegypti and Ae albopictus) had been established by several researchers (Macasaet et al 1969, Campos et al 1969, Zytoom et al 1993 and Joselito et al 1998). By the end of 1990s, chikungunya viral infection seemed to have deep-rooted in the African and Asian countries as the third emerging mosquito-borne disease.

1.2 Problems of Mosquito-borne Diseases in India

In India, the geo-climatic peculiarities and man-made and other natural habitats in urban agglomerations form the mosquitogenic conditions conducive for the transmission of different vector-borne diseases (Rajagopalan & Das 1987 and Mariappan 2000).

Malaria is major public health problem in India. After the independence, an estimate of the malaria problem made in 1953 by Central Bureau of Health Education (CBHE 1958) indicated an annual incidence of 75 million cases with 0.8 million deaths. According to the Directorate of National Malaria Eradication Programme (NMEP 1968), the malaria incidence had dropped down to 2 million cases in 1958. According to the report of Government of India (GoI 1986), an upsurge of malaria occurred in 1965 and the cases rose from 1.48 lakhs in 1966 to 6.4 million in 1976. Despite the efforts by implementing nation-wide control programmes, the malaria incidence since 1984 remained more or less static with about 2.1 million cases per year. Two years after launching the Malaria Action Programme i.e. since 1997, there was a constantly declining trend in the annual malaria incidence in the country.
But till 1999, India could not achieve the target fixed for reducing Annual Parasite Incidence (API) from 4.5 in 1981 to 2.7 in 1985, 1.9 in 1990 and to less than 0.05 in 2000 A.D (Park 2002).

In India, the second major public health problem is lymphatic filariasis which had been increasing every year due to gross mismanagement of the environment. In India the predominant form of lymphatic filariasis is due to Wuchereria bancrofti transmitted by *Culex quinquefasciatus* mosquito (Menon & Rajagopalan 1980 and Rajagopalan et al 1977) which breeds in sewage and in unsanitary conditions. The brugian filariasis is limited to only few pockets in India (Singh et al 1956) and is transmitted by the Mansonoides group of mosquitoes.

The population exposed to the risk of infection was only 25 million in 1953 (GoI 1986), in comparison to 428.28million in 1996 (Sharma & Rahman 1998). India contributes about 40% of the total global burden of filariasis and accounts for about 50% of the people at risk of infection. Recent estimates (ICMR 2002) have also shown that out of 25 states/ Union Territories surveyed, 22 were found endemic for filariasis and nine states: Andhra Pradesh, Bihar, Gujarat, Kerala, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal contributed to about 95% of total burden of filariasis. The present filariasis scenario is alarmingly significant in the context that the World Health Organization (WHO) has targeted lymphatic filariasis for elimination by 2020 through the World Health Assembly Resolution 50.29 in May, 1997 (WHA 1997). To attain this global aim, being a Member State, India has to strengthen activities of mass drug administration, appropriate management of filaria patients and vector control strategies.

Dengue fever is an important emerging public health problem in India. The first major outbreak of DF accompanied by DHF was reported in Calcutta in 1963. According to
the report of Directorate General of Health Services (DGHS 1998), about sixty outbreaks have occurred during the period 1956 to 1996. In India, major outbreaks of the disease have occurred in cities/towns of different regions except North-East. *Aedes aegypti* mosquitoes were attributed to the role of transmission of DF during several outbreaks (Carey et al 1964, Ramachandra Rao 1964 and Sharma 1996). Epidemiologically important new introductions of Dengue Haemorrhagic Fever/Dengue Shock Syndrome (DHF/DSS) were reported in India in 1988. Interestingly, viral surveillance in India documented the endemic transmission of all four dengue virus serotypes accompanied by dengue cases only after 1988 outbreak (WHO 1997).

Problem of DF was found extended to rural situations in the states of Karnataka, Tamil Nadu and Maharashtra due to the establishment of vectors in those situations which are similar to urban areas. Fast urbanization and vector adaptation were contributing factors for increased distribution and emergence of dengue outbreaks. Moreover, the principal vector, *Aedes aegypti* mosquito which is usually not found above 1000 meters has been reported at 2121 meters in India (WHO 1997).

Japanese Encephalitis (JE) is the second emerging mosquito-borne viral disease in India. The disease has epidemic potential and high case fatality. In addition it causes neurological sequelae. The earliest serological evidence of JE virus activity was identified in India in 1952 (Smithburn et al 1954). The disease has been recognized in India since 1956 (Carey et al 1969).

The disease was recorded in India predominantly from rural areas but reports were there from sub-urban areas also. Outbreaks of JE have occurred in different parts of India from time to time, closely associated with monsoon and agricultural practices. The earlier notable outbreaks of JE have occurred in Nagpur during 1954-55, North Arcot, Madras in
1955 and in Agra, U.P. in 1958 (CBHE 1981). Until early 1970, the disease was reported only from southern parts of India. Outbreaks of JE have become almost a routine affair after the first major outbreak was reported from Bunkura district in West Bengal during July-October 1973, causing large scale morbidity and mortality (ICMR 1980). The largest of the reported outbreaks of JE in India between 1973-'99 was from Uttar Pradesh in 1988 when 4485 cases with 1413 deaths were recorded (GoI 1999). Culex (Cx) species of mosquitoes especially Culex vishnui and Culex tritaeniorhynchus were considered to be the principal vectors of JE in West Bengal (Chakravarty et al 1975). Other species included were Cx gelidus, Mansonia annulifera, and Ma uniformis (Reuben and Gajanana 1997).

In India, the first outbreak of chikungunya (CHIK) viral disease was recorded in 1963 in Calcutta and was followed by epidemics in different places in many states in 1964, 1965 and 1973 (Jupp and McIntosh 1988). During 2000, outbreaks occurred in Maharashtra State. Later, massive outbreaks were reported from October 2005 through March 2006, in many districts from Andhra Pradesh, Karnataka and Maharashtra states (Prasanna et al 2006). Madhya Pradesh, Tamil Nadu, Gujarat and Kerala were other worst affected states during 2006. Till November 2007, in India a total number of 43111 suspected cases were recorded from fourteen States/Union Territories (GoI 2007).

1.3 Kerala Scenario of Mosquito-borne Diseases

In the context of the established facts and figures on the prevalence and problems of major mosquito-borne diseases in the Indian sub continent, an analysis of Kerala scenario is made here to know the extent of the problem. The major mosquito borne diseases like malaria, filariasis, dengue and Japanese Encephalitis prevalent now in any other part of India is present in Kerala too. From time immemorial, malaria and filariasis were the important public health issues in Kerala. Nagam Aiya (1906) has documented in “The Travancore State
Manual” the account on Malaria in Kerala, which seemed to be earliest of its kind. Hills and forests were endemic zones of malaria, where primitive tribes and aborigines lived and probably were the reservoirs of infection. Thus in Kerala, from hilly terrains, malaria had gradually spread to foothills and adjoining areas and paved the way to occasional outbreaks and epidemics. During 1935-36, one such epidemic occurred in Nedumangad and Neyyanttinkara taluks of the erstwhile Travancore State, took the life toll of more than 5000 people and ten years later during another epidemic, malaria killed over 2000 persons (Dass et al 1996).

Several researchers (Milton 1914, Horne 1914, Iyengar 1934, Covell & Harbhagwan 1939 and Mathew 1939) who undertook studies had brought out the role of Anopheles mosquitoes as the important vectors of malaria in Kerala. Anopheles fluviatilis was recognized as the principal vector, in the hills and foothill regions, and other species like An culicifacies, An varuna and An jeyporiensis var. candidiensis were only of local importance.

In Kerala, the malaria control activities had been started in December 1953, as part of National Malaria Control Programme (NMCP) launched in the country in 1953. The activities were continued and intensified since the implementation of National Malaria Eradication Programme (NMEP) in 1958 with indoor residual spraying of Dichloro Diphenyl Trichloroethane (DDT). And Kerala was the first state in India to attain the unique distinction of being recommended for complete withdrawal of DDT spraying in 1963 as per the report of Directorate of Health Services (DHS Kerala 1964). The virtual reintroduction of malaria cases was reported by around 1975 (DHS Kerala 1978). Thereafter, from 1984 onwards statistics showed that indigenous malaria cases in Kerala were increasing. Though malaria was a rural problem in Kerala, by 1990 it began to spread to urban places.
This indicates the availability of anopheles vectors in the state. The occurrence of urban malaria vector, *Anopheles stephensi* was reported for the first time in Kerala from Cochin in 1992 (Mariappan et al 1992), before which urban malaria cases were not recognized in the State (DHS Kerala 1998). By the mid 1990, a shift in malaria endemic foci from hills and foothills to coastal regions was noticed, so also a disappearance or lowered density of *An fluviatilis* and invading by *An stephensi*. This type of contribution of vector mosquitoes in changing the epidemiological conditions of malaria has been well documented in Brazil in 1930 (Soper and Wilson 1943).

In Kerala, the early reference on filariasis is contained in the travelogues and memoirs of Jacobus Canter Visscher, a Dutch captain who lived in Cochin between 1717 and 1723 A.D. The disease was then known as “Cochin leg”. Some glimpses of the actual prevalence of the disease in Kerala of the early part of 18th century was given by Day, who was the State Physician in Cochin whose estimates showed that about 5% of the population in Cochin Town were affected. From the report of Government of Kerala (GoK 1961) it was further understood that, Waring, the Durbar physician in Travancore could reveal through a survey in 1855 that one in every twenty three of the population in the Taluk of Sherthala was having elephantiasis.

The first important official document of the incidence of filariasis in the Travancore State appeared in the census report of 1901 (Nagam Aiya 1906). This revealed the maximum incidence in Sherthalai Taluk with persons afflicted one in every twenty seven of the population, followed by Ambalappuzha with one in 194 persons. Among the coastal towns, Alappuzha and Trivandrum (Thiruvananthapuram) were recorded as highly filarial, with endemicity rates 20.5% and 13.6% respectively (Iyengar 1938). Studies of National Filarisis Control Programme (NFCP) in Alappuzha and Kozhikode revealed the endemicity rates of
21.6% and 14.94% respectively during 1975 and 1960. Later in early 1990s studies showed diminishing of lymphatic filariasis in certain foci in Kerala (Arunachalam et al 1996). Absence of brugian type of infection and low vector density of *Mansonioides* species as against predominance of bancroftian infection and *Culex quinquefasciatus* vectors were the trend of changes occurred over the years in Kerala. Towards the end of 1990s, the endemicity rates had been reduced to a low level, being 2.6%, 1.7% and 1.58% respectively during 1998, 1999 and 2000 periods (NFCP, Kerala 2001).

Among mosquito borne viral diseases, Japanese Encephalitis (JE) and Dengue fever were reported from Kerala in mid 1990s. Kerala, which was so far free from JE, experienced the first outbreak in 1996 and since then sporadic cases were being reported. During 1996, the first affected district was Alappuzha followed by Kottayam and Pathanamthitta. There were twenty eight deaths reported out of the suspected JE cases during the year (DHS Kerala 1997). In January 1997, seven southern districts in Kerala were affected with JE and out of ninety nine cases reported; sixteen had died (DHS Kerala 1997). Though the year 1998 was rather a silent year for JE, during three subsequent years there were respectively 214, 164 and 125 cases and 4, 2 and 5 deaths reported (DHS Kerala 2001). Again after two years gap, JE cases appeared in the years 2004, 2005 and 2006 with reported deaths (DHS Kerala 2006), thereby showing the persistence of virus activity in the state.

The vector mosquitoes attributed to JE transmission belong to *Culex vishnui* complex species, *Mansonioides* and certain *Anopheles* species. Four isolations made from a small number of wild-caught Mansonia species mosquitoes during the outbreak of JE in Kerala in 1996 (Dhanda et al 1997) is highly noteworthy and indicative of detailed study on the vectorial potential of Mansonia species (which are the already established vectors of brugian filariasis in Kerala) for JE transmission in Kerala (Gajanana 1998).
Coming to the scenario of Dengue fever infections, Kerala was totally unaffected till 1996. First report of DF in Kerala came from Kottayam district in 1997 with a total of fourteen cases and four deaths, followed by Thiruvananthapuram, Kollam, Idukki and Ernakulam districts in the year 2001 to claim a total of sixty six cases and one death for entire Kerala (DHS Kerala 2005). Since then, Dengue case reports became a routine affair in all the fourteen districts in Kerala, creating public health problem.

In 2006, the new viral disease, Chikungunya fever also appeared in Kerala for the first time, affecting so badly Thiruvananthapuram and Alapuzha districts. In 2007, the state reported 24052 suspected Chikungunya virus (CHIKV) infections, with highest number of cases from Kottayam district followed by Pathanamthitta district (DHS Kerala 2007). All districts reported serologically confirmed cases. CHIKV fever is also transmitted by Aedes species mosquitoes, namely *Aedes aegypti* (*Ae ag*) and *Aedes albopictus* (*Ae al*), which are the established vectors of DF (Zytoom et al 1993, WHO 1997 and Joselito et al 1998).

The incidence of mosquito-borne diseases in Kerala was found to be fluctuating since 1990s not only in terms of number of cases and deaths, but also in the number of newly emerging and re-emerging diseases. Various mosquito transmitted diseases seemed to be widely distributed in almost all the fourteen districts. The scenario of malaria in Kerala State has been found to be contrastingly changed from 1930-1940s to 1990s in terms of epidemics and the distribution and encroachment of new vector species like *Anopheles stephensi*, in the districts of Thiruvananthapuram, Kollam, Thrissur, Malappuram, Kozhikode, Kasargode and Idukki (DHS Kerala 2002). In certain urban agglomerations, disappearance of brugian filariasis is noticed due to drastic reduction in the Mansonioides breeding habitats, as a result of rapid urbanization coupled with improved socio-economic conditions (Arunachalam et al 1996).
Various factors like developmental activities, human interference, climatic changes and availability of parasitic load in the community and socio-cultural practices have contributed to increased mosquito menace and prevalence of mosquito-borne diseases (Panicker 1986). This seemed to be true in the case of emergence of JE, dengue and chikungunya fever. Other supporting factors that lead to the occurrence of emerging and re-emerging diseases is population migration, mobility of vectors and pathogens; all facilitated by modern transportation (Reiter et al 2006).

The qualitative and quantitative composition of the each organism or each biocoenosis or fauna is determined not only by the character of the species and the conditions prevalent at the moment but it is the end result of long series of interplay of geological tectonic and climatic factors. Climate depends upon latitude and altitude. It is determined by temperature, humidity, rainfall, light, atmospheric pressure, wind, composition of the air, atmospheric electricity etc. Temperature is the most important of the abiotic factors. Not only does temperature act on insects indirectly in a variety of ways, but it also influences them indirectly by acting on other ecological factors like humidity, rainfall, atmospheric pressure, wind current, food etc. It is also the most important single factor that determines the climate of a region (Mani 1970).

The distribution, variety, density, abundance etc of mosquito genera and their species is dependent on several of the biotic and abiotic environmental factors (Rahman et al 1989). The biotic factors emanate from the living environment like fauna and flora of a particular area. The abiotic factors like temperature, humidity and rainfall have a profound influence on the life of a mosquito and on the development of parasites in its body (Russel et al 1963). In Kerala climate is more or less tropical with seasonal fluctuations in temperature, humidity and rainfall which influence the flora and fauna. Hence longitudinal studies are needed to
understand the distribution, variety, density and fluctuations due to seasonal changes occurring in the fauna of mosquito species (Tandon and Ray 2000).

It is an established fact that the studies on mosquito taxonomy would reveal the immense species and varieties prevalent in various locations (Ramachandra Rao 1984). Mosquito systematics had been described by several taxonomists (Christophers 1933, Horsfall 1955 and Knight & Stone 1977) which enabled researchers to find out newer and newer species and make new additions to the mosquitoes of the world. The basic terminology used to make morphologic descriptions was also contributed by eminent taxonomists (Harbach and Knight 1980, Wilkerson and Peyton 1990). Many of these studies on mosquito systematics have been conducted in different regions of India as well as abroad.

Investigations and studies conducted on the vector mosquitoes during outbreaks and epidemics would give only a glance of the vectors prevalent in one particular place for a specific period of time. Faunistic studies on mosquitoes of different districts in Kerala are highly lacking except for the observations made in the contexts of early malaria epidemics (Iyengar 1934, Covell and Harbhaghwan 1939) and filariasis endemicity (Iyengar 1938 and Arunachalam et al 1996) in Wyanad, Cherthalai and Mattancherry areas. Recently Mosquito-borne diseases have become a very serious public health issue in Kerala which required envisaging emergency actions on war-footing and have raised several queries as to the vector capacities of mosquitoes and transmission of new viral infections, in different regions of the affected districts. These situations need the utility of adequate information on profile of mosquito species and varieties, their distribution and taxonomy. It has become hence inevitable to have in-depth understanding of profile of mosquitoes in the districts of Kerala.

It was in this background that, the present research work entitled “A study of the mosquito profile in the areas of Japanese Encephalitis Virus activity with reference to
selected districts in Kerala State” was undertaken in two of the southern districts in Kerala, namely Thiruvananthapuram and Kottayam. The entire course of work was carried out to study the distribution, prevalence, species and varieties, diversity and seasonal fluctuations of mosquitoes in terms of established vectors of different mosquito transmitted diseases prevalent in the two selected districts of Kerala. The information thus acquired would form a back-bone of future research work and would be of special interest for planners, taxonomists, health care providers and researchers.

1.4 Objectives of the Study

The General Objective of the present research work was to study the profile of mosquito fauna in selected districts of Kerala with reference to established vectors of mosquito-borne diseases prevalent in Kerala.

1.4.1 Specific Objectives

- To study the distribution of mosquito genera and species in Thiruvananthapuram and Kottayam districts in Kerala.
- To understand the fluctuations in density and indices of biodiversity of mosquitoes in the two districts during different seasons.
- To find out the resting behavior of mosquitoes in the study area.
- To know the host seeking preference of mosquitoes, particularly of the major established vectors in the study area.
- To correlate the climatic factors with the mosquito fauna of the study area.
- To understand the prevalence and distribution of mosquitoes with reference to established vectors of major diseases.