ENTOMOLOGICAL AND ENVIRONMENTAL STUDIES ON THE ENDEMICITY OF FILARIASIS IN KERALA

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IN

ENVIRONMENTAL SCIENCE

by

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CERTIFICATE

This is to certify that the thesis entitled **Entomological and Environmental studies on the Endemicity of Filariasis in Kerala, s**ubmitted to the University of Calicut by Mr. Sajith U., in partial fulfillment of the award of the degree of Doctor of Philosophy in Environmental Science is a *bona fide* record of the research work carried out by him under my supervision and guidance. No part of the present work has formed the basis for the award of any other degree or diploma previously.

Calicut University
17th July 2017

Dr. C. C. Harilal
(Supervising Teacher)

DECLARATION

The thesis entitled **Entomological and Environmental studies on the Endemicity of Filariasis in Kerala,** submitted by me in partial fulfillment of the requirement for the award of the degree of Doctor of Philosophy in Environmental Science of the University of Calicut is an original research work carried out by me under the guidance and supervision of Dr. C.C. Harilal, Assistant Professor, Division of Environmental Science of the Department of Botany, University of Calicut. No part of the work formed the basis for the award of any other degree or diploma of any University.

Calicut University **SAJITH U.**

17th July 2017

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CONTENTS

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Dedication

To my Beloved Family

ABBREVIATIONS

LF	:	Lymphatic filariasis
mf	:	microfilaria
JE	:	Japanese encephalitis
DO	:	Dissolved oxygen
sq. km	:	Square kilometer
mm	:	millimeter
m^2	:	Square meter
Kg	:	Kilogram
^oC	:	Degree Celsius
NTU	:	Nephelometric Turbidity Unit
mg/l	:	Milligram/Litre
ml	:	Milliliter
An.	:	*Anopheles*
Ar.	:	*Armigeres*
Ae.	:	*Aedes*
Cx.	:	*Culex*
Mn.	:	*Mansonia*

GENERAL INTRODUCTION

Vectors are organisms which carry pathogens and transmit diseases from a reservoir to a susceptible host. The vectors are able to transmit a wide array of pathogens such as viruses, bacteria, or other parasites between humans and from humans to other warm-blooded hosts. Deliberate interactions between the pathogen and host, along with vigorous immersion of vectors ensues effective transmission of so many infectious diseases. The infection to hosts renders some damage to their tissues that sometimes enables them to infect and transmit diseases more effectively. Even within closely related groups, each of vector organisms has unique habitat requirements and feeding behaviors, which can vary prominently (Anderson et al. 2004).

As vectors are deeply ingrained to the geography and ecology of the areas they infest, they have been considered as the most difficult group as far as prevention and control concerned. They ultimately enhance the range and transmissibility of pathogens than any other means, especially over those that would depend on transmission by direct human contact. Worldwide, vector-borne diseases are considered to be one of the supreme causes of human morbidity and mortality (WHO 2004). Such diseases have the potential to cause enormous economic harm in the form of livestock and crops, and even the threat of infection can severely limit trade. Vectors and their associated pathogens have coevolved in discrete geographic locations with climates, hosts and habitats that favor the transmission of many diseases (FAO 2007).

Most of the animal vectors are bloodsucking insects that ingest pathogens during a blood meal from an infected host (human or animal) and later inject them into a new host during their next blood meal (WHO 1994). Changes in the environment can act very sensitively on the occurrence of vector borne diseases. This has been evidenced by various intricate ecological processes that regulate vectors in the environment with respect to their distribution and abundance and also with their contact with human and non-human hosts

(Sutherst 2004). Short term seasonal fluctuations in weather and resultant long term climatic changes also influence the incidence of many vector borne diseases. Such influences create hindrance to the motility and multiplication of pathogens and their vectors in a process by which, climate modifies the ecological balance between the behavioral patterns of both human as well as pathogen (Patz et al. 2000).

Among the diverse array of vectors, mosquitoes stand at the top, spreading many devastating diseases to human beings (WHO 1966). They are the most diversified and studied group of arthropod vectors that has supreme role in the field of public health. Mosquitoes are distributed all over the world, including tropics and temperate regions, except some islands and Antarctica that are permanently frozen. They can thrive in a variety of habitats with fresh, clear, turbid or polluted water with very high rate of survivability, except in marine habitats with high salt concentration (Rueda 2008). Environmental factors along with habitat heterogeneity and host preferences play significant role in the growth and development of mosquito vectors. The increase in density of a vector species is very much dependent on climatological attributes favorable for its breeding and adult survival (WHO 1975). Lack of appropriate strategies for the disposal of wastes, unhealthy sanitary and sewerage systems along with chaotic growth and developments within rural and urban environments have subsidized the generation of so many ideal breeding habitats for mosquitoes (Douglas 2004).

Mosquitoes belong to the family Culicidae, order Diptera, class Insecta (Hexapoda), phylum Arthropoda. Anophelinae and Culicinae are the two subfamilies of which Anophelinae has three genera and Culicinae has 11 tribes. Under 42 genera and 140 subgenera, 3,554 species of mosquitoes have been reported so far from different sectors of the world (Harbach 2017). In terms of mosquito diversity, India ranked fifth after Brazil, Indonesia, Malaysia and Thailand (Foley et al. 2007). The distribution status from India revealed a total number of 393 species coming under 49 genera and 41 subgenera. Subfamily Anophelinae contains 61 species in one genus followed by subfamily Culicinae with 332 species in 11 tribes and 48 genera. Tribe Aedini of subfamily Culicinae contains the highest number of 176 species in 33 genera (Bhattacharya et al. 2014).

Among the diversity of mosquitoes, a considerable number acts as vectors of many diseases in different sectors of the world. As far as human health concerned, they are more harmful than any other group of arthropod vectors. The most important mosquito vectors are belonging to the genera *Anopheles*, *Aedes*, *Culex* and *Mansonia*. Mosquito vectors transmit parasites responsible for diseases such as malaria, dengue fever, chikungunya, filariasis, yellow fever and various forms of encephalitis such as Japanese encephalitis (JE), Eastern equine encephalitis, St Louis encephalitis, Western equine encephalitis, Venezuelan equine encephalitis etc. (Youdeowei and Service 1986; Rozendaal 1997).

Mosquitoes and mosquito borne diseases are known to affect 700 million people in Africa, Central America, South America, Mexico, Russia and much of Asia leading to 2 million deaths every year (WHO 2002). Mosquito borne diseases have the history of producing terrible distress to humanity in the form of death and also instigated hindrance to the growth and development of many countries (Pearis and Cranshaw 2010).

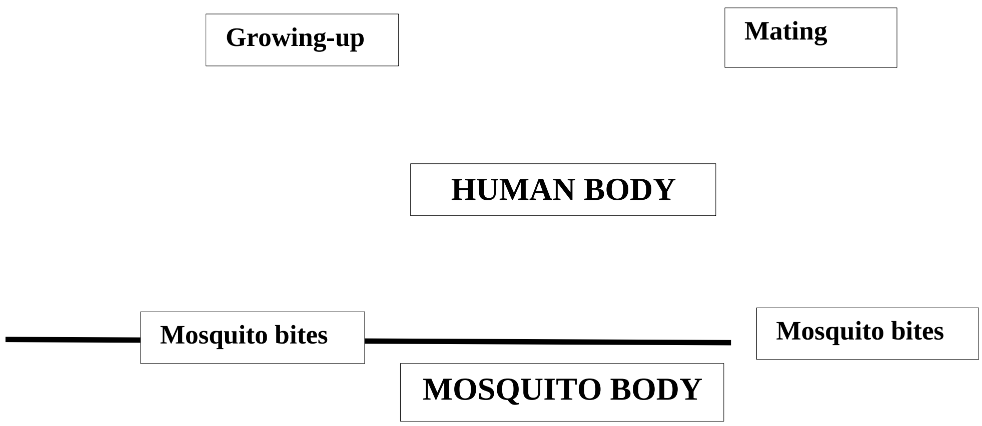
Filariasis is a group of vector - borne parasitic diseases of humans and other animals, caused by long, threadlike parasitic round worms (nematodes). The disease is characterized by fever, chills, headache, and skin lesions in the early stages and if untreated, can progress to gross enlargement of the limbs and genitalia, a condition called elephantiasis. There are three types of filariasis: lymphatic filariasis that affects the circulatory system, which moves tissue fluids and immune cells and is the most common type; subcutaneous filariasis, which infects the areas beneath the skin and whites of the eye and serous cavity filariasis, which infects body cavities, but does not cause disease. Among the eight filarial parasites that commonly infect man, three species account for most of the pathological symptoms. They include *Wuchereria bancrofti*, *Brugia malayi* and *Brugia timori* (Ottesen 1984).

The known mosquito vectors of *Wuchereria bancrofti*, *Brugia malayi*, and *Brugia timori* belong to four main genera: *Anopheles*, *Aedes*, *Culex*, and *Mansonia* (Stone et al. 1959). The efficiency of specific mosquito species to transmit filarial infection to humans is determined by multiple factors. Some species do not transmit the parasite because ingested microfilariae fail to develop to infective forms in the insect. Some mosquitoes may be poor vectors because their population density is too low or simply because they do not bite humans (Mattingly 1969; Wharton 1962). Infection by *W. bancrofti* transmitted by the ubiquitous vector, *Culex quinquefasciatus* is the most common and accounts globally for approximately 90% of all infections (Anosike et al. 2005). Infection is prevalent in both urban and rural areas. *Brugia malayi* infection (10%) is mainly restricted to rural areas due to peculiar breeding habits of the vector associated with floating vegetation. *Mansonia annulifera* is the principal vector of *Brugia malayi* (Wharton 1962). The Periodicity and distribution of parasites of human lymphatic filariasis (Sasa 1976) is given in the following table.

Organism	**Periodicity**	**Distribution**	**Main vector**
Wuchereria bancrofti	Nocturnal periodic	Worldwide, including Africa, Indonesia, Melanesia, Micronesia, Middle East, South America, South Asia	*Anopheles, Culex*
	Nocturnal sub-periodic	South-East Asia	*Aedes*

	Diurnal sub-periodic	Polynesia	*Aedes*
Brugia malayi	Nocturnal periodic	India, Indonesia, South-East Asia	*Anopheles, Mansonia*
	Nocturnal sub-periodic	Indonesia, South-East Asia	*Mansonia*
	Diurnal sub-periodic	Thailand	*Mansonia*
Brugia timori	Nocturnal periodic	Alor, Flores, Indonesia, Roti, Timor	*Anopheles*

The adult worms are located in the lymphatic system of the human host, where they live for 5-10 years (Vanamail et al. 1996; Subramanian et al. 2004). During their lifespan, after mating, female worms bring millions of immature microfilariae (mf) into the blood. Some of these microfilariae may be engorged by mosquitoes while taking a blood meal. Inside a mosquito, microfilariae develop in about 12 days into infective larvae that can enter a new human body when a mosquito takes a blood meal. Some will migrate to the lymphatic system and develop into mature worms. Maturation takes 6-12 months (WHO 1992). Microfilariae cannot develop into adult worms without passing through the developmental stages in the mosquito. The life span of mf in the human body is estimated as 6-24 months (Plaisier et al. 1999). When the worms are challenged either physically or therapeutically, they release immunologically provocative substances which cause inflammation of the lymphatic vessels (lymphangitis). Successive bouts of lymphangitis inevitably lead to severe fibrosis of the lymphatic vessels and formation of lymphatic hypertension and lymphoedema. Longstanding (3–7 years) lymphatic hypertension generally results in elephantiasis (Bahr and Bell 1987).



Wuchereria bancrofti and *Brugia malayi* microfilariae have unique circadian rhythms manifested as a variability of their number or concentration in the peripheral circulation (Hawking 1968; Turner and Edeson 1957). The mosquitoes, the vectors of *Wuchereria* and *Brugia* species, also have a circadian rhythm which describes their feeding time. The highest concentration of microfilariae in the peripheral blood occurs at a time concurrent with the period of most active feeding by the local vector. This coincidence suggests that the parasites have adapted their periodicity to the vector feeding behavior, possibly to facilitate their transmission (Wang and Saz 1974).

Comprehensive strategies for monitoring lymphatic filariasis have been provided by World Health Organization. Various methods have been established for the clinical diagnosis of lymphatic filariasis in humans. As human filarial parasites have nocturnal periodicity, blood films taken at night are used (Ottesan et al. 1997). Modified approaches like concentration techniques (nucleopore filtration) or detection in larger quantities of lysed blood using a counting chamber have been developed as there is limited sensitivity of blood films (Molyneux and Zagaria 2002). In cases of areas wherein night blood films could not be done, a drug based provocation test is used. Supplementing drugs such as diethyl carbamazine during the day will ‘provoke’ the appearance of microfilaria in the blood (Ottesan 2006). In addition, an assay based on the detection of circulating filarial antigen known as Immuno Chromatographic Test (ICT) has been employed for the mapping and distribution of the disease (Weil et al. 1997). ELISA-based approach using the Og4C3 monoclonal antibody has been using as an alternative to the ICT (Njenga et al. 2007). Both of these tests can be done at any time in a day irrespective of the circadian rhythms shown by the filarial parasites and the vector mosquitoes.

Treatment of asymptomatic filarial parasite carriers and clinical management of patients are two different entities and need to be dealt with separately. The anti-filarial drugs (Diethyl carbamazine, Ivermectin, Albendazole, etc.) are given to individuals with microfilariae, or to the community in endemic areas mainly to eliminate the parasites and to interrupt transmission (Sabesan 2005). Early diagnosis and treatment of infection carriers will prevent most of them from producing clinical expressions.

Lymphatic filariasis commonly known as elephantiasis is a painful and profoundly disfiguring disease that has a major social and economic impact in Asia, Africa, Western Pacific and parts of America (Ottesen et al. 1997). It is one of the leading causes of permanent and long-term disability in the world (WHO 1995). Worldwide, there are 1.2 billion people fronting the risk of lymphatic filariasis and 128 million are known to be the carriers of filarial worms (Kumaraswami et al. 2000).

Estimates in India show that 473 million people are exposed to the risk of bancroftian infection and of these, about 348 million are estimated to be harbouring microfilaria (mf) and over 23 million suffer from filarial disease manifestations (WHO 2006). India has reported to have 40 % of the prevalence of filariasis across the globe (WHO 2006). Bihar has highest endemicity (over 17%) followed by Kerala (15.7%) and Uttar Pradesh (14.6%). Andhra Pradesh and Tamil Nadu have about 10% endemicity. Goa showed the lowest endemicity (less than 1%) followed by Lakshadweep (1.8%), Madhya Pradesh (above 3%) and Assam (about 5%). The seven states namely Andhra Pradesh, Bihar, Kerala, Orissa, Uttar Pradesh, Tamil Nadu, and West Bengal contribute over 86% of mf carriers and 97% of the disease cases in the country. *B malayi* infection is prevalent only in Kerala, Tamil Nadu, Andhra Pradesh, Orissa, Madhya Pradesh, Assam and West Bengal (WHO 2006).

The single largest tract of this infection lies along the west coast of Kerala, comprising districts of Thrissur, Ernakulam and Alleppey. Alleppey and associated regions like Cherthala were particularly notorious for the occurrence of the disease even now. In Ernakulam district, the disease confines to Vypin / Mattanchery areas. In Thrissur district, 573 cases of filariasis were detected in a rapid survey.Even though filariasis control programmes are operational from 1955 and mass administration of drug as an annual exercise from 1997, an effective eradication programme is yet to be achieved.

The disease, which has already been kept away by most developed countries, is still rampant in some of the coastal and non-coastal districts of Kerala. For the last several years, coastal pockets of many of the districts have been facing the devastating effects of this disease. Non-coastal district like Palakkad is reported for a highest endemicity rate in recent times.

Latest report from the district vector control units revealed that the disease is still endemic in 10 districts of Kerala. The locations pertaining to higher endemicity in each district has also been reported and is depicted in the table given below.

Sl. No	District	Location	Number of microfilaria cases reported
1	Trivandrum	Manacaud	6
2	Kollam	Mangad	3
3	Alleppey	Kommady	4
4	Ernakulam	Thoppumpad y	3
5	Thrissur	Chavakkad	11
6	Palakkad	Thirunellai	23
7	Malappura m	Ponnani	56
8	Kozhikode	Vellayil	7
9	Kannur	Thalassery	3
10	Kasaragod	Thalangara	6

Among different districts, Ponnani of Malappuram district and Thirunellayi of Palakkad district were reported for highest prevalence of the disease.

The present study is an attempt to elucidate the environmental, entomological, social, occupational and cultural reasons responsible for the endemicity of filarial disease in 10 locations falling in Trivandrum, Kollam, Alleppey, Ernakulam, Thrissur, Palakkad, Malappuram, Kozhikode, Kannur and Kasaragod districts of Kerala state. For a strategic approach, the results of the present study are depicted in 3 chapters in which, chapter 1 is dealing with habitat characterization of mosquitoes; chapter 2 with evaluation of the diversity of intermediary mosquito vectors with reference to their lifecycle pattern and disease transmittance and chapter 3 with Socio-economic cause of filariasis and impact of therapeutic practices This is with the intention of assessing the impact of socioeconomic factors in disease transmission and also the effectiveness of therapeutic practices.

CHAPTER I
HABITAT CHARACTERIZATION

Introduction

Mosquito borne diseases are known to be endemic in different parts of the world. Ambient changes in the population of mosquitoes and resultant diseases are due to various human interferences on environment and thereby climate. Changes in environmental settings and climatic conditions determine the prevalence, survival rate and distribution of mosquitoes and other vectors. Such changes impart phenomenal modifications in the behavior and resistance, enabling transmission of pathogen in a more persistent way.

The imminent issue of change in climate has risen as a new threat and challenge for ongoing efforts to comprehend vector borne diseases. Successful transmission of vector borne diseases involves interaction among the vector mosquitoes, pathogen and host. Normally, any disease causing pathogen competes for their most adaptive vector and undergoes a crucial stage of their life within them. Being cold blooded creatures, mosquitoes are influenced by external climatic conditions in the process of growth and development of different parasites within them (Dhiman et al. 2011).

Environmental factors mainly related to the fluctuations in mosquito abundance and resultant diseases are land use and land cover changes in terms of agricultural and industrial development, urbanization and deforestation. The important climatic attributes having vital role on the mosquito emergence and diseases are atmospheric minimum and maximum temperature, relative humidity, seasonal rain fall, exposure to sunlight, wind velocity, greenhouse effect and global warming (Patz et al. 2000). Depending on the extent of changes to all the above mentioned attributes, the effect on mosquito abundance may ensue for a shorter period or throughout the year and determines the endemicity and epidemicity of various diseases.

Alterations in land use for human settlement have influenced the occurrence of mosquito borne diseases in a positive way. The seasonality along with changes in soil type determines the disease incidence (Patz et al. 2000). Increased population growth has demanded drastic changes with respect to different land forms. Land use and land cover modifications for the wellbeing of human have created back grounds for the origin of many mosquito vectors. Such anthropogenic interferences have contributed to the degradation of different land forms that alter the ecological balance to give away convenient background for the breeding and development of mosquito vectors and subsequent diseases transmission (Kweka et al. 2016). Expansion of cities to rural peripheral areas along with aggregate land cover changes in cities creates dramatic differences in mosquito larval habitats. Urbanization result in the defective management of underground distribution of water, surface storm water and domestic or industrial sewage water. Such created water sources serve as the breeding ground of mosquitoes like *Culex*. Reports reveal that 78% of the mosquitoes in the urban area prefer sewage and underground water for their growth and proliferation (Kay et al. 2000). Urbanization also contributes to the occurrence of different artificial containers within the area that can act as unique habitat of diverse mosquito species (Douglas 2004).

Deforestation with the aim of developmental activities, constructing roads and others has contributed to increased vector abundance. Forests after clearance are used normally for various purposes such as development of agricultural plots, human inhabitations, feeding plots for cattle etc. Human inhabitations will influence the entire ecology of the area, as there will be enhancement of different vegetation as food source. Human settlement and agricultural practices along with the introduction of domesticated animals may contribute to an altered environmental background that enables growth and proliferation of either new or existing adaptive pathogens or their vectors (Patz et al. 2000).

Also there will be formation of new water bodies in the forest cleared area for the establishment of different agricultural crops. The soil type and elevation of the area determines the type of water body to be evolved and also its quality parameters. As forest cleared lands are more sun-drenched, there will be changes with respect to the soil texture that cause fluctuations in pH of the water column above. Any change in pH from acidic to alkaline and reduction in salinity may enhance the fecundity and emergence rate of many mosquito species, especially *Anopheles* (Southgate 1997).

As part of agricultural development, water bodies with sufficient area and volume are getting deepened. Water bodies for such purposes and their improper management result in the creation of suitable habitats for the origin of different mosquito species (Ramasamy et al. 1992). Agricultural development also causes varying levels of surface soil run off and subsequent sedimentation in the adjoining water bodies. Increased sedimentation in the water reservoirs decelerates or pauses its flow and also result in a reduced water depth. In this way, sedimentation persuades the creation of suitable mosquito habitats, as mosquitoes prefer warm, shallow water sources with diminished or restricted flow for breeding. Agricultural practices within a vast area also result in climatic changes in the form of temperature that leads to enhanced vectorial capacity of mosquitoes. Paddy fields are the most significant environmental modification as part of agricultural development. The shallow nature with no flow enables so many mosquito species to use them as potential breeding grounds. They are the exclusive breeding habitats of some of the mosquito species belonging to the genera *Culex* and *Anopheles*, which are involved in the transmission of diseases like Japanese encephalitis and malaria. Water column within the paddy fields are sustained throughout the year, as most of them have adjoining networks in the form of canals or lakes with incessant supply of water (Douglas 2004).

Considering climatological characteristics, atmospheric temperature have supreme role on the rate of reproduction, biting behavior, survival rate and transmissibility of mosquitoes. Increased temperature upsurges the disease transmission potential of mosquitoes. This is a result of enhanced blood meal digestion and subsequent processes related to ovarian and egg development. Such changes induce the mosquitoes to take more blood meal by feeding on their hosts (Martens et al. 1995). The entry of different parasites in to mosquito body and their development time are influenced by the number of days with varying temperature. Comprehensive studies pertaining to the effect of temperature on the development of parasites within mosquito genera like *Anopheles* revealed that, elevated temperature alters the sporogony duration of malarial parasites within the mosquitoes and by pass the normal days for development (WHO 1975). A prominent upsurge in the abundance of mosquitoes around 30-100% could be reached in accordance with a fluctuation of 0.5^0C in the mean ambient air temperature (Pascual et al. 2006). The transmission of different pathogen by mosquitoes are affected when the temperature become too high or too low. This is due to the effect of temperature on the development and efficiency of pathogen within the mosquitoes and also by the shortening of the lifespan and survivability of mosquitoes (Tsai et al. 2012). Evidences have shown that, ambient temperature influences the resistance phenotypes of mosquitoes. Development of parasite and mosquito phenotype resistance is achieved in two ways. Host body temperature directly affects the parasite development without the involvement of mosquitoes and effect of mosquito innate immunity mechanism on the parasites. Even though elevated temperature enhances disease transmission potential of mosquitoes, higher values around 38^0C may result in drastic diminution in the daily survival of mosquitoes and will lead to enhanced mortality rate (Martens 1997).

Rainfall has been described as the most essential physical factor as far as mosquito abundance is concerned. Mosquito populations are influenced by the extent, intensity and period of rainfall (Russell et al. 1963). Rainfall creates new habitats with all possible volume in the tropical and subtropical regions and affects the reproduction and abundance of mosquitoes. Other than the large water reservoirs, total rainfall recharges a wide variety of areas including artificial containers. Excess rainfall have negative effect on the survivability of mosquitoes as all most all the immature larvae are used to get flushed off. Total rainfall has a direct effect on the relative humidity and atmospheric temperature. Both the attributes are usually get modified by rainfall pattern and will make the environment suitable for the breeding, emergence of mosquitoes and thus enhance the longevity and disease transmission (Molineaux and Gramiccia 1980). Rainfall in association with near surface humidity increases the mosquito flight activity and host seeking behavior (Shaman and Day 2007). Rainfall also enhances the nature and extends of vegetation within the water. Growth of vegetation in water will reduce its flow, depth and exposure of sun that all influences the mosquito abundance (Devi and Jahuri 2007). Considerable increase in the mosquito fauna are noticed after 7 days of heavy rain in environments possessing optimum weather conditions of temperature and humidity.

Relative humidity is one of the other important attributes in determining the abundance, distribution and survivability of mosquitoes. The optimum values of relative humidity for the growth and development of mosquitoes is 65-90%. There is species or genera wise sensitivity towards ranges of humidity and each prefer optimum values. Diminishing tendency with respect to mosquito survivability and disease transmission were noticed when the relative humidity falls below 60%. As far as *Anopheles* species considered, the optimum values of relative humidity is 60-80% and this range also influences the transmission of malaria (Pampana 1969). Relative humidity increases in accordance with the atmospheric temperature and total rainfall. As humidity increases, the abundance of mosquito larvae increases and vice versa. In this way, the pattern of interaction among the above climatological attributes determines the richness and abundance of mosquitoes along with the multiplication and development of pathogen within them.

Water is regarded as the most essential element among all other natural resources and is vital for the existence of living organisms including human beings. It is the basin for the origin and sustenance of many life forms. Organisms that use water as a platform for their origin in terms of breeding are many. They use both natural and artificial water sources irrespective of its quantity and quality. Among different organisms that breed in aquatic environments, those involved in the transmission of different diseases prefer more over contaminated or quality deficient water. Organisms even up to microbial level easily enter water systems and to the food chains. Such water resources become reservoir of so many disease-causing agents like bacteria, virus, helminthes and other parasites.

Insects are the principal group of organisms that use water as a breeding ground and many of them are vectors of different diseases. Most of such vectors are belonging to the class, Arthropoda and mosquitoes holds the major part. Mosquitoes breed in a wide variety of water sources resulting in the infestation of so many pathogens such as viruses (dengue fever, chikungunya, Japanese encephalitis etc.), protozoa (malaria) and helminthes (lymphatic filariasis).

Nature and abundance of water sources within a geographical area have very important role in the breeding and subsequent emergence of different species of mosquitoes. Water sources within or adjoining a locality comprises of so many categories as permanent or temporary, small or large in volume, fresh or brackish or polluted. There are so may means to manage water sources within a geographical area that eventually result in the creation or modification of mosquito breeding habitats. Different strategies pertaining to the management of water sources like ponds, canals, rice field, sewerage systems and storm water will contribute to an increased diversity in mosquito breeding habitats. Their role in enhancing breeding habitats are either direct by increasing the surface area of available water sources or indirect by generating new water sources in areas wherein, occurrence of natural surface water is deficient (Amerasinghe and Ariyasena 1990).

The mechanism of development is unique to all the genera of mosquitoes and they breed in a heterogeneous mix of aquatic habitats. The choice of breeding habitats is different for each species as most of them are adapted to distinct water environments. Irrespective of volume, they breed in water habitats that may be fresh or polluted. The most common mosquito habitats include ponds, slow moving canals, sewerages, ground pits, paddy fields, tree holes, discarded tires, coconut shells, ground pools, salt marshes and other artificial containers (Tennesson 1993). In other words, anything that can hold water for a particular period of time can act as potential background for the origin of so many mosquito species. They prefer stagnant or slow moving water for oviposition as the process of breeding is hindered by water flow. If they can do so, the flowing water downpours the immature forms that cannot develop in to their respective adult forms (Tennesson 1993).

Mosquito eggs are deposited on the surface or near the surface of water or in an area where water source can be expected. The egg lying pattern is dissimilar among different genera of mosquitoes. Some genus lay eggs directly on to the water surface as a single unit (*Anopheles, Toxorhynchites*), some in batches pressed in a boat raft like outline (*Culex, Culiseta, Mansonia*) and other genera prefer moistened surfaces, soil surfaces, surfaces close to water and surfaces that expect water in the near future (*Aedes*).

Water depth is a significant factor determining the breeding and subsequent emergence of some mosquito species. Species like *Cx. quinquefasciatus* and *Cx. tritaeniorhynchus* are found to be breed in variety of habitats with high water depth. There is a nonlinear relationship between water depth and breeding of mosquitoes especially in the case of *Ae. aegypti* and *Ae. albopictus*. These species prefer shallow water resources as they are well adapted to breed in small water content. Species like *An. maculates* breed in habitats like shallow pools (5.0–15.0 cm deep) with clear water, mud substrate and plants (Rohani et al. 2011).

Development of eggs to adult mosquitoes occurs through immature forms involving larvae and pupae. All such immature stages are strictly aquatic in nature. Each larva will develop into pupae through four instars or growth stages and normally take 5-15 days to complete. The larvae get their food and nutrients from the water they live and the main source of food are detritus matter, algae, and biofilms. Factors like geographic location, size of the water body, variation in the seasonal distribution of water, sustenance of water volume throughout the year, presence of vegetation in the water, presence of predator in the water, organic composition of water, various nutrients and water temperature determine the abundance of mosquitoes (Tennesson 1993; Russel 1999).

Generally mosquitoes prefer shallow nutrient rich small water bodies (Tennesson 1993). The shallow nature of the water sources will attribute to the reduced abundance of predator organisms and aid in the survivability of mosquitoes. The oviposition, survivability and abundance of different mosquito species are depend on some of the physicochemical and biological attributes of the water. They are pH, turbidity, temperature, organic matter, presence or absence of plants, light and shade, degree of eutrophication and other salts (Mogi 1978; Amerasinghe et al. 1995). Presence of vegetation in the water also favors mosquito breeding. Aquatic vegetation slows down the water flow which is preferentially ideal for the oviposition of mosquitoes. Such habitat also serves as hideouts or mosquito larvae from different predators.

Water temperature plays significant part in the breeding, emergence of a diverse group of mosquitoes and also on the transmission potential of diseases. There exist a strong or moderate correlation between the water temperature and rate of mosquito emergence. The correlation show variation with respect to mosquitoes as the preferred optimum temperature varies among different species and genera. Standardization studies revealed that there will be an upsurge of larval abundance when the temperature is between 23°C and 33°C (Fritsch 1997). Increased water temperature enhances the production of larval food sources like detritus matter, algae etc. so that, there will be an early development of larvae (Mwangangi 2006). Factor like growing vegetation may reduce the incidence of light on the surface of water leading to decline in water temperature. Diminished temperature retards the production of microbial foods on which the mosquito larvae feeds, that eventually lengthens its developmental time. Such delay may result in a longer exposure of larvae towards their predators and thus there will be reduced survivability (Muturi et al. 2008).

pH of water is an influential attribute pertaining to the abundance of mosquito larvae. The range of pH value noticed to be ideal for the growth of mosquito larvae is 5.8 to 8.6. There is variation among different mosquitoes in preference of pH and *Anopheles* mosquitoes have a wider range than *Culicines* (White 1926). Extreme pH conditions have a negative impact on diversity and distribution of mosquitoes. The ideal range of pH for the emergence of *Culex* species like *Culex quinquefasciatus* is found to be 7.1 to 8. Some of the species within the genus *Armigers* can breed in water bodies where the pH values goes beyond 9 (Thavaselvam and Kalyanasundaram 1991).

Generally mosquitoes prefer water with reduced Dissolved Oxygen (DO) content (Tennesson 1993). This has been evidenced by the excess utilization of detritus matter by microorganisms and some of them become food for the developing larvae. There are exceptional cases in which some of the *Anopheles* species show very high upsurge in elevated level of DO (Mukhtar 2003). Studies on *Culex* species showed that the range at which optimum breeding take place is 1-6.2mg/l (Thavaselvam and Kalyanasundaram 1991). There are different opinions on the effect of DO on mosquito emergence. Studies pertaining to *Culex* species show that, there exists a negative correlation between DO and abundance of mosquitoes. Enhanced algal production and associated photosynthesis increases the DO content in water that favors the mosquito larval survivability (Sunish et al. 2006).

The other important water quality attributes that are expected to have influence on the abundance of mosquitoes are total alkalinity, acidity, total hardness, chloride, ammonia nitrogen, nitrate, phosphate, total solids, total dissolved solids and organic detritus matter. (Mogi 1978; Tennesson 1993; Fritsch 1997; Amerasinghe et al. 1995). There are species wise differences in the pattern of selecting ideal sites for oviposition and the most crucial attribute effecting their growth are also different. Total dissolved solids and total solids are essential for the breeding of some of the *Culex* and *Armigeres* species especially *Culex quinquefasciatus* and *Armigeres subalbatus*. Their influences in other mosquito abundance are unclear. Organic matter enhances the breeding of certain *Culex* species. There are so many reports on the positive influence of ammonia nitrogen on the emergence of *Anopheles* mosquitoes. All the mosquitoes preferring sewerage systems prefer high levels of total alkalinity whereas, the acidity poses a negative correlation. Various reports on the effect of chemical nature of breeding habitats revealed the importance of total hardness and chloride in the emergence of some species of *Culex* and *Anopheles*. In this way, it can be concluded that, various environmental and climatological attributes have direct impact on the emergence and abundance of mosquitoes and mosquito borne diseases.

Various factors like distribution of surface water sources and its physico-chemical characteristics are known to considerably influence on the emergence different mosquito vectors. The role of climatological attributes is also significant. All such factors also have impact on specific host -pathogen and pathogen-vector interactions. Upsurges in the mosquito population, especially the medically relevant species enhances the prevalence of so many overwhelming diseases. In the present study, an attempt has been carried out to assess the geo environmental settings of selected locations falling in 10 districts of Kerala for the period 2012-13, wherein highest endemicity rate of filariasis is reported. The study congregate information regarding the extent of water sources, its physico-chemical characteristics and climatological attributes to elucidate the impact on the disease endemicity.

Review of Literature

Environment and Climate plays supreme role in the emergence and resurgence of pathogens and their vectors. They have specific role on the pathogen-vector relationship and also on the vector-host interactions. Geography and topography also determines the type of pathogen to be evolved and its area of distribution by specific vectors. Mosquitoes are the most important disease vectors and transmit so many devastating diseases to humans causing millions of death every year.

Mosquitoes are distributed all over the world except some islands and Antarctica that are permanently frozen. They can thrive in a variety of habitats with the fresh, clear, turbid or polluted water with very high rate of survivability, except in marine habitats with high salt concentration (Rueda 2008). Worldwide, around 3,554 species of mosquitoes have been reported of which only few are medically important and involved in the transmission of diseases (Harbach 2017). *Aedes*, *Anopheles*, *Culex* and *Mansonia* are the important genera of mosquitoes involved in the transmission of major vector borne diseases in the world (Tyagi 2003). Mosquito vectors transmit parasites responsible for diseases such as malaria, dengue fever, chikungunya, filariasis, yellow fever and Japanese encephalitis (Youdeowei and Service 1986; Rozendaal 1997). Each genus of mosquitoes has their own breeding ecology and ovipositional characteristics so that they can prefer specific habitat and season to breed and emerge out. Also they possess different mechanism to withstand in unfavorable climatic and ecological conditions.

There are so many ecological processes that regulate the occurrence of mosquitoes with respect to their abundance and distribution. Such processes are influenced by the changes in the environment and have vital role in the interaction between mosquitoes and human/nonhuman hosts (Sutherst 2004). Both short-term seasonal fluctuations and resultant long-term climatic changes create hindrance to the motility and multiplication of pathogens and their vectors. This is due to the effect of climatic factors in modifying the pathogen and human hosts with respect to their behavior pattern (Patz et al. 2000).

The important human interference affecting the occurrence of vector mosquitoes and their diseases are deforestation, mining, irrigation practices, human inhabitation and urbanization (Vasconcelos et al 2001). Patz et al. (2000) reported the various effects of environmental change on emerging parasitic diseases. Parasites in association with their vectors ensues the transmittance of so many diseases resulting in increased morbidity and mortality of human. Deforestation is the main changes in land use which can result in the formulation of so many other factors including human inhabitation, commercial growth, road construction and water regulator systems. Forests are modified to more reliable agricultural lands that create ambient environment for parasites and their vectors. Such factors along with improper water source management can bring a wide array of breeding habitats for so many vector mosquitoes (Patz et al. 2000).

There are numerous studies pertaining to the effect of climate and environment on pathogens, their vectors and occurrence of diseases. Land use change is an important attribute having enormous impact on the local ecology and habitats that influence mosquito abundance, species composition and ultimately, pathogen transmission. Deforestation, agricultural practices, urbanization and irrigation practices are the important land use changes that are known to affect the emergence of mosquitoes. Such impacts of land use change on mosquito fauna are concomitant to so many other factors resulting in the vector abundance and disease incidence (Douglas 2004).

Landau and Leeuwen (2012) analyzed the spatial urban land cover factors associated with adult mosquitoes like *Aedes aegypti* and *Culex quinquefasciatus* abundance in Tucson, Arizona. Mosquitoes were trapped and land cover variables were extracted from buffer zones around the trapping sites. The most influential variable was determined in terms of stepwise regression. The study revealed that the spatial distribution of mosquitoes in the urban areas is influenced by the microhabitat land cover variables. Land cover partially determined the *Ae. aegypti* and *Cx. quinquefasciatus* habitat suitability in urban environments. Comparison of the regression models specified that land cover changes have more impact on the abundance of *Ae. aegypti* than that of *Cx. quinquefasciatus*. Abundance of these two mosquitoes in the area was supposed to be the reason for occurrence of yellow fever and filariasis.

Land cover factors have also been shown to play pivotal role in the distribution and abundance of *Ae. aegypti*. The container breeder *Ae. aegypti* was studied both under field and laboratory level to find out the effect of land cover on its breeding and emergence. The study revealed that, land use changes especially deforestation affects the abundance and distribution of the mosquitoes and also the incorporation and transmission of dengue virus (Focks et al. 1993). Reiter and La Pointe (2007) studied the landscape factors influencing the spatial distribution and abundance of mosquito vector *Culex quinquefasciatus* in a mixed residential-agricultural community in Hawaii. The effect of varied landscapes like agriculture and forest fragmentation in determining relative abundance of adult *Cx. quinquefasciatus* was studied and reported. The results show that number of mosquito capture was carried out in the agricultural lands and forest fragmentation signifying the importance of filarial disease spread by the vector mosquito.

Land cover changes can bring significant alteration in the temperature and increases the incidence of so many diseases like malaria and filariasis. Kweka et al. (2016) studied the effect of deforestation and land use changes on mosquito productivity and development in western Kenya highlands with special reference to the occurrence of malaria and filariasis. The study revealed that compared to deforested area, the life span of mosquitoes was found to be higher in the forested area. In the forested area, the survival rate of mosquitoes was higher both in the rainy and dry seasons. Deforested low lands were noticed for a shorter survival period than deforested highlands. Such changes in temperature has caused considerable enhancement of sporogony development and adult vector survival highlighting the transmission of malaria and filariasis in the highlands (Kweka et al. 2016).

Deforestation is one of the important land modification creating new territories for the establishment of mosquitoes and their diseases. Studies pertaining to microclimatic changes as a result of land use and land cover pattern like deforestation determined the extent and intensity of many mosquito borne diseases. It is having supreme role on various interactions between mosquitoes and pathogens. The impact of deforestation on the microclimatic attributes determining development of malarial vector *Anopheles gambiae* in Kenya has been reported. The gonotrophic cycle of the malarial vector are affected by the average air temperature. The indoor temperature has shown variation with respect to forested and deforested areas during dry and rainy seasons. The study concluded that, deforestation has enhanced the indoor temperature that minimizes mosquito gonotrophic cycle. This in turn resulted in the increased emergence, biting frequency and vectorial capacity (Afrane 2005).

Increased land vegetation cover along the sides of aquatic habitats may have a positive influence on the abundance of mosquitoes. Vegetation cover such as trees and shrubs may act as sugar sources for both sexes of mosquitoes. The inputs of vegetation in the surrounding water may create sufficient organic detritus matter that influences its chemical attributes. Both factors can attract mosquitoes for their oviposition. The impact of terrestrial vegetation and water chemistry on the emergence of *Culex* mosquitoes were assessed and reported from Chicago. The results revealed that, in the urban landscapes, vegetation cover in the form of shrubs contributed to an increased abundance of *Culex* mosquitoes. Ammonia and nitrate content of water also provided adequate platform for the emergence of mosquitoes (Gardner et al. 2013).

Surtees (1970) studied the impacts caused by paddy field extension and related irrigation on the abundance and occurrence of mosquito-borne diseases such as filariasis. Environment modifications particularly in the form of paddy field development and irrigation have resulted in the enhancement of different mosquito species and diseases. Increased water column in the paddy fields as a result of irrigation will expose them to various pathogenic organisms. Also the increased vegetation may modify the paddy fields as more reliable habitats of mosquitoes.

The important climatological attributes that have impact on the abundance of mosquitoes and their diseases are mean atmospheric temperature, total rain fall and relative humidity. Enhanced temperature enables the mosquitoes to breed and develop in varied environments. In such conditions, mosquitoes take more blood meals as there will be increased digestion. Elevated temperature also helps different pathogens to get develop inside the mosquitoes and shorten the number of days for them to become infective. Mosquito populations are influenced by the extent, intensity and period of rainfall (Russell et al. 1963). Rainfall creates new habitats in the tropical and subtropical regions and affects the reproduction and abundance of mosquitoes. Rainfall in association with near surface humidity increases the mosquito flight activity and host seeking behavior (Shaman and Day 2007). Rainfall also enhances the nature and extends of vegetation within the water. Growth of vegetation in water will reduce its flow, depth and exposure of sun that influences the mosquito abundance (Devi and Jahuri 2007). The optimum values of relative humidity for the growth and development of mosquitoes is 65-90%. Diminishing tendency with respect to mosquito survivability and disease transmission were noticed when the relative humidity falls below 60%.

Possible impact of the climate change on mosquitoes in terms of seasonality of breeding and emerging rates have been studied and reported in Africa. The results revealed that, increased temperature widens the breeding sites heterogeneity and also persuades the mosquitoes to occupy more and more new territories. The study also discussed the possible health threats that are likely to affect these areas including yellow fever, filariasis and dengue fever (Deichstetter 2017).

Epstein et al. (1998) conducted climatic studies with special reference to the occurrence of mosquito borne diseases in Europe. In an interdisciplinary approach, change in the climate has been detected in terms of data from glacial records. Comparison of the glacier data along with temperature profile and mosquito records were carried out at high elevation mountain regions to find out the possible effect of climate on mosquito borne diseases. The study concluded that, at high elevations, there is an increased internal consistency among the attributes studied. The varying temperature ranges contribute to enhanced emergence of mosquitoes signifying public health implications such as malaria.

Evaluation on the impact of climate change on the abundance of mosquitoes and their health implications in Europe have been carried out and reported. The study pointed out that temperature fluctuation affected the overall development of mosquitoes, but the role in the transmission of malaria was insignificant. The climatic changes also affected the mosquito control strategies. Another factor contributing to the enhanced emergence of mosquitoes and prevalence of malaria was agricultural practices (Becker 2008).

Laboratory level examination on the effects of temperature on the transmission of West Nile virus by *Culex tarsalis* was conducted and reported (Reisen et al. 2006). The virus infected mosquitoes were incubated at temperature 10-30^{0}C. The median time between virus imbibitions and its transmission was analyzed using probit analysis as a function of temperature in the range 14-30^{0}C. The results revealed that when temperature increased, the number of days for virus development within the mosquitoes is shortened (Reisen et al. 2006).

Average atmospheric temperature may increase due to the deteriorating influence of global warming. Global warming causes climatic imbalances like alternation in precipitation, increase in the daily average temperature and sea level rise (Reeves et al. 1994). Effect of the varying levels of temperature on the survival rate of *Culex* mosquitoes were analyzed and reported from California. The western equine encephalomyelitis and St. Louis encephalitis vector, *Culex tarsalis* was subjected to studies reliant on temperature. The study revealed that, 1 % temperature increase caused 1% increase in the daily mortality rate of adult mosquitoes. At lower temperature, only few percentages of mosquitoes were surviving. The study as a whole concluded that, mosquito survivorship and virus activity were reduced when there is a temperature increase of 5^{0}C within hotter climate. Both the attributes were decreased when the temperature was increased by 5^{0}C in the colder regions (Reeves et al. 1994).

Studies pertaining to the impact of climate on mosquito borne diseases in Australia revealed that, the seasonal and geographical abundance of vector mosquitoes and their hosts are affected by greenhouse effect induced changes in rainfall and temperature. The effects were mainly on some of the *Anopheles* species causing malaria and *Aedes* species causing yellow fever.

There were also increased occurrence of epidemic polyarthritis as the enhanced winter temperature and summer rainfall favored its vector *Culex annulirostris* (Liehne 1988).

The influence of climate on mosquitoes and mosquito borne diseases has been conducted and reported form different parts of India. Most of them were done in areas wherein repeated occurrences of diseases like malaria or dengue fever have reported. Detailed analysis on the projection of malaria in the near future using baseline data pertaining to climatological attributes were carried out. The four vulnerable areas selected were Himalayan region, northeast, the Western Ghats and coastal region. The results showed that changing climate altered the malarial transmission intensity. There was 5 months increase of transmission intensity in the Himalayan region and 3 months in northeast region. A minimum increase was noticed in the Western Ghats. As there was increased temperature, the transmission intensity was reduced with respect to the coastal region (Dhiman et al. 2011).

There are many organisms that use water as a platform for their growth and development. Contaminated water may contain disease causing agents like Bacteria, Virus, Helminthes and other parasites that are carried to humans by different vectors. Insects are the principal group of organisms that use water as a breeding ground and many of them are vectors of different diseases. Among various insect vectors, mosquitoes stand at the top that breed in a wide variety of water sources and aid in the transmission of infectious diseases like chikungunya, dengue fever, malaria, Japanese encephalitis and filariasis (WHO 1999). They use both natural and artificial water sources, irrespective of its quantity and quality.

Surface water distribution has a pivotal role in the breeding emergence of different species of mosquitoes. Different strategies pertaining to the management of water sources like ponds, canals, rice field, sewerage systems and storm water will contribute to an increased diversity in mosquito breeding habitats (Amerasinghe and Ariyasena 1990). Mosquitoes breed in a heterogeneous mix of aquatic habitats and the mechanism of development is unique to all the genera. Ponds, slow moving canals, sewerages, ground pits, paddy fields, tree holes, discarded tires, coconut shells, ground pools, salt marshes and other artificial containers are the most common mosquito breeding habitats.

Mosquitoes prefer stagnant or slow moving water for oviposition as the process of breeding. Eggs are deposited on the surface or near the surface of water and the lying pattern are dissimilar among different genera of mosquitoes. Development of eggs to adult mosquitoes occurs through immature forms involving larvae and pupae. All such immature stages are strictly aquatic in nature. Factors like geographic location, size of the water body, variation in the seasonal distribution of water, sustenance of water volume throughout the year, presence of vegetation in the water, presence of predator in the water, organic composition of water, various nutrients and water temperature determine the abundance of mosquitoes (Tennesson 1993; Russel 1999).

Water depth is a significant factor determining the breeding and subsequent emergence of some mosquito species (Rohani et al. 2011). Generally mosquitoes prefer shallow nutrient rich small water bodies with low content of dissolved oxygen (Tennesson 1993). The physicochemical and biological attributes determining oviposition, survivability and abundance of different mosquito species in water are pH, turbidity, temperature, organic matter, presence or absence of plants, light and shade, degree of eutrophication and other salts (Mogi 1978; Amerasinghe et al. 1995).

Standardization studies revealed that there will be an upsurge of larval abundance when the water temperature is between 23°C and 33°C (Fritsch 1997). Increased water temperature enhances the production of larval food sources like detritus matter, algae etc. so that, there will be an early development of larvae (Mwangangi 2006). The range of pH value noticed to ideal for the growth of mosquito larvae is 5.8 to 8.6. There are differences in the preference of pH with respect to species or genera and *Anopheles* mosquitoes have a wider range than *Culicines* (White 1926). Generally mosquitoes prefer water with reduced Dissolved Oxygen (DO) content (Tennesson 1993).

From the early 19^{th} century, there were comprehensive studies on the association between abundance of different mosquito species and physico-chemical attributes of breeding habitats. The association among soil nitrification and occurrence of malarial disease (Waddell 1902), positive correlation between mosquito abundance and water pH (Macgregor 1921), role of organic matter in the abundance of mosquito species (Buxton and Hopkins 1924), the negative correlation between ammonia nitrogen and some Indian species of mosquitoes (White 1927) were the important earlier studies. Studies pertaining to the elucidation of most influential physico-chemical factors determining the abundance of mosquitoes in pond ecosystems in America were conducted and reported. The results revealed that pH, dissolved oxygen, organic nitrogen and hydrogen sulphide have supreme role in mosquito abundance (Mary and Beattie 1930). Some mosquito species prefer habitats with high concentration of salts and such associations were well elucidated (Beadle 1939).

Habitat heterogeneity plays a very significant part in the development of mosquitoes. Minakawa et al. (1999) investigated the distribution status and habitat characteristics of mosquitoes from western Kenya. The abundance of some of the *Anopheles* species were evaluated with respect to various attributes such as size of water sources, distance to the nearest human inhabitation, emergent vegetation, algae, detritus matters, habitat types, turbidity and pH. The influence of environmental variables on the emergence of mosquitoes was carried out using multiple linear or multiple logistic regression analysis. The results showed that, all the variable contributing a certain part in the mosquito breeding and the most crucial one was habitat heterogeneity. Studies of similar sort was reported from Kenyan coast in which, physico-chemical attributes of water sources like ponds, drains and mangrove swamps were analyzed to describe their role in the emergence of the mosquito species *Anopheles merus*. Among the various attributes studied, temperature, salinity, conductivity, total dissolved solids and algae were found to be most influential in the abundance of the mosquito species and transmission of malaria (Kipyab et al. 2015).

Studies from Srilanka on the effect of various physico-chemical attributes in the abundance of malarial vector mosquitoes were reported. The results showed that, there were a positive correlation between water temperature and abundance of malarial vector *Anopheles culicifacies*. The other malarial vector *Anopheles varuna* was dependent only on the calcium level in water. Incident light and presence of aquatic vegetation also had influence on the emergence of *Anopheles varuna* (Piyaratne et al. 2005).

Increased population and water scarcity have demanded the use of waste water from urban zones for irrigation purposes in the rural and semi urban areas. Before dispensing, it should be treated properly to minimize the health implications hazards as; it may contain different pathogens. Waste stabilization ponds are the low cost approach to treat waste water, which was adopted by many of the developing countries. Even though waste stabilization ponds remove pathogenic organisms, they generate many open water systems within the urban area that can act as breeding grounds of mosquitoes (Mukhtar et al. 2006). Investigation on the effect of waste stabilization ponds and resultant waste water irrigation of water bodies on the emergence of mosquitoes of medical importance was carried out in Pakistan. Both systems were analyzed for the occurrence of mosquitoes like *Anopheles subpictus*, *Anopheles stephensi*, *Culex quinquefasciatus* and *Culex tritaeniorhynchus*. The study revealed that the aquatic systems under study were involved in the emergence of all the above four mosquito species compared to other natural or artificial habitats. This is due to the fact that, there will be an upsurge in growth of vegetation in the water systems as, they are rich in nutrients. Such vegetation cover could provide enough nutrients for the development of larvae and ensures the protection of larvae from predators (Mukhtar et al. 2006).

Understanding of the habitat ecology and spatial distribution of mosquitoes are very vital in the formulation of their control strategies. Studies in Ethiopia pertaining to the impact of different environmental attributes on the abundance of mosquitoes were carried out and reported. Various water quality parameters studied were area of water sources, vegetation cover, dissolved oxygen, hardness, conductivity, chloride, nitrate, total dissolved solids, pH, temperature, orthophosphate and alkalinity. Climatological variables like temperature and relative humidity were also assessed. Results of the study using different variables and regression analysis revealed that, the abundance of mosquito larvae was influenced by factors like water temperature, incidence of predators or competitors, canopy cover and vegetation (Mereta et al. 2013).

Improper planning related to urban water management and solid waste disposal may result in the formation of drains and ditches, which can enhance the abundance of mosquitoes. Studies in the urban areas of Tanzania revealed that, 70% of the mosquito larvae were emerged from drains with stagnant flow of water. Of the total mosquito fauna identified, *Anopheles* and *Culex* mosquitoes were most predominant groups (Castro et al. 2010).

Studies pertaining to the habitat characteristics and species composition of different mosquito species in Bangladesh were carried out and reported. Different attributes assessed were water depth, temperature, pH, dissolved oxygen, chemical oxygen demand, chlorophyll content, ammonia, incidence of light, turbidity and vegetation. The results showed that, among various parameters studied, mosquito abundance was predominantly affected by dissolved oxygen and chlorophyll a content in water. Positive correlation was observed between water temperature and emergence of *Anopheles* species. Water depth, surrounding vegetation and alkalinity were also found to be influential. Some species of *Culex* and *Toxorhynchites* showed maximum emergence from water sources with high chemical oxygen demand (Bashar et al. 2016).

Lentic aquatic habitats like ponds and rice fields have supreme role in contributing platform for the emergence of mosquito vectors (Koehler 1999). Studies on the role of water reservoirs like ponds and paddy fields on mosquito abundance were carried out in Ludhiana. The water systems were subjected to assessment of various parameters to elucidate their role in the emergence of mosquitoes. The important attributes studied were water temperature, pH, total dissolved solids, alkalinity, free carbon dioxide and dissolved oxygen. The correlation studies showed that, water temperature and alkalinity were the most important parameters determining mosquito abundance. pH, total hardness and total dissolved solids had considerable effect on certain ponds and paddy fields. Dissolved oxygen was found to be negatively correlated with mosquito abundance in all the aquatic habitats (Kocher and Dipthi 2014).

Thavaselvam and Kalyanasundaram (1991) reported the physico-chemical factors influencing the breeding and abundance of *Culex quinquefasciatus* in Pondicherry. Water samples were collected from heterogeneous habitats that were noted to be carrying the larvae of the mosquito species. The water quality attributes studied were pH, temperature, acidity, total solids, salinity, total alkalinity, total hardness, dissolved oxygen, biological oxygen demand, nitrate nitrogen and phosphate. The results explained the limit of all the above attributes in determining maximum emergence of the mosquito species in the study area. Low levels of dissolved oxygen were noticed in all the habitats. Optimum ranges of water temperature and pH that enabled maximum growth of mosquitoes were 23-30^{0}C and 7-9 respectively. Among the different variables studied, ammonia nitrogen and biological oxygen demand were found to the most influential parameters in determining the abundance of mosquitoes.

Identification and characterization of larval habitats of *Anopheles* mosquitoes were carried out with reference to the occurrence of malaria in Thailand. The impact of physicochemical characteristics of breeding habitats like temperature, hardness, carbon dioxide, dissolved oxygen, nitrate, phosphate, silica and pH on the emergence of four species of malarial vector were carried out and reported (Kengluecha et al. 2005). Multiple regression models based results revealed that, out of the 10 categories of habitats identified, 6 contained the malarial vectors. Water temperature, carbon dioxide and hardness were the most influential parameters that determined the abundance of *Anopheles minimus* and it has been observed as the most common vector throughout the year. The results also showed that, no association was noticed between other malarial vectors and any of the environmental variables studied.

Mosquitoes prefer shallow, nutrient rich, small water bodies for oviposition. Water depth is found to be a significant entity determining the breeding and subsequent emergence of some mosquito species as small and shallow water sources are devoid of predator organisms (Rohani et al. 2011). Studies on the abundance of mosquito species *Culex pervigilans* with respect to container surface area and water depth in New Zealand were carried out and reported (Lester and Pike 2003). Influence of container surface area and water depth on the mosquito abundance was analyzed using a multiple regression model. The results revealed that, containers with low surface area were noticed for higher abundance, evidencing the fact that increase in the surface area has decreased the mosquito abundance. No significant relation was noticed among mosquito abundance and occurrence of macro invertebrate predators in the containers.

Different studies carried out on habitat characteristics emphasized the effect of various climatological and hydro geochemical factors that are having an impact on the emergence of different mosquito species. Many of the studies were designed and focused on the prevalence of diseases especially malaria and dengue fever. However, studies with respect to the incidence of filariasis and description regarding its endemicity at different environmental conditions are limited.

In light of the above, the present study has been attempted with the objective of 1) assessment of the geo-environmental conditions of the area having confinement of filariasis and 2) evaluation of the extent of hydrological environments of the area and assessment of their physico-chemical characteristics which are suspected to have an impact on disease confinement. For the study, efforts were carried out to assess the geo environmental settings of selected locations falling in 10 districts of Kerala for the period 2012-13, wherein highest endemicity rate of filariasis is reported. Assessment of the effect of various climatological and hydro geochemical attributes in the origin and emergence of different mosquito species were carried out. Complete details of water environment within the study area were physically verified and measured. Special importance was given to the sewerage system wherein the breeding of filarial vector, *Culex quinquefasciatus* was considerably prominent. Mosquito larvae bearing water samples were analyzed for selected physico-chemical parameters, seasonally for a period of one year from February 2012 to January 2013 to describe its role in mosquito emergence. Climatological attributes like total rainfall, temperature and humidity were also taken in to consideration to explain their possible influence in mosquito abundance and disease endemicity.

Materials and Methods

The present study has been carried out to evaluate the impact of various environmental and climatological attributes responsible for the prevalence of vectors, especially of filariasis in selected locations falling in 10 districts of Kerala. Geo environmental settings of hydrological habitats, their physicochemical characteristics together with climatological attributes were assessed seasonally for a period of one year from February 2012 to January 2013 for deriving conclusions.

The details regarding study area falling in each district, sampling procedures and methods of analysis are summarized in the following section.

I.Study area

1) Trivandrum

Trivandrum is the capital district of Kerala with a total geographic area of 2192 sq. km and the major physiographic unit is midland. Coastal low lands and high lands are also present. The terrain is characterized by geological formations like crystallines and alluvium. The land use pattern shows both forest cover and agricultural lands. Important soil types in the district are red loam, alluvium, brown hydromorphic soil and lateritic soil. The climate experienced in the district is tropical monsoon with a normal annual rainfall of 2035mm. The mean maximum air temperature and humidity experienced in the district are 34^0C and 90% respectively (CGWB 2013).

Recent reports on filariasis in the district reveal that, Manacaud of Trivandrum corporation area has the highest endemicity rate. Hence the present study has been conducted at Manacaud and adjoining places (8°47’19” N latitude and 76° 95’18” E longitude) having a total area of 8.26 sq. km. Geographical boundaries of the location are given in Plate 1.1. The physiography of the location is mid land type with undulating lateritic formations. The area is highly populated and has intermittent vegetation cover. The important places falling / adjoining this site are Kamaleswaram, Ambalathara, Attakualngara, Sreevaraham, Attukal, Chalai and Killipalam.

2) Kollam

Kollam district has a total geographic area of 2491 sq. km with coastal plain, mid land and high land as important physiographic units. The terrain is highly complex with geological formations such as recent alluvium, sub-recent laterite, tertiary sedimentary formations, Archaean crystallines and forest loam. The major soil types are laterite, brown hydromorphic, grayish onattukara and coastal riverine alluvium. The district experiences a tropical humid climate with definite southwest and northeast monsoon seasons. The normal annual rainfall available in the district is 2428mm. The annual mean maximum temperature and humidity are 36.4^{0}C and 89% respectively (CGWB 2013).

The area that is reported for a high endemicity of filariasis in Kollam district was Mangad. This region (8°91’49” N latitude and 76°62’11” E longitude) is situated at a distance of 4 Km from Kollam city. Geographical boundaries of the location are given in Plate 1.1. It is a village coming under Kollam Taluk of Kollam Corporation and accounts for about 5.75 sq. km. The physiography is midland with laterite as the major soil type. Other than having an undulating terrain, the area has a significant cover of paddy fields. The important places within or adjoining Mangad are Anchalummood, Thannikkalmukku, Ambazhavayal, Kandanchira, Palakkadavu, Kilikollur, Aratinmukku and Erapanchal.

3) Alleppey

Alleppey is one among the most established coastal district of Kerala, holding a total area of 1,414 sq.km. There is no reserved forest in the district. The major physiographic units in the district are low land (coastal plain) and mid land. The land use pattern shows built up lands, agriculture lands, water bodies and waste lands of which agriculture land constitutes the major share. There are 4 distinct soil types; coastal alluvium, riverine alluvium, brown hydromorphic soil and lateritic soil. Geological formations like sub-recent laterites and tertiary sediment are distributed along the south east part of the district. The district experiences both tropical humid climate and imperious summer with intermittent seasonal rainfall. The average rainfall accounts for about 2965.4 mm. The mean annual maximum temperature and humidity experienced in the district are 30.7ºC and 87% respectively (CGWB 2013).

Kommady (North latitudes 9°51’39” and East longitude 76°33’04”) was the area under study wherein, highest endemicity of the filarial diseases was reported. Kommady is situated 2Km away from the Alleppey town and coming in Aryad Panchayat under Alleppey Municipality. Geographical boundaries of the location are given in Plate 1.2. The total study area is 7.62 sq. km. Most of the area is costal plane/ low land with alluvial sand as the major soil type. Important local places within or adjoining to Kommady are Thumboli, Chettikkad, Pattukulam, Mangalam, Omanapuzha, Poomkavu, Kattoor and Pathirapally.

4) Ernakulam

Ernakulam district in the state of Kerala is spanning to an area of 3068 Sq. km. The total area can be divided into three distinct units, namely high land, midland and coastal plain. The major soil types of the district are coastal alluvium, riverine alluvium, brown hydromorphic soil and lateritic soil in which lateritic soil covers the major area. The land use pattern of the district comprises of forests, cultivable land, waste land, uncultivable land and cultivable waste land in which cultivable land constitute the major part followed by forests. The district experiences a wet monsoon type climate with substantial raining during north east and southwest monsoon seasons. The normal average annual rainfall obtained in the district is 3359.2 mm. The annual mean values of climatological attributes like maximum temperature and humidity experienced in the districts are 31.40C and 88% respectively (CGWB 2013).

In Ernakulam district, the highest endemicity was reported at Thoppumpady (9°93’56” N latitude and 76°26’09” E longitude). It is located within the Kochi Corporation and regarded as one of the most important fishing units in Kerala. The total study area accounts for 8.54 sq. km. Geographical boundaries of the location are given in Plate 1.2. The physiography of the location is midland with laterite soil. It is a commercial area with lots of buildings and less vegetation cover. The important local places within or adjoining Thoppumpady of the present study site are Karuvelipady, Kallath, Mattancherry and Panayapilly.

5) Thrissur

Thrissur district is located in the central part of Kerala with a total geographic area of 3032 Sq. km, representing 7% of the total area of the state. The geomorphologic categorization include low land (coastal planes and Kole land), mid land and high land. The major soil is of lateritic type. Other types such as brown hydromorphic, river alluvium, coastal soil and forest loam are also present. Archaean crystalline formation, tertiary formation, sub-recent laterite and recent riverine alluvium are the important geological formations within the terrain. The climatic pattern comprised of 4 definite seasons including hot summer, cool winter, northeast and southwest monsoon. The mean annual rainfall experienced in the district is 3198.133 mm. The annual mean maximum atmospheric temperature and relative humidity in the district are 36.2^{0}C and 93% respectively (CGWB 2013).

Chavakkad municipal area (10°58’33” N latitude and 76.0189° E longitude) has reported for a high endemicity of filariasis in Thrissur district. The study site in Chavakkad municipal area is with a total area of 6.67 sq. km Geographical boundaries of the location are given in Plate 1.3. The physiography is a mixture of low costal plane and mid land. The area has medium levels of vegetation. The major soil type is alluvial sand. Important places within or adjoining Chavakkad are Palayoor, Ovungal, Blangad, Thangalpadi and Gurupadapuri.

6) Palakkad

The district of Palakkad has a total geographical area of 4480 Sq. km. The physiographic features divide the district in to midland and high land with highly or moderately undulating terrain. Important soil types in the districts are laterite soil, virgin forest soil, black cotton soil and alluvial soil. The district experiences a tropical humid climate with rainfall at southwest and northeast monsoon. The annual average rainfall available in the district is 2362 mm., which is comparatively less than other districts. The average annual maximum values of atmospheric temperature and humidity experienced in the district are 32.3^{0}C and 90% respectively (CGWB 2013).

The location at which highest endemicity reported in the district of Palakkad was Thirunellai (10°75’52”N latitude and 76°62’32” E longitude). Geographical boundaries of the location are given in Plate 1.3. It is a place coming under Palakkad municipality, 3 Km from Palakkad town. The total study area is around 8.13 sq. km. The location possesses midland and highland physiography with laterites as the major soil type. It is a dry area with hot climate. The important local places within or adjoining Thirunellai are Melamuri, Kallikkad, Vennakkara, Mepparanba and Vaniyamparambu.

7) Malappuram

Malappuram district constitutes 9.13 % of the total area of the state of Kerala and has a total cover of 3550 sq.km. Three physiographic units of the districts are low land, mid land and high land, of which mid land constitutes the major area. The important soil types are laterite, brown hydromorphic, coastal and river alluvium and forest loam. The climate of the district is generally humid with definite dry or wet seasons, with adequate rainfall in the northeast and southwest monsoon seasons. Normal annual average rainfall is 2793.3 mm.

Annual average values of climatological attributes like maximum temperature and relative humidity experienced in the districts are 31.8^{0}C and 92% respectively (CGWB 2013).

Ponnani municipal area (10°76'77" N latitude and 75°92'59" E longitude) in Malappuram district has been selected for the study as it was reported for a higher endemicity of filariasis. The total study area accounts for 5.9 sq. km. Geographical boundaries of the location are given in Plate 1.4. The location has alluvial sand as the major soil type with a low, costal plane physiography. It is a highly populated area with mixed vegetation cover. The important local places within or adjoining Ponnani are Puthuponnani, Ponnani nagaram, Chanthappadi, Chammaravattom Junction, Kollanpadi, Thrikkavu, Mukkadi and Mukkilepeedika.

8) Kozhikode

Kozhikode district has a total geographical area of 2344 sq.km. The physiographic units of the districts are low land that stretches along the costal plane, mid land with rolling or undulating terrain and high land. The important soil types of the district are alluvial, laterite and forest loam. The most common soil is of lateritic type and is distributed mainly along the mid lands. The district experiences tropical monsoon climate with 4 distinct seasons. Tropical rainfall of both southwest and northeast monsoon is contributing to an average annual rainfall of 3698 mm. The average annual maximum temperature and humidity experienced in the district are 30.5^{0}C and 91% respectively (CGWB 2013).

In Kozhikode district, Vellayil (11°26'63" N latitude and 75°77'16" E longitude) of Kozhikode corporation area has been selected for the study as there were reports of high endemicity of filariasis. Geographical boundaries of the location are given in Plate 1.4. The major portion of the study area is coastal plane with alluvial sand as major soil type. The total study area accounts for about 3.53 Km^2. The important local places within or adjoining

Vellayil, the present study site are West hill, Kozhikode beach, Puthiyakadavu, Thoppayil, Kamburam, Kandamkadavu and Konad.

9) Kannur

Kannur district has a total areal extent of 2966 sq.km. Physiographically, the district has low lands, mid land with undulating terrain of laterite formation and high lands with rugged terrains. The major soil types in the districts are laterite, brown hydromorphic, coastal and river alluvium and forest loam. There are several geological formations like gneiss, schist, charnockite and coastal alluvium. The district experiences a wet climate with heavy rainfall in the southwest and northeast monsoon. The average annual rainfall, maximum temperature and relative humidity experienced in the district are 3438 mm, 23.9^{0}C and 88 % respectively (CGWB 2013).

Thalassery municipal area (11°75’33” N latitude and 75.4929° E longitude) in Kannur district has been selected for the study as it was reported for a higher endemicity of filariasis. The total study area accounts for about 4.58 sq. km. Geographical boundaries of the location are given in Plate 1.5. The location has lateritic and alluvial sand as the major soil type with a low, costal plane and midland physiography. The important local places within or adjoining the present study site include Chalil, Gopalpetta, Saidharpalli, Thalayi, Makootam, Chakyattumukku and Punnol.

10) Kasaragod

Kasaragod is the northernmost district of Kerala with a geographical area of 1992 sq.km. The three distinct physiographic units of the districts are coastal plains, midland and high land. The midlands contain rugged terrain with lateritic, colluvium and alluvium deposits. Lateritic, brown hydromorphic, alluvial and forest loam are important soil types of the district of which lateritic soil have a wider coverage. The climate in the district is that of typical Kerala with heavy rain in the monsoon. The average annual rainfall experienced in the district is 3500 mm. Climatological attributes like maximum temperature and relative humidity has annual average values of 31.3^{0}C and 90% respectively (CGWB 2013).

In Kasaragod district, the highest endemicity was reported at Thalangara (12°48’41” N latitude and 74°99’25” E longitude). It is coming under Kasaragod Taluk. The total study area accounts for 3.54 sq. km. Geographical boundaries of the location are given in Plate 1.5. The physiography of the location is midland and high land with undulating lateritic formations. It is a dry area with humid climate and less vegetation cover. The important local places within or adjoining Thalangara are Theruvath, Pallikkal, Kunil, Kandathil and Kadavath.

II. Assessment of habitat characteristics

Assessment of different categories of surface water sources within the study areas of all the districts were carried out. Each location was analyzed for surface water sources like ponds, canals, rice fields, ground pools, sewerages and other impoundments to find out their extend and possible influence on the emergence of mosquitoes. Special emphasis was given to the sewerage system as it is the major breeding ground of filarial vector, *Culex quinquefasciatus*.

Collection of water within specific groves of the land, with moreover a permanent sustenance were treated as ponds. Water sources with a minimum depth of 1 m were categorized as ponds. All other water sources with shallow nature having a depth below this limit were treated as ground pools. Both the systems were stagnant and only few have channels to large water sources. Surface water sources with a minimum length of 100 meters were categorized as canals. The pattern of branching and connections to large water sources were also taken in to consideration. Low land with evidences of farming practices and holding a minimum area of 2000m^2 were treated as paddy fields. Paddy fields that are separated by any natural or artificial land form were separately counted. Criteria accepted in the assessment of sewerage system were, width of the channels, its type (open or closed), site of origin and destination. Based on width, the sewerage systems were placed under 6 categories, consecutively from A to F with a width of 0.25, 0.4, 0.6, 1.0, 1.5 and 2.0 meters respectively, and are separately counted.

Irrespective of the nature of water sources, whether it is fresh or polluted, area of each water systems were evaluated in all the locations under study. The length/width/radius of each water sources was separately measured. Measurement of small sized water sources (ponds and ground pools) were carried out using ordinary measuring tape. Water sources covering large areas (paddy fields and sewerages) were measured using a surveyor's wheel. Longer distances were measured using digital odometer of survey vehicle. For better understanding of connected water bodies, google maps were referred. The length / breadth / radius / area of water resources were estimated and the results are reported.

III. Physico-chemical characterization of water

Along with the quantification of water resources within each area under study, samples were collected for the analysis of selected quality parameters to have an assessment on the influence of such attributes on the emergence of mosquito vectors. Water samples were collected from 6 heterogeneous environments in each location during 3 distinct seasons of the year 2012 to 2013, ie. pre monsoon, monsoon and post monsoon. Sample were collected in 1000 ml volume capacity bottles and brought to laboratory for the analysis of various attributes like pH, temperature, turbidity, total solids, acidity, alkalinity, dissolved oxygen, total hardness and chloride. For the analysis of dissolved oxygen, samples were fixed on spot using specific reagents. All the parameters were analyzed following standard instruments / procedures (APHA 2005).

a) pH

pH of the collected water samples were measured electrometrically using a pH meter (Systronics, MK IV).

b) Temperature

Temperature of all the water samples was measured at the field level using a normal mercury thermometer.

c) Turbidity

Turbidity of samples was determined by Nephelometric method using a Digital Nephelometer (Systronics, Model 341). The results were presented in NTU.

d) Total solid (TS)

Total solid content measure the amount of all kinds of solids (suspended, dissolved, volatile, etc.) in water. Total solids can be determined as the residue left after evaporation of the unfiltered sample.

For the present study, evaporating dishes of suitable size were taken and weighed. 100 ml of respective unfiltered water samples were taken and evaporated to dryness in an oven. After evaporation, the samples were heated at 103ºC for 1 hour in a hot air oven (Rotek, Model 07253). These were then cooled in a desiccator and weighed. Total solids (mg/l) were estimated following the equation:

$$\text{Total solid, mg/L } \frac{(a-b)\times 1000\times 1000}{v}$$

Where,

a	=	Final weight of the dish in g.
b	=	Initial weight of the dish in g
v	=	volume of sample evaporated in ml

e) Acidity

It is measure of the aggregate property of water to react with a strong base with a particular pH. In natural waters, the most important attribute that imparts acidity are carbon dioxide.

Reagents

1. 0.05N Sodium hydroxide
2. Phenolphthalein indicator

Procedure

To 100 ml of water sample in conical flask, added few drops of Phenolphthalein indicator and mixed well. The contents were titrated against 0.05N Sodium hydroxide taken in the burette. The end point was noticed as appearance of pink color

$$\text{Acidity, mg/L} = \frac{(\text{ml x N}) \text{ of NaOH x 1000 x 44}}{\text{ml sample}}$$

f) Total alkalinity

Alkalinity of the water is the capacity to neutralize a strong acid and is characterized by the presence of all hydroxyl ions. The free hydroxyl groups impart alkalinity in natural waters. Such ions are also formed in water due to the hydrolysis of salts such as carbonates and bicarbonates.

Reagents

1. 0.1N Hydrochloric acid
2. 0.1N Sodium Carbonate
3. Methyl orange indicator

Procedure

100ml water sample was taken in conical flask and added 2-3 drops of methyl orange indicator. Mixed well and titrated the contents against 0.1N HCl taken in the burette. The end point was noted as color change from yellow to pink.

$$\text{Total alkalinity as } CaCO_3\text{, mg/L} = \frac{(\text{ml x N}) \text{ of HCl x 1000 x 50}}{\text{ml sample}}$$

g) Dissolved oxygen

Dissolved oxygen is inevitable to keep the water body healthy and to maintain a proper balance among the organisms. Presence of oxygen determines various chemical and biological processes of water bodies. The dissolved oxygen content of water samples were estimated by following Winkler's method.

Reagents

1. 0.025 N Sodium thiosulphate
2. Alkaline Potassium iodide solution
3. Manganous sulphate solution
4. Starch solution
5. Concentrated sulphuric acid

Procedure

Water samples were filled in BOD bottles of 125ml capacity without bubbling and air trapping. Added 1ml of each alkaline Potassium iodide solution and Manganous sulphate solution to the samples along the side of the bottles. Presence of oxygen creates a brown precipitate. Mixed well and kept for 10 minutes. 2 ml of concentrated sulphuric acid was added and mixed well to dissolve the precipitate. The contents (50 ml) were titrated against sodium thiosulphate solution using starch as indicator. The end point was noted as disappearance of dark blue color.

$$\text{Dissolved oxygen, mg/L} = \frac{(\text{ml x N}) \text{ of sodium thiosulphate x 8 x 1000}}{V_2 (V_1 - V/V_1)}$$

Where, V_1 = Volume of sample bottle

V_2 = Volume of content titrated

V = Volume of Potassium iodide and Manganous sulphate

h) Total hardness

Hardness increases the boiling point of water and prevents lather formation with soap. Both cations and anions are responsible for hardness of water. The important cations imparting hardness in water are calcium and magnesium. Anions like carbonates, bicarbonates and sulphates are the major anions giving hardness to water.

Reagents

1. 0.01 M EDTA solution
2. Buffer solution- Mixture of Ammonium chloride, Ammonium hydroxide and disodium EDTA.
3. Eriochrome Black T indicator

Procedure

To 50 ml of water sample in conical flask, added 1 ml of buffer solution. Added 10 mg of Eriochrome Black T indicator and mixed well. Development of a wine red color was noticed. The contents were then titrated against EDTA solution taken in the burette. The end point was noticed as color change from wine red to blue.

$$\text{Total Hardness as } CaCO_3\text{, mg/L} = \frac{\text{(ml EDTA used x 1000}}{\text{ml sample}}$$

i) Chloride

Chlorides are present in all natural waters. Sewage discharges in to the water bodies will enhance the chloride content.

Reagents

1. 0.02 N Silver nitrate
2. 5% potassium chromate solution

Procedure

To 50 ml of water samples, added 2 ml of 5% potassium chromate solution and mixed well. Titrated the contents against 0.02 N Silver nitrate solution taken in the burette. Appearance of reddish brown color persisting for 30 seconds was noted as end point.

$$\text{Chloride, mg/L} = \frac{\text{(ml x N) of } AgNO_3 \text{ x 1000 x 35.45}}{\text{ml sample}}$$

IV. Assessment of climatological characteristics

The most important climatological attributes that are expected to have supreme role on the abundance of mosquito vectors are maximum and minimum atmospheric temperature, total rainfall and relative humidity. District wise values of each of these attributes with special reference to the study locations for a period of one year from February 2012 to January 2013 were procured from the office of the Meteorological Department of the Government of India, located at Trivandrum. The mean values of all the attributes experienced at each location during pre monsoon, monsoon and post monsoon seasons were calculated and presented in tables.

Results and Discussion

The present study investigated hydro-geographical and hydro-geochemical characteristics of selected locations in 10 districts of Kerala, which are reported to have the endemicity of filariasis. In pursuit of availing information on the role of various environmental and climatic factors on the occurrence of filarial disease, assessment of the total surface of water resources, their physic-chemical attributes along with selected climatological parameters were carried out seasonally for a period of one year from February 2012 to January 2013. The most ideal attributes determining the endemicity of filarial disease and the occurrence its vector mosquitoes were also evaluated.

Assessment of water resources in all the locations falling in 10 districts of Kerala were carried out. The type, nature, number and distribution of all the water sources along with their area were estimated to have an evaluation on their influence on the abundance of mosquito vectors and occurrence of filariasis. The pattern of categorization of water sources to particular types sturdily followed certain criteria which include size of water sources, area, depth characteristics, sustenance period, branching points etc. Also the physico chemical characterization of water bodies was carried out in accordance with the analytical results of water quality. Meteorological data has been procured for analyzing climatological inputs. Results showing the types and numbers of water sources within the study area of all the districts under study are depicted in Table 1.1. Area of water sources in the study area of all the districts under study are given in Table 1.2. Total area of water sources in all the locations under study along with their percentage contribution are depicted in Table 1.3 and percentage of water resources to the total study area of all the districts are depicted in Table 1.4. Plate 1.6 shows heterogeneity of water sources from all the districts under study.

Table 1.1. Types and number of water resources within the study area of all the districts under study

Sl No	District	Location	Pond	Canal	Sewerage	Ground Pool	Rice field	Total
1	Trivandrum	Manacaud	3	3	33	-	3	42
2	Kollam	Mangad	1	5	12	1	10	29
3	Alleppey	Kommady	14	9	15	1	-	39
4	Ernakulam	Thoppumpady	6	2	39	-	-	47
5	Thrissur	Chavakkad	7	2	16	7	2	34
6	Palakkad	Thirunellai	8	2	19	-	6	35
7	Malappuram	Ponnani	6	5	23	8	1	33
8	Kozhikode	Vellayil	3	4	26	1	-	34
9	Kannur	Thalassery	1	-	21	-	2	24
10	Kasaragod	Thalangara	1	1	17	-	-	19

Table 1.2. Area of water resources in the study area of all the districts under study

Sl No	District	Location	Pond (m^2)	Canal (m^2)	Sewerage (m^2)	Ground Pool (m^2)	Rice field (m^2)	Total area of water resources (m^2)
1	Trivandrum	Manacaud	29350	3870	14400.5	-	130000	177620.5
2	Kollam	Mangad	2400	2430	3728	4000	238200	250758
3	Alleppey	Kommady	1446	31930	2050	6400	-	41826
4	Ernakulam	Thoppumpady	10670	20890	17033.5	-	-	48593.5
5	Thrissur	Chavakkad	10650	64800	9265	2777	54500	141992
6	Palakkad	Thirunellai	25724	5200	6414	-	586400	623738
7	Malappuram	Ponnani	11512	4020	10458	1452	3600	31042
8	Kozhikode	Vellayil	9900	4775	9715.2	800	-	25190.2
9	Kannur	Thalassery	120	-	10086.8	-	83875	94081.8
10	Kasaragod	Thalangara	300	2555	8674.6	-	-	11529.6

Table 1.3. Percentage of water resources within the study area of all the districts under study

Sl No	District	Location	Pond (%)	Canal (%)	Sewerage (%)	Ground Pool (%)	Rice field (%)
1	Trivandrum	Manacaud	16.52	2.18	8.11	-	73.19
2	Kollam	Mangad	0.96	0.97	1.48	1.6	94.99
3	Alleppey	Kommady	3.46	76.34	4.9	15.3	-
4	Ernakulam	Thoppumpady	21.96	42.99	35.05	-	-
5	Thrissur	Chavakkad	7.50	45.65	6.52	1.95	38.38
6	Palakkad	Thirunellai	4.12	0.83	1.03	-	94.01
7	Malappuram	Ponnani	37.08	12.95	33.69	4.68	11.60
8	Kozhikode	Vellayil	39.30	18.96	38.56	3.18	-
9	Kannur	Thalassery	0.13	-	10.72	-	89.15
10	Kasaragod	Thalangara	2.6	22.16	75.24	-	-

Table 1.4. Percentage of water resources to the total study area of all the districts under study

Sl No	District	Location	Total study area (sq. km)	Total area of water resources within the study area (sq. km)	Percentage of water sources to the total study area
1	Trivandrum	Manacaud	8.26	0.178	2.15
2	Kollam	Mangad	5.75	0.251	4.37
3	Alleppey	Kommady	7.62	0.042	0.55
4	Ernakulam	Thoppumpady	8.54	0.049	0.57
5	Thrissur	Chavakkad	6.67	0.142	2.12
6	Palakkad	Thirunellai	8.13	0.624	7.67
7	Malappuram	Ponnani	5.90	0.031	0.52
8	Kozhikode	Vellayil	3.53	0.025	0.71
9	Kannur	Thalassery	4.58	0.094	2.05
10	Kasaragod	Thalangara	3.54	0.012	0.34

Field level assessment of all the locations under study revealed that, the heterogeneity of water sources included ponds, canals, ground pools, paddy fields and sewerage channels. Evaluation of water sources with respect to its area and heterogeneity at Manacaud and adjoining places of Trivandrum district revealed that, there were a total number of 42 water sources including 3 ponds, 3 canals, 33 sewerage channels and 3 rice fields. The total water source area evaluated was 177620.5 m^2 to which, rice fields contributed a higher percentage (73.19%) followed by ponds (16.52%), sewerages (8.11%) and canals (2.18%). The overall assessment shows that, 2.15% area of the

Manacaud and adjoining places holds water sources in the form of ponds, sewerages, canals and rice fields.

In Kollam district, the study area Mangad and adjoining places occupied a total number of 29 water sources including 1 pond, 3 canals, 12 sewerage channels, 1 ground pool and 10 rice fields. Rice fields occupied maximum area and percentage (238200 m^2, 94.99%) followed by ground pools (4000 m^2, 1.6%), sewerages (3728 m^2, 1.48%), canals (2430 m^2, 0.97%) and ponds (2400 m^2, 0.96%). The results showed that, the total area of water sources evaluated was 250758 m^2 and it account for 4.37% area of total area under study within Mangad and adjoining places.

Assessment of water sources at the filarial endemic locations such as Kommady and adjoining places of Alleppey district revealed that, there were a total number of 39 water sources inclusive of 14 ponds, 9 canals, 1 ground pool and 15 sewerage channels. The area of each water sources such as ponds, canals, ground pools and sewerages evaluated were 1446 m^2 (3.46%), 31930 m^2 (76.34%), 6400 m^2 (15.3%) and 2050 m^2 (4.9%) respectively. The total water source area evaluated was 41826 m^2 that comes around 0.55% of the total study area.

In Ernakulam district, assessment of water sources at the filarial endemic areas such as Thoppumpady and adjoining places revealed that, there were a total number of 47 water sources inclusive of 6 ponds, 2 canals and 39 sewerage channels. Canals occupied a major area and percentage (20890 m^2, 42.99%), followed by sewerages (17033.5 m^2, 35.05%) and ponds (10670 m^2, 21.96%). The total water sources area evaluated was 48593.5 m^2 which makes 0.57% of the total study area.

Evaluation of water sources at the filarial endemic locations within Thrissur district revealed that, Chavakkad municipal area and adjoining places occupied a total number of 34 water sources. 7 ponds, 2 canals, 16 sewerage channels, 7 ground pools and 2 rice fields contributed to a total area of 141992 m^2. Of the total area of water sources, canals occupied higher area of

64800 m^2 (45.65%) followed by rice fields, 54500 m^2 (38.38%). The area contributed by ponds, sewerages and ground pools were 10650 m^2 (7.5%), 9265 m^2 (6.52%) and 2777 m^2 (1.95%) respectively. The results have concluded that, 2.12% of the total study area was occupied by the water sources.

In Palakkad district, the location where in highest endemicity of filariasis reported was Thirunellai and adjoining places. Assessment of water sources within these areas revealed a total number of 35 water sources. The total water source area evaluated was 623738 m^2 of which 586400 m^2 (94.01%) was rice fields. The other water sources assessed were ponds (25724 m^2, 4.12%), canals (5200 m^2, 0.83%) and sewerage channels (6414 m^2, 1.03%). The results showed that, 7.67% of the total study area was occupied by these water sources.

Ponnani municipal area and adjoining places were the locations in Malappuram district wherein highest endemicity of filariasis has reported. Evaluation of total area of water sources within these locations showed that, there were a total of 33 water sources inclusive of 6 ponds, 5 canals, 23 sewerage channels, 8 ground pools and 1 rice field. The total water sources area assessed was 31042 m^2 that comes around 0.52% of the total study area. Of the total water sources, 37.08% (11512 m^2) was ponds, 12.95% (4020 m^2) was canals, 33.69% (10458 m^2) was sewerages, 4.68% (1452 m^2) was ground pools and 11.60% (3600 m^2) was rice fields.

Evaluation of water sources at the filarial endemic locations in Kozhikode district revealed that, Vellayil and adjoining places occupied a total number of 34 water sources. 3 ponds, 4 canals, 26 sewerage channels, 1 ground pool contributed to a total area of 25190.2 m^2. Of the total area of water sources, ponds occupied a higher area of 9900 m^2 (39.3%) followed by sewerages, 9715.2 m^2 (38.56%). The area contributed by canals and ground pools were 4775 m^2 (18.96%) and 800 m^2 (3.18%) respectively. The results have evidenced that, 0.71% of the total study area was occupied by the water sources.

Assessment of water sources at the filarial endemic locations such as Thalassery municipal area of Kannur district revealed that, there were a total of 24 water sources inclusive of 1 pond, 21 sewerage channels and 2 rice fields. The area of each water sources such as ponds, sewerages and rice fields evaluated were 120 m^2 (0.13%), 10086.8 m^2 (10.72%) and 83875 m^2 (89.15%) respectively. The total water source area evaluated was 94081.8 m^2 that comes around 2.05% of the total study area.

In Kasaragod district, the location where in highest endemicity of filariasis reported was Thalangara and adjoining places. Assessment of water sources within these locations revealed a total number of 19 water sources. The total water source area evaluated was 11529.6 m^2 of which 8674.6 m^2 (75.24%) was sewerage channels. The other water sources assessed were ponds (300 m^2, 2.6%) and canals (2555 m^2, 22.16%). The results showed that, 0.34% of the total study area was occupied by these water sources.

Analysis based on the number, area and percentage of water sources revealed a varied statistics among the districts. Upon considering the number of water sources in all the locations under study, Thoppumpady of Ernakulam district occupied most number of water sources (47) followed by Manacaud of Trivandrum (42) and Kommady of Alleppey (39) districts. Least number of water sources was recorded at Thalangara of Kasaragod district (19). As far as the number of each type of water sources concerned, Kommady and adjoining places of Alleppey district was noticed for most number of ponds (14) followed by Thirunellai of Palakkad (8) and Chavakkad of Thrissur (7) districts. Similarly most number of canal systems were reported from Kommady of Alleppey district (9) followed by Mangad of Kollam (5) and Ponnani of Malappuram (5) districts. Among the 10 districts under study, most number of ground pools was recorded at Ponnani of Malappuram district (8) followed by Chavakkad of Thrissur (7) districts. Mangad of Kollam was notice for most number of rice fields (10) followed by Thirunellai of Palakkad (6) and Manacaud of Trivandrum (3) districts. As far as the sewerage system concerned, Thoppumpady of Ernakulam district (39) was noticed for most number of sewerage channels followed by Manacaud of Trivandrum (33) and Vellayil of Kozhikode (26) districts.

Upon considering the area of each water sources, Manacaud of Trivandrum holds a large area of ponds (29350 m^2) followed by Thirunellai of Palakkad (25724 m^2) and Ponnani of Malappuram (11512 m^2) districts. Chavakkad of Thrissur district occupied larger canal area (64800 m^2) followed by Kommady of Alleppey (31930 m^2) and Thoppumpady of Ernakulam (20890 m^2) districts. Larger area of ground pools were recorded at Kommady of Alleppey district (6400 m^2) followed by Mangad of Kollam (4000 m^2) and Chavakkad of Thrissur (2777 m^2) districts. Thirunellai of Palakkad district was noticed for a larger area of rice fields (586400 m^2) followed by Mangad of Kollam (238200 m^2) and Manacaud of Trivandrum (130000 m^2) districts. A larger area of sewerage system were recorded at Thoppumpady of Ernakulam district (17033.5 m^2) followed by Manacaud of Trivandrum (14400.5 m^2) and Thalassery of Kannur (10086.8 m^2) districts.

Upon considering the percentage area contribution of each water sources in all the locations under study, maximum percentage area contribution with respect to ponds was noticed at Vellayil of Kozhikode district (39.3%) followed by Ponnani of Malappuram (37.08%) and Thoppumpady of Ernakulam (21.96%) districts. Percentage area contribution by canals was higher at Kommady of Alleppey district (76.34%) followed by Chavakkad of Thrissur (45.65%) and Thoppumpady of Ernakulam (42.99%) districts. Similarly, Percentage area contribution by ground pools was higher at Kommady of Alleppey district (15.3%) followed by Ponnani of Malappuram (4.68%) and Vellayil of Kozhikode (3.18%) districts. Percentage area contribution by rice fields was maximum at Mangad of Kollam district (94.99%) followed by Thirunellai of Palakkad (94.01%) and Thalassery of Kannur (89.15%) districts.

Percentage area contribution by sewerage systems was higher at Thalangara of Kasaragod District (75.24%) followed by Vellayil of Kozhikode (38.56%) and Thoppumpady of Ernakulam (35.05%) districts.

The overall assessment revealed that, upon considering the water sources area to the total study area, Thirunellai of Palakkad district occupied a larger area of water sources (7.67%) followed by Mangad of Kollam (4.37%) and

Manacaud of Trivandrum (2.15%) districts. This is attributed to the fact that, all of these locations have a larger area of rice fields. Thalangara of Kasaragod (0.34%), Ponnani of Malappuram (0.52%) and Kommady of Alleppey (0.55%) districts were noticed for a lower percentage of water sources to the total study area.

Mosquitoes breed in a wide variety of habitats and the most important types of habitat noticed in the study was sewerage systems. As these systems are the major breeding grounds of the filarial vector, *Culex quinquefasciatus*, detailed study pertaining to them were carried out.

Based on width, sewerage channels were grouped in to 6 categories. The different categories of sewerage systems noticed in the study areas of all the districts under study were Category A (0.25 m width), Category B (0.4 m width), Category C (0.6 m width), Category D (1 m width), Category E (1.5 m width) and Category F (2 m width). Details of sewerages with respect their category and type (open or closed) in the study area of all the districts under study is depicted in Table 1.5. Percentage area of each category of sewerage channels in the study areas of all the districts under study is depicted in Table 1.6. Plate 1.7 shows different types of sewerage channels noticed at all the locations.

Table 1.5. Details of sewerage in the study area of all the districts under study

Sl. No	Location	District	Sewerage category	Sewerage width (m)	Sewerage Type				Total area of each category of sewerage (m^2)	Total area of sewerage in the study area (m^2)
					Open		Closed			
					Length (m)	Area(m^2)	Length (m)	Area(m^2)		
1	Manacaud	Trivandrum	A	0.25	2740	685	5830	1457.5	2142.5	14400.5
			C	0.6	890	534	3340	2004	2538	
			E	1.5	560	840	5920	8880	9720	
		Total area of each type of sewerage (m^2)			2059		12341.5			
2	Mangad	Kollam	B	0.4	940	376	4680	1872	2248	3728
			D	1	160	160	1320	1320	1480	
		Total area of each type of sewerage (m^2)			536		3192			
3	Kommady	Alleppey	B	0.4	1420	568	1780	712	1280	2050
			D	1	90	90	680	680	770	
		Total area of each type of sewerage (m^2)			658		1392			
4	Thoppumpad y	Ernakulam	A	0.25	3230	807.5	4260	1065	1872.5	17033.5
			B	0.4	1240	496	4450	1780	2276	
			E	1.5	260	390	8330	12495	12885	
		Total area of each type of sewerage (m^2)			1693.5		15340			
5	Chavakkad	Thrissur	A	0.25	1920	480	2860	715	1195	9265
			B	0.4	1110	444	2590	1036	1480	
			D	1	340	340	6250	6250	6590	

Sl. No	Location	District	Sewerage category	Sewerage width (m)	Sewerage Type				Total area of each category of sewerage (m^2)	Total area of sewerage in the study area
					Open		Closed			
					Length (m)	Area(m^2)	Length (m)	Area(m^2)		
		Total area of each type of sewerage (m^2)			1264		8001			
6	Thirunellai	Palakkad	B	0.4	3980	1592	3680	1472	3064	6414
			D	1	650	650	2700	2700	3350	
		Total area of each type of sewerage (m^2)			2242		4172			
7	Ponnani	Malappuram	B	0.4	7960	3184	3110	1244	4428	10458
			D	1	210	210	5820	5820	6030	
		Total area of each type of sewerage (m^2)			3394		7064			
8	Vellayil	Kozhikode	B	0.4	2760	1104	6698	2679.2	3783.2	9715.2
			D	1	676	676	3486	3486	4162	
			F	2	360	720	525	1050	1770	
		Total area of each type of sewerage (m^2)			2500		7215.2			
9	Thalassery	Kannur	B	0.4	3796	1518.4	6196	2478.4	3996.8	10086.8
			E	1.5	380	570	3680	5520	6090	
		Total area of each type of sewerage (m)			2088.4		7998.4			
10	Thalangara	Kasaragod	B	0.4	2628	1051.2	4636	1854.4	2905.6	8674.6
			E	1.5	196	294	3650	5474	5768	
		Total area of each type of sewerage (m)			1345.2		7329.4			

Table 1.6. Percentage area of different types of sewerage in the study area of all the districts under study

	District	Location				Sewerage Type

Sl No			Sewerage category	Sewerage Width (m)	Percentage area to total area (m^2)	Open (%)	Closed (%)
1	Trivandrum	Manacaud	A	0.25	14.88	31.97	68.03
			C	0.6	17.62	21.04	78.96
			E	1.5	67.50	8.64	91.36
2	Kollam	Mangad	B	0.4	60.30	16.73	83.27
			D	1	39.70	10.81	89.19
3	Alleppey	Kommady	B	0.4	62.44	44.38	55.62
			D	1	37.56	11.69	88.31
4	Ernakulam	Thoppumpady	A	0.25	10.99	43.12	56.88
			B	0.4	13.36	21.79	78.21
			E	1.5	75.65	3.03	96.97
5	Thrissur	Chavakkad	A	0.25	12.90	40.17	59.83
			B	0.4	15.97	30	70
			D	1	71.13	5.16	94.84
6	Palakkad	Thirunellai	B	0.4	47.77	51.96	48.04
			D	1	52.23	19.4	80.6
7	Malappuram	Ponnani	B	0.4	42.34	71.91	28.09
			D	1	57.66	3.48	96.52
8	Kozhikode	Vellayil	B	0.4	38.94	29.18	70.82
			D	1	42.84	16.24	83.76
			F	2	18.22	40.68	59.32
9	Kannur	Thalassery	B	0.4	39.62	37.99	62.01
			E	1.5	60.38	9.36	90.64
10	Kasaragod	Thalangara	B	0.4	33.50	36.18	63.82
			E	1.5	66.50	5.1	94.9

The total sewerage channel area evaluated at Manacaud of Trivandrum district was 14400.5 m^2 of which, both open and closed types occupied 2059 m^2 (14.3%) and 12341 m^2 (85.7%) area respectively. Based on width, three categories of open and closed types of sewerage channels were noticed. Sewerage category A occupied a total area of 2142.5 m^2 (14.88%), category C occupied 2538 m^2 (17.62%) and category E occupied 9720 m^2 (67.5%). Detailed analysis of each category of sewerage channels revealed that, 31.97% (685 m^2) area of category A was open and 68.03% (1457.5 m^2) was closed. Category C comprised of 21.04% (534 m^2) area as open and 78.96% (2004 m^2) as closed. 8.64% (840 m^2) area of sewerage category E was open and 91.36% (8880 m^2) area was closed.

Mangad of Kollam district was noticed for a total sewerage network area of 3728 m^2 of which, 536 m^2 (14.37%) was open and 3192 m^2 (85.62%) was closed types. There were 2 categories of open and closed types of sewerage channels of which, category B occupied a total area of 2248 m^2 (60.3%) and category D occupied 1480 m^2 (39.7%). Analysis of each category of sewerage channels revealed that, 16.73% (376 m^2) area of category B was open and 83.27% (1872m^2) was closed. Category D comprised of 10.81% (160 m^2) area as open and 89.19% (1320 m^2) as closed.

The total area of sewerage channels assessed at Kommady of Alleppey district was 2050 m^2 of which, both open and closed types occupied 658 m^2 (32.1%) and 1391 m^2 (67.9%) area respectively. Two categories of open and closed types of sewerage channels were noticed of which, category B occupied a total area of 1280 m^2 (62.44%) and category D occupied 770 m^2 (37.56%). Detailed analysis of each category of sewerage channels revealed that, 44.38% (568 m^2) area of category B was open and 55.62% (712 m^2) was closed. Category D comprised of 11.69% (90 m^2) area as open and 88.31% (680 m^2) as closed.

Thoppumpady of Ernakulam district was noticed for a total sewerage channel area of 17033.5 m^2 of which, 1693.5 m^2 (9.94%) was open and 15340 m^2

(90.06%) was closed types. Three categories of open and closed types of sewerage channels were recorded. Sewerage category A occupied a total area of 1872.5 m^2 (10.99%), category B occupied 2276 m^2 (13.36%) and category E occupied 12885 m^2 (75.65%). Detailed analysis of each category of sewerage channels revealed that, 43.12% (807.5 m^2) area of category A was open and 56.88% (1065 m^2) was closed. Category B comprised of 21.79% (496 m^2) area as open and 78.21% (1780 m^2) as closed. 3.03% (390 m^2) area of sewerage category E was open and 96.97% (12495 m^2) area was closed.

The total sewerage channel area evaluated at Chavakkad of Thrissur district was 9265 m^2 of which, both open and closed types occupied 1264 m^2 (13.64%) and 8001 m^2 (86.36%) area respectively. There were three categories of open and closed types of sewerage channels. Sewerage category A occupied a total area of 1195 m^2 (12.9%), category B occupied 1480 m^2 (15.97%) and category D occupied 6590 m^2 (71.13%). Analysis of each category of sewerage channels revealed that, 40.17% (480 m^2) area of category A was open and 59.83% (715 m^2) was closed. Category B comprised of 30% (444 m^2) area as open and 70% (1036 m^2) as closed. 5.16% (340 m^2) area of sewerage category D was open and 94.84% (6250 m^2) area was closed.

Thirunellai of Palakkad district was noticed for a total sewerage network area of 6414 m^2 of which, 2242 m^2 (34.95%) was open and 4172 m^2 (65.05%) was closed types. There were two categories of open and closed types of sewerage channels of which, category B occupied a total area of 3064 m^2 (47.77%) and category D occupied 3350 m^2 (52.23%). Analysis of each category of sewerage channels revealed that, 51.96% (1592 m^2) area of category B was open and 48.04% (1472 m^2) was closed. Category D comprised of 19.4% (650 m^2) area as open and 80.6% (2700 m^2) as closed.

Evaluation of total sewerage channel area at Ponnani of Malappuram district revealed that, there were a total of 10458 m^2 area of which, 3394 m^2 (32.45%) was open and 7064 m^2 (67.55%) was closed types. Two categories of open and closed types of sewerage channels were noticed of which, category B occupied a total area of 4428 m^2 (42.34%) and category D occupied 6030 m^2 (57.66%). Analysis of each category of sewerage channels revealed that, 71.91% (3184 m^2) area of category B was open and 28.09% (1244 m^2) was closed. Category D comprised of 3.48% (210 m^2) area as open and 96.52% (5820 m^2) as closed.

Vellayil of Kozhikode district was noticed for a total sewerage channel area of 9715.2 m^2 of which, 2500 m^2 (25.73%) was open and 7215.2 m^2 (74.27%) was closed types. There were 3 categories of open and closed types of sewerage channels. Sewerage category B occupied a total area of 3783.2 m^2 (38.94%), category D occupied 4162 m^2 (42.84%) and category F occupied 1770 m^2 (18.22%). Analysis of each category of sewerage channels revealed that, 29.18% (1104 m^2) area of category B was open and 70.82% (2679.2 m^2) was closed. Category D comprised of 16.24% (676 m^2) area as open and 83.76% (3486 m^2) as closed. 40.68% (720 m^2) area of sewerage category F was open and 59.32% (1050 m^2) area was closed.

The total area of sewerage channels assessed at Thalassery of Kannur district was 10086.8 m^2 of which, both open and closed types occupied 2088.4 m^2 (20.7%) and 7998.4 m^2 (79.3%) area respectively. Two categories of open and closed types of sewerage channels were noticed of which, category B occupied a total area of 3996.8 m^2 (39.62%) and category E occupied 6090 m^2 (60.38%). Detailed analysis of each category of sewerage channels revealed that, 37.99% (1518.4 m^2) area of category B was open and 62.01% (2478.4 m^2) was closed. Category E comprised of 9.36% (570 m^2) area as open and 90.64% (5520 m^2) as closed.

Thalangara of Kasaragod district was noticed for a total sewerage area of 8474.6 m^2 of which, 1345.2m^2 (15.51%) was open and 7329.4 m^2 (84.49%) was closed types. Two categories of open and closed types of sewerage channels of which, category B occupied a total area of 2905.6 m^2 (33.5%) and category E occupied 5768 m^2 (66.5%). Analysis of each category of sewerage channels revealed that, 36.18% (1051.2 m^2) area of category B was open and 63.82% (1854.4 m^2) was closed. Category E comprised of 5.1% (294 m^2) area as open and 94.9% (5474 m^2) as closed.

Upon comparing the sewerage systems of all the locations under study, it can be concluded that, Thoppumpady of Ernakulam district occupied a larger area of sewerage channels (17033.5 m^2) with 3 categories (A,B,E) followed by Manacaud of Trivandrum (14400.5 m^2) with 3 categories (A,C,E) and Ponnani of Malappuram (10458 m^2) with 2 categories (B,D). The most common sewerage category was B, which occupied at 9 locations under study. Categories D, E and A were present at 6, 4 and 3 locations respectively. Categories C and F were present at only one location each. All the districts occupied both open and closed types of sewerages. A larger area of open sewerage system was noticed at Ponnani of Malappuram district (3394 m^2) followed by Vellayil of Kozhikode (2500 m^2) and Thirunellai of Palakkad (2242 m^2) districts.

In the present study, water sources in all the locations under study were evaluated to elucidate their influence on the abundance of mosquitoes and occurrence / confinement of filariasis. The results revealed that, all the locations retained significant area of water sources. Abundance of water sources within a geographical area have very important role in the breeding and subsequent emergence of different species of mosquitoes. Different strategies pertaining to the management of water sources like ponds, canals, rice field, sewerage systems and storm water are known to enhance the heterogeneity mosquito breeding habitats (Amerasinghe and Ariyasena 1990).

With respect to number and area, water sources showed varied statistics in all the locations under study. There were 42 water sources at Manacaud of Trivandrum, 29 at Mangad of Kollam, 39 at Kommady of Alleppey, 47 at Thoppumpady of Ernakulam, 34 at Chavakkad of Thrissur, 35 at Thirunellai of Palakkad, 33 at Ponnani of Malappuram, 34 at Vellayil of Kozhikode, 24 at Thalassery of Kannur and 19 at Thalangara of Kasaragod districts.

Lentic aquatic habitats like ponds and rice fields have supreme role in contributing platform for the emergence of mosquito vectors (Koehler 1996). Paddy fields are the most significant environmental modification as part of agricultural development. The shallow nature with no flow enables so many mosquito species to use them as potential breeding grounds. Water column within the paddy fields are sustained throughout the year as most of them have adjoining networks in the form of canals or lakes with incessant supply of water (Douglas 2004).

Generally mosquitoes prefer shallow nutrient rich water bodies (Tennesson 1993) for their growth and multiplication. The shallow nature of the water sources will attribute to the reduced abundance of predator organisms and aid in the survivability of mosquitoes. Irrespective of volume, they breed in water habitats that may be fresh or polluted. Different types of water sources assessed in the present study along all the locations were ponds, canals, sewerages, ground pools and rice fields. In accordance with the climatic events experienced in these locations especially total rainfall, all of these systems are retained varied volume of water during different seasons. This also resulted in variation in available water and its surface area for the mosquito breeding. The water systems assessed from all the locations under study were rich enough in volume to support the growth of different mosquito species.

Increased population and urbanization have resulted in the enhanced generation of solid and liquid wastes. All the locations under study are part of urban or semi urban environments wherein, an enhanced production of daily sewage occurs. Most of the water sources under study have been noticed for the disposal of domestic wastes. Failure in developing strategies pertaining to the disposal of wastes have created so many open or closed stagnated aquatic habitats. Studies reported that, in the urban systems, 70% of the mosquito larvae and adults are emerging from drains and sewers with stagnant flow of water. The most important categories of mosquitoes preferring these systems are *Culex, Anopheles and Armigeres* (Castro et al. 2010). Upon comparing the sewerage systems of all the locations under study, it can be concluded that, significant percentages of water sources in all the locations are occupied by sewerage channels. This has been more pronounced at Thoppumpady of Ernakulam, Manacaud of Trivandrum and Ponnani of Malappuram districts. All the districts occupied both open and closed types of sewerages.

The total number of microfilaria (mf) cases reported from each district has been correlated with different aspects of water sources (Table 7). The total number of water sources and number of mf cases reported from all the locations were noticed to be negatively correlated (-0.00997). However, the total area of water sources and mf cases from all the locations was positively correlated but weak (0.096403). Upon correlating the number, area and types of sewerage systems with the number of mf cases in all the locations, it can be concluded that, the number of sewerage channels was noticed to be negatively correlated (-0.02948). However, a slight positive correlation has been noticed between number of mf cases and total area of sewerage systems (0.033059). The open nature of sewerage channels has supreme influence on the emergence of mosquitoes. A strong positive correlation has been noticed between the total areas of open sewerage channels and number of mf cases (0.713181).

The overall results showed that, even though all the locations occupied higher number of water sources for the breeding and emergence of mosquitoes, their influence on the occurrence of filarial disease was very nominal. But, total area has been shown to influence the occurrence of the disease. Presence of sewerage channels in all the locations may enhance the emergence of filarial vector, *Culex quinquefasciatus*. Sewerage channels are known to harbor a large percentages of *Culex* mosquitoes especially the filarial vector, *Culex quinquefasciatus* (Thavaselvam and Kalyanasundaram 1991). This fact has been evidenced by the results of present study. All the locations occupied significant area of sewerage channels and a significant percentage of them were open type. Larger area of sewerage channels along with their open nature may result in the enhanced emergence and abundance of filarial vector. Dasgupta (1984) reported that by increasing the number of potential vector breeding sites owing to various human activities, the spread of filarial parasite *W. bancrofti* increases. The positive correlation between the number of microfilaria cases and area of open type sewerage channels establish the fact that, such systems can have enormous impact on the transmission of filariasis.

From the overall results it can be concluded that, all the locations under study showed water sources of heterogeneous types. They are ponds, canals, sewerages, ground pools and rice fields. Larger water bodies sustained the water throughout the year irrespective of seasons. Many of the ponds and canals were also polluted with domestic sewage. Improper management of wastes has demanded the creation of many sewerage systems. All such factors may contribute to enhanced emergence and abundance of mosquitoes. All the locations have been noticed for larger area of sewerage channels and significant percentages of them were open type. Among the different aspects of water sources studied, total area has got impact on the occurrence of filarial disease. The positive correlation between the number of microfilaria cases and area of open type sewerage channels establish the fact that, such systems can have enormous impact on the transmission of filariasis.

Various physical and chemical attributes of water plays significant role in the oviposition, survivability and abundance of different mosquito species. In the present study, physico chemical characteristics of water samples were analyzed seasonally for a period of one year to elucidate their possible influence on the occurrence of mosquitoes. 6 water samples were collected from heterogeneous habitats of each location falling in 10 districts during pre monsoon, monsoon and post monsoon seasons. The samples were analyzed for physic-chemical parameters like pH, temperature, turbidity, total solids, acidity, total alkalinity, dissolved oxygen, total hardness and chloride. As per the pattern of climatic events and available literature, the seasonality has been described. The period February to May was treated as pre monsoon season, June to September as monsoon and October to January as post monsoon. The data were then used to evaluate the correlation of each parameter with the growth and development of mosquito vectors in general and filarial vectors in particular.

Analytical Results of various physico-chemical parameters of water collected from all the locations under study during pre monsoon, monsoon and post monsoon seasons are depicted in Tables 1.7 (a)-(c), Table 1.8 (a)-(c) and Tables 1.9 (a)-(c) respectively. Also the mean values of all the physico-chemical characteristics of water samples experienced at all the locations during pre monsoon, monsoon and post monsoon seasons are depicted in Table 10 - 12 respectively.

Table 1.7(a). Various physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during pre monsoon season (February 2012 to May 2012).

District	Sampling Station	pH	Temperature (°C)	Turbidity (NTU)	Total Solids (mg/l)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
Trivandrum	1	6.67	26.9	23.4	10600	35.2	150	1.63	240	234.3
	2	7.41	27.4	17.8	6500	26.4	250	0	190	184.6
	3	8.81	27.8	12.6	2300	17.6	450	0.82	210	149.1
	4	6.36	28.1	1.1	700	48.4	150	3.67	160	269.8
	5	6.48	28.3	19.8	4600	57.2	200	0	130	347.9
	6	7.69	28.1	0.6	300	17.6	250	5.71	280	42.6
Kollam	1	8.11	26.9	1.7	300	26.4	450	4.49	85	220.1
	2	7.59	27.4	9.4	2600	17.6	300	3.26	60	298.2
	3	6.42	27.8	17.3	6200	61.6	150	1.22	130	205.9
	4	7.13	27.5	2.3	200	17.6	200	5.71	105	78.1
	5	6.76	28.1	13.2	1300	44	150	0	230	127.8
Alleppey	1	6.82	27.9	24.8	11700	39.6	200	1.22	60	468.6

	2	6.91	27.6	1.1	300	35.2	150	4.49	100	340.8
	3	6.56	28.2	1.6	400	48.4	125	6.53	120	227.2
	4	6.32	28.4	2.7	700	52.8	175	4.9	230	127.8
	5	6.86	28.2	16.3	3300	35.2	150	1.63	440	134.9
	6	6.94	28.4	12.8	2400	35.2	125	2.45	130	149.1
Ernakulam	1	7.22	28.1	13.2	2400	17.6	250	2.86	140	170.4
	2	7.11	28.5	16.4	5600	13.2	200	1.63	280	262.7
	3	7.02	29.2	14.3	2400	17.6	150	1.22	440	149.1
	4	6.73	28.8	9.7	2200	35.2	125	1.63	190	78.1
	5	7.12	28.4	6.4	2100	17.6	200	3.67	140	127.8
	6	6.71	28.8	19.2	5700	39.6	150	0.82	360	220.1

Table 1.7(b). Various physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during pre monsoon season (February 2012 to May 2012).

District	Sampling Station	pH	Temperature (ºC)	Turbidity (NTU)	Total Solids (mg/L)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
Thrissur	1	6.89	26.8	13.4	5800	35.2	125	0	110	255.6
	2	6.13	27.4	27.8	10700	66	200	1.63	90	205.9
	3	7.64	27.2	2.6	500	22	300	1.43	70	56.8

	4	6.11	27.1	19.4	5600	57.2	150	0	170	149.1
	5	6.93	28.2	23.1	6800	39.6	150	2.45	280	184.6
	6	7.04	27.7	1.8	100	26.4	175	4.08	40	78.1
Palakkad	1	7.50	29.1	0.7	300	26.4	275	6.63	60	92.3
	2	7.48	29.8	1.1	100	24.2	250	4.49	90	127.8
	3	7.40	28.7	19.4	4000	26.4	300	0.41	230	191.7
	4	7.03	28.9	31.2	5800	17.6	150	1.63	180	276.9
	5	6.62	26.6	4.6	4400	39.6	125	1.22	70	149.1
	6	5.72	29	23.2	6000	70.4	100	0.82	70	85.2
Malappuram	1	8.18	29.5	11	4200	14.1	340	2.58	1880	105.08
	2	7.48	29	13.2	14100	24.6	370	0.48	138	336.54
	3	7.97	28.5	3.2	15500	22.9	270	1.45	1160	136.32
	4	7.41	29	16.1	16200	28.2	250	0.322	164	215.84
	5	6.97	29.5	0.8	6000	35.2	150	1.94	70	63.9
	6	6.87	29	1	8700	49.3	180	2.25	56	97.98
Kozhikode	1	6.71	28	15.8	5300	23.76	110	0.8	76	42.6
	2	7.72	30.5	5.4	11800	10.56	290	2.09	1740	221.52
	3	7.82	29	10	10700	18.48	300	0.48	192	458.66
	4	7.74	29.5	12	5900	20.24	400	0	288	107.92
	5	7.57	27	7.7	12200	11.44	240	1.45	264	29.82
	6	7.96	27.5	11.3	35300	31.68	430	0.64	92	133.48

Table 1.7(c). Various physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during pre monsoon season (February 2012 to May 2012).

District	**Sampling Station**	**pH**	**Temperature (°C)**	**Turbidity (NTU)**	**Total Solids (mg/L)**	**Acidity (mg/l)**	**Total Alkalinity (mg/l)**	**Dissolved oxygen mg/l**	**Total Hardness (mg/l)**	**Chloride (mg/l)**
Kannur	1	7.06	27.8	33.2	15700	17.6	150	0.82	80	198.8

	2	7.24	27.6	19.4	4800	13.2	125	0	190	276.9
	3	8.19	27.2	26.8	6500	22	250	2.04	240	504.1
	4	7.74	28.3	23.6	7400	22	300	0	230	468.6
	5	7.71	28.1	17.9	4700	28.6	350	2.86	160	333.7
	6	7.39	27.9	23.2	12800	35.2	250	0.41	280	205.9
Kasaragod	1	7.96	28.1	1.9	500	22	300	5.3	290	134.9
	2	6.47	27.6	16.6	7700	57.2	150	1.63	240	234.3
	3	7.38	27.8	2.3	1800	26.4	250	0	100	85.2
	4	6.69	27.3	24.8	8700	48.4	150	0	70	113.6
	5	6.41	28	13.9	4500	52.8	200	1.22	210	198.8
	6	7.34	27.9	2.7	900	26.4	250	3.26	320	78.1

All the physico-chemical parameters showed considerable variations with respect to seasons. In the pre monsoon season, the ranges of all the physico-chemical parameters experienced at Manacaud of Trivandrum district were temperature (26.9-28.3 ^{o}C), pH (6.36-8.81), turbidity (0.6-23.4 NTU), total solids (300-10600 mg/l), acidity (17.6-57.2 mg/l), total alkalinity (150-450 mg/l), dissolved oxygen (0-5.71 mg/l), total hardness (130-280 mg/l) and chloride (42.6-347.9 mg/l). The ranges at Mangad of Kollam district were temperature (26.9-28.1 ^{o}C), pH (6.42-8.11), turbidity (1.7-17.3 NTU), total solids (200-6200 mg/l), acidity (17.6-61.6 mg/l), total alkalinity (150-450 mg/l), dissolved oxygen (0-5.71 mg/l), total hardness (60-230 mg/l) and chloride (78.1-298.2 mg/l). At Kommady of Alleppey district the ranges were temperature (27.6-28.4 ^{o}C), pH (6.32-6.94), turbidity (1.1-24.8 NTU), total solids (300-11700 mg/l), acidity (35.2-52.8 mg/l), total alkalinity (125-200 mg/l), dissolved oxygen (1.22-6.53 mg/l), total hardness (60-440 mg/l) and chloride (127.8-468.6 mg/l). Different ranges of physico-chemical parameters experienced at Thoppumpady of Ernakulam district were temperature (28.1-29.2 ^{o}C), pH (6.71-7.22), turbidity (6.4-19.2 NTU), total solids (2100-5700 mg/l), acidity (13.2-39.6 mg/l), total alkalinity (125-250 mg/l), dissolved oxygen (0.82-3.67 mg/l), total hardness (140-440 mg/l) and chloride (78.-262.7 mg/l).

In the pre monsoon season, Chavakkad of Thrissur district showed different ranges as temperature (26.8-28.2 ^{o}C), pH (6.11-7.64), turbidity (1.8-27.8 NTU), total solids (100-10700 mg/l), acidity (22-66 mg/l), total alkalinity (125-300 mg/l), dissolved oxygen (0-4.08 mg/l), total hardness (40-280 mg/l) and chloride (56.8-255.6 mg/l).The ranges with respect to Thirunellai of Palakkad district were temperature (26.6-29.8 ^{o}C), pH (5.72-7.5), turbidity (0.7-31.2 NTU), total solids (100-6000 mg/l), acidity (17.6-70.4 mg/l), total alkalinity (100-300 mg/l), dissolved oxygen (0.41-6.63 mg/l), total hardness (60-230 mg/l) and chloride (85.2-276.9 mg/l). Ponnani of Malappuram district showed different ranges as temperature (28.5-29.5 ^{o}C), pH (6.87-8.18), turbidity (0.8-16.1 NTU), total solids (4200-16200 mg/l), acidity (14.1-49.3

mg/l), total alkalinity (150-370 mg/l), dissolved oxygen (0.322-2.58 mg/l), total hardness (56-1880 mg/l) and chloride (63.9-336.54 mg/l).

Similarly, ranges of physico-chemical parameters experienced at Vellayil of Kozhikode district were temperature (27-30.5 ^{o}C), pH (6.71-7.96), turbidity (5.4-15.8 NTU), total solids (5300-35300 mg/l), acidity (10.6-31.7 mg/l), total alkalinity (110-430 mg/l), dissolved oxygen (0-2.09 mg/l), total hardness (76-1740 mg/l) and chloride (29.8-458.7 mg/l). At Thalassery of Kannur district, different ranges experienced were temperature (27.2-28.3 ^{o}C), pH (7.06-8.19), turbidity (17.9-33.2 NTU), total solids (4700-15700 mg/l), acidity (13.2-35.2 mg/l), total alkalinity (125-350 mg/l), dissolved oxygen (0-2.86 mg/l), total hardness (80-280 mg/l) and chloride (198.8-504.1 mg/l). Thalangara of Kasaragod showed ranges of different attributes as temperature (27.3-28.1^{o}C), pH (6.41-7.96), turbidity (1.9-24.8 NTU), total solids (500-8700 mg/l), acidity (22-57.2 mg/l), total alkalinity (150-300 mg/l), dissolved oxygen (0-5.3 mg/l), total hardness (70-320 mg/l) and chloride (78.1-234.3 mg/l).

Table 1.8(a). Various physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during monsoon season (June 2012 to September 2012).

District	Sampling Station	pH	Temperature (°C)	Turbidity (NTU)	Total Solids (mg/L)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
Trivandrum	1	6.94	28.2	1.4	600	15.5	80	5.30	68	21.84
	2	7.26	28.6	2.9	1200	10.8	520	2.04	48	182.46
	3	7.21	29.4	7.6	4100	12.4	380	2.24	362	126.9
	4	7.58	29.5	1.7	900	17.0	760	3.26	48	56.44
	5	6.97	28.9	14.1	5700	35.6	160	1.63	188	161.24
	6	6.85	29.6	6.7	2300	40.3	100	2.44	132	413.46
Kollam	1	7.21	29.4	2.1	900	10.1	230	5.28	84	87.5
	2	7.63	30.1	3.7	1400	7.0	340	3.88	56	56.26
	3	7.57	28.4	4.9	1700	7.7	300	1.68	76	259.4
	4	7.26	29.1	8.6	3300	40.3	190	3.47	168	161.2
	5	7.14	29.5	1.4	800	9.3	160	4.44	64	28.6
	6	7.44	29.7	3.3	1200	7.7	240	5.92	32	77.41
Alleppey	1	6.92	29.8	0.8	450	7.0	40	3.64	38	42.83
	2	6.94	27.6	0.7	200	9.3	20	4.08	16	56.44
	3	7.13	28.4	1.9	900	17.0	240	1.84	244	147.26
	4	6.96	28.1	1.1	600	10.8	180	4.86	32	52.54
	5	7.26	29.3	1.7	650	20.9	260	2.44	152	203.61
	6	7.10	27.6	0.5	150	9.3	250	4.48	48	35.04
Ernakulam	1	7.14	29.2	4.8	2200	9.3	180	1.84	52	91.12
	2	7.28	29.6	1.1	300	4.6	80	3.88	36	49.06
	3	7.03	28.4	2.3	900	17.0	260	1.22	108	133.17
	4	6.92	28.2	1.7	600	18.6	320	2.86	76	175.16
	5	6.97	29.2	2.1	650	17.8	240	2.45	136	189.24
	6	7.21	28.8	2.8	1200	13.9	400	3.26	104	273.47

Table 1.8(b). Various physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during monsoon season (June 2012 to September 2012).

District	Sampling Station	pH	Temperature (ºC)	Turbidity (NTU)	Total Solids (mg/L)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
Thrissur	1	7.26	29.2	1.0	300	5.4	270	7.54	26	56.44
	2	7.14	29.4	1.3	800	7.7	220	5.30	48	66.53
	3	6.97	29.1	5.8	1800	13.9	80	3.26	72	532.41
	4	6.89	29.4	2.8	100	17.0	60	0.82	212	287.39
	5	6.92	28.9	1.2	600	18.6	90	3.67	64	1.5.44
	6	7.35	29.6	1.5	900	12.4	230	1.42	108	133.18
Palakkad	1	7.15	28.6	0.9	600	12.4	220	7.34	48	56.28
	2	7.06	28.4	0.5	200	9.3	220	6.32	54	42.34
	3	6.94	29.3	1.2	800	18.6	140	4.49	72	35.44
	4	6.86	29	1.7	1100	20.9	180	1.63	244	189.26
	5	7.52	28.8	4.4	1700	7.0	370	2.24	188	133.28
	6	7.18	28.4	1.5	1200	10.1	240	3.88	52	91.91
Malappuram	1	6.84	29.1	1.2	1100	48.0	140	4.08	24	63.41
	2	6.92	28.6	1.1	700	40.3	170	5.10	48	59.54
	3	6.96	28.4	1.1	900	34.1	150	3.85	44	77.06
	4	6.93	28.6	2.9	1800	32.5	180	1.63	108	224.83
	5	7.08	28.9	1.3	1400	29.4	220	4.69	68	63.41
	6	7.14	28.2	0.8	500	27.1	190	3.88	72	45.54
Kozhikode	1	7.14	28.4	1.1	400	6.2	180	6.94	32	84.46
	2	7.38	28.6	1.3	700	4.6	220	5.91	52	98.32
	3	6.87	29.2	4.7	2100	18.6	80	3.26	68	189.48
	4	6.94	28.1	2.3	1100	13.9	110	4.49	56	133.34
	5	7.32	28.4	2.6	1500	6.2	200	2.45	104	231.16
	6	7.56	28.9	1.4	500	5.4	350	5.10	44	56.18

Table 1.8(c). Various physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during monsoon season (June 2012 to September 2012).

District	Sampling Station	pH	Temperature (°C)	Turbidity (NTU)	Total Solids (mg/L)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
Kannur	1	7.54	29.2	1.9	1300	10.1	640	2.04	76	301.46
	2	7.28	27.8	3.1	1900	13.9	420	2.65	112	399.18
	3	6.92	28.1	1.0	700	20.1	220	4.89	52	28.44
	4	6.82	28.3	2.7	1700	29.4	160	3.26	64	161.41
	5	7.11	28.9	0.9	400	12.4	260	5.30	44	49.60
	6	6.87	29.1	1.2	900	27.1	190	3.88	48	42.38
Kasaragod	1	6.94	29.6	3.8	1400	14.7	160	4.49	96	119.15
	2	7.34	28.4	1.1	500	6.2	320	7.34	36	42.16
	3	6.82	28.6	1.3	800	18.6	80	4.69	44	49.38
	4	6.91	29.6	9.2	3800	25.6	160	2.86	152	196.46
	5	6.96	28.4	1.2	700	17.0	220	4.08	64	56.38
	6	7.56	29.8	1.3	900	10.8	420	5.71	32	28.44

In the monsoon season, the ranges of all the parameters at Manacaud of Trivandrum district were temperature (28.2-29.6^{o}C), pH (6.85-7.58), turbidity (1.4-14.1NTU), total solids (600-5700mg/l), acidity (10.8-40.3mg/l), total alkalinity (80-760mg/l), dissolved oxygen (1.63-5.3 mg/l), total hardness (48-362 mg/l) and chloride (21.84-413.46 mg/l). The ranges at Mangad of Kollam district were temperature (28.4-30.1^{o}C), pH (7.14-7.63), turbidity (1.4-8.6 NTU), total solids (800-3300mg/l), acidity (7-40.3 mg/l), total alkalinity (160-340 mg/l), dissolved oxygen (1.68-5.92 mg/l), total hardness (32-168 mg/l) and chloride (28.6-259.4 mg/l). At Kommady of Alleppey district the ranges were temperature (27.6-29.8^{o}C), pH (6.92-7.26), turbidity (0.5-1.9 NTU), total solids (150-900 mg/l), acidity (7-20.9 mg/l), total alkalinity (20-260 mg/l), dissolved oxygen (1.84-4.86 mg/l), total hardness (16-244 mg/l) and chloride (35.04-203.61 mg/l). Different ranges of physico-chemical parameters experienced at Thoppumpady of Ernakulam district were temperature (28.2-29.6 ^{o}C), pH (6.92-7.28), turbidity (1.1-4.8 NTU), total solids (300-2200 mg/l), acidity (4.6-18.6 mg/l), total alkalinity (80-400 mg/l), dissolved oxygen (1.22-3.88 mg/l), total hardness (36-136 mg/l) and chloride (49.06-273.47 mg/l).

Chavakkad of Thrissur district showed different ranges of parameters in the monsoon season as temperature (28.9-29.6 ^{o}C), pH (6.89-7.35), turbidity (1-5.8 NTU), total solids (100-1800 mg/l), acidity (5.4-18.6 mg/l), total alkalinity (60-270 mg/l), dissolved oxygen (0.82-7.54 mg/l), total hardness (26-212 mg/l) and chloride (56.44-532.41 mg/l).The ranges with respect to Thirunellai of Palakkad district were temperature (28.4-29.3 ^{o}C), pH (6.86-7.52), turbidity (0.5-4.4 NTU), total solids (200-1700 mg/l), acidity (7-20.9 mg/l), total alkalinity (140-370 mg/l), dissolved oxygen (1.63-7.34 mg/l), total hardness (48-244 mg/l) and chloride (35.44-189.26 mg/l). Ponnani of Malappuram district showed different ranges as temperature (28.2-29.1 ^{o}C), pH (6.84-7.14), turbidity (0.8-2.9 NTU), total solids (500-1800 mg/l), acidity (27.1-48 mg/l), total alkalinity (140-220 mg/l), dissolved oxygen (1.63-5.1 mg/l), total hardness (24-108 mg/l) and chloride (45.54-224.83 mg/l).

Similarly, ranges of physico-chemical parameters experienced at Vellayil of Kozhikode district were temperature (28.1-29.2 ^{o}C), pH (6.87-7.56), turbidity (1.1-4.7 NTU), total solids (400-2100 mg/l), acidity (4.6-18.6 mg/l), total alkalinity (80-350 mg/l), dissolved oxygen (2.45-6.94 mg/l), total hardness (32-104 mg/l) and chloride (56.18-231.16 mg/l). At Thalassery of Kannur district, different ranges experienced were temperature (27.8-29.2^{o}C), pH (6.82-7.54), turbidity (0.9-3.1 NTU), total solids (400-1900 mg/l), acidity (10.1-29.4 mg/l), total alkalinity (160-640 mg/l), dissolved oxygen (2.04-5.3 mg/l), total hardness (44-112 mg/l) and chloride (28.44-399.18 mg/l). Thalangara of Kasaragod showed ranges of different attributes as temperature (28.4-29.8 ^{o}C), pH (6.82-7.56), turbidity (1.1-9.2 NTU), total solids (500-3800 mg/l), acidity (6.2-25.6 mg/l), total alkalinity (80-420 mg/l), dissolved oxygen (2.86-7.34 mg/l), total hardness (32-152 mg/l) and chloride (28.44-196.46 mg/l).

Table 1.9(a). Various physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during post monsoon season (October 2012 to January 2013).

District	Sampling Station	pH	Temperature (°C)	Turbidity (NTU)	Total Solids (mg/L)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
Trivandrum	1	6.56	28.4	3.1	100	52.8	100	0.82	76	156.2
	2	6.77	28.5	12.7	300	48.4	250	0.41	68	213
	3	7.17	29.5	10.1	500	22	350	0	150	198.8
	4	7.41	29.2	40.2	900	26.4	500	0	132	255.6
	5	6.16	29.6	32.3	400	66	200	1.02	136	198.8
	6	7.09	29.5	7.2	300	17.6	350	0	168	355
Kollam	1	7.19	27.5	5.7	300	26.4	300	7.75	204	326.6
	2	6.85	28.3	5.2	200	39.6	200	5.32	112	170.4
	3	7.04	28.6	1.4	100	26.4	200	5.36	68	213
	4	6.68	29.4	3.4	200	33.2	100	4.22	212	294.8
	5	7.24	28.7	1.9	50	8.3	250	3.74	34	166.4
	6	6.91	29.2	4.8	300	22.1	50	3.36	72	332.6
Alleppey	1	6.87	29.1	16.1	1300	44	300	4.46	270	766.8
	2	7.18	29.5	14.2	600	35.2	400	0.41	140	489.9
	3	7.36	27.3	21.4	100	79.2	800	1.22	190	291.1
	4	7.24	29.2	23.2	800	48.4	500	5.83	240	284
	5	6.69	29.5	19.7	1900	61.6	350	0.82	220	369.2
	6	6.88	29	7.8	400	30.8	250	3.78	70	156.2
Ernakulam	1	6.81	26.8	4.6	800	48.4	200	2.45	130	937.2
	2	6.46	27.3	9.3	3700	74.8	350	1.22	90	667.4
	3	7.96	26.4	4.4	3500	26.4	1000	1.02	160	475.7
	4	6.51	27.9	6.7	13700	83.6	350	3.67	270	333.7
	5	7.59	27	6.2	1400	30.8	700	2.45	190	702.9
	6	6.28	27.1	14.1	15600	101.2	250	3.47	240	127.8

Table 1.9(b). Various physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during post monsoon season (October 2012 to January 2013).

District	Sampling Station	pH	Temperature (°C)	Turbidity (NTU)	Total Solids (mg/L)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
Thrissur	1	6.33	27.2	17.6	4500	61.6	150	0	300	681.6
	2	7.22	27.5	11.2	5500	39.6	500	0.41	470	454.4
	3	7.81	27	8.1	7700	17.6	850	1.22	360	291.1
	4	7.19	28.8	10.4	2700	35.2	450	0.41	830	560.9
	5	6.76	28.5	14	1300	48.4	200	0	280	489.9
	6	6.49	27.5	5.9	300	83.6	200	3.67	160	36.92
Palakkad	1	7.76	29.7	1.6	200	30.8	950	5.3	70	68.16
	2	7.11	29.9	1.4	300	22	850	3.26	50	176.08
	3	7.43	29.1	6.9	900	26.4	600	0.41	190	305.3
	4	7.09	28.7	7.1	7700	26.4	400	0	270	489.9
	5	6.92	28.8	14.3	4900	57.2	200	0.82	540	269.8
	6	6.81	29.2	9.0	1300	48.4	200	0	780	227.2
Malappuram	1	7.76	27.5	19.4	700	26.4	600	1.22	270	624.8
	2	7.22	27.5	3.8	300	26.4	400	4.9	244	184.6
	3	6.84	28.2	11.5	800	48.4	200	2.45	52	440.2
	4	6.62	27.5	11.9	700	57.2	150	0.41	68	397.6
	5	7.59	28.1	6.6	5600	17.6	550	0	36	1050.8
	6	7.03	28.5	13.2	500	17.6	300	0.41	124	596.4
Kozhikode	1	7.94	29.7	34.7	1400	21.1	350	0	316	326.6
	2	6.09	30.5	71.2	700	35.2	150	0	52	269.8
	3	7.88	29.5	2.8	1500	10.6	300	0	390	610.6
	4	7.86	29.9	5.9	1500	10.6	250	2.45	312	937.2
	5	7.6	28.1	6.1	300	12.3	250	6.94	96	255.6
	6	7.24	28.6	43.3	300	10.6	200	0	136	269.8

Table 1.9(c). Various physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during post monsoon season (October 2012 to January 2013).

District	Sampling Station	pH	Temperature (°C)	Turbidity (NTU)	Total Solids (mg/L)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
Kannur	1	6.68	28.6	17.6	6700	48.4	250	0.41	570	440.2
	2	6.49	28.2	28.6	7300	57.2	200	0	130	269.6
	3	6.71	27.8	23.2	1000	35.2	250	0	620	376.6
	4	7.43	27.4	19.6	500	17.6	350	0	410	383.4
	5	7.29	28.1	14.1	15800	22	450	1.22	470	1056
	6	6.79	28	15.8	1700	35.2	250	0.61	320	681.6
Kasaragod	1	6.49	28.5	6.9	9300	48.4	150	1.22	770	539.6
	2	7.68	27.5	1.3	100	22	450	5.7	170	153.36
	3	6.87	28.1	14.8	4300	39.6	250	1.22	280	93.72
	4	6.46	28.6	13.1	16500	79.2	300	0	610	323.76
	5	7.11	27.9	9.4	15300	26.4	500	0.41	490	48.28
	6	6.54	27.6	13.6	11300	92.4	300	1.63	510	210.16

In the post monsoon season, the ranges of all the physico-chemical parameters experienced at Manacaud of Trivandrum district were temperature (28.4-29.6 ^{o}C), pH (6.16-7.41), turbidity (3.1-40.2 NTU), total solids (100-900 mg/l), acidity (17.6-66 mg/l), total alkalinity (100-500 mg/l), dissolved oxygen (0-1.02 mg/l), total hardness (68-168 mg/l) and chloride (156.2-355 mg/l). The ranges of all the parameters at Mangad of Kollam district were temperature (27.5-29.4 ^{o}C), pH (6.68-7.24), turbidity (1.4-5.7 NTU), total solids (50-300 mg/l), acidity (8.3-39.6 mg/l), total alkalinity (50-300 mg/l), dissolved oxygen (3.36-7.75 mg/l), total hardness (34-212 mg/l) and chloride (166.4-332.6 mg/l). At Kommady of Alleppey district, the ranges were temperature (27.3-29.5 ^{o}C), pH (6.69-7.36), turbidity (7.8-23.2 NTU), total solids (100-1900 mg/l), acidity (30.8-79.2 mg/l), total alkalinity (250-800 mg/l), dissolved oxygen (0.41-5.83 mg/l), total hardness (70-270 mg/l) and chloride (156.2-766.8 mg/l). Different ranges of physico-chemical parameters experienced at Thoppumpady of Ernakulam district were temperature (26.4-27.9 ^{o}C), pH (6.28-7.96), turbidity (4.4-14.1 NTU), total solids (800-15600 mg/l), acidity (26.4-101.2 mg/l), total alkalinity (200-1000 mg/l), dissolved oxygen (1.02-3.67 mg/l), total hardness (90-270 mg/l) and chloride (127.8-937.2 mg/l).

At Chavakkad of Thrissur district ranges of different water quality parameters were temperature (27-28.8 ^{o}C), pH (6.33-7.81), turbidity (5.9-17.6 NTU), total solids (300-7700 mg/l), acidity (17.6-83.6 mg/l), total alkalinity (150-850 mg/l), dissolved oxygen (0-3.67 mg/l), total hardness (160-830 mg/l) and chloride (36.92-681.6 mg/l).The ranges of all the parameters with respect to Thirunellai of Palakkad district were temperature (28.7-29.9 ^{o}C), pH (6.81-7.76), turbidity (1.4-14.3 NTU), total solids (200-7700 mg/l), acidity (22-57.2 mg/l), total alkalinity (200-950 mg/l), dissolved oxygen (0-5.3 mg/l), total hardness (50-780 mg/l) and chloride (68.16-489.9 mg/l). Ponnani of Malappuram district showed different ranges of attributes as temperature (27.5-28.5 ^{o}C), pH (6.62-7.76), turbidity (3.8-19.4 NTU), total solids (300-5600 mg/l), acidity (17.6-57.2 mg/l), total alkalinity (150-600 mg/l), dissolved oxygen (0-4.9 mg/l), total hardness (36-270 mg/l) and chloride (184.6-1050.8 mg/l).

Different ranges of physico-chemical parameters of water experienced at Vellayil of Kozhikode district were temperature (28.1-30.5 ^{o}C), pH (6.09-7.94), turbidity (52.8-71.2 NTU), total solids (300-1500 mg/l), acidity (10.6-35.2 mg/l), total alkalinity (150-350 mg/l), dissolved oxygen (0-6.94 mg/l), total hardness (52-390 mg/l) and chloride (255.6-937.2 mg/l). At Thalassery of Kannur district, different ranges of water quality attributes experienced were temperature (27.4-28.6 ^{o}C), pH (6.49-7.43), turbidity (14.1-28.6 NTU), total solids (500-15800 mg/l), acidity (17.6-57.2 mg/l), total alkalinity (200-450 mg/l), dissolved oxygen (0-1.22 mg/l), total hardness (130-620 mg/l) and chloride (269.6-1056 mg/l). Thalangara of Kasaragod showed ranges of different attributes as temperature (27.5-28.6 ^{o}C), pH (6.46-7.68), turbidity (1.3-14.8 NTU), total solids (100-16500 mg/l), acidity (22-92.4 mg/l), total alkalinity (150-500 mg/l), dissolved oxygen (0-5.7 mg/l), total hardness (170-770 mg/l) and chloride (48.28-539.6 mg/l).

The analysis of various physico-chemical attributes experienced at all the locations during pre monsoon season revealed that, the mean values of pH was maximum at Vellayil of Kozhikode (7.59) followed by Thalassery of Kannur (7.56) and Ponnani of Malappuram (7.48) districts. Lower values of mean pH was noticed at Kommady of Alleppey (6.74) followed by Chavakkad of Thrissur (6.79) and Thirunellai of Palakkad (6.96) districts. Highest mean value of temperature was noticed at Ponnani of Malappuram (29 ^{o}C) followed by Thirunellai of Palakkad (28.7 ^{o}C) and Vellayil of Kozhikode (28.6 ^{o}C) districts whereas, temperature mean showed a lower value at Chavakkad of Thrissur (27.4 ^{o}C) followed by Mangad of Kollam (27.5 ^{o}C) and Manacaud of Trivandrum (27.8 ^{o}C) districts. Turbidity showed a higher mean value at Thalassery of Kannur (24.1 NTU) followed by Chavakkad of Thrissur (14.7 NTU) and Thirunellai of Palakkad (13.4 NTU) districts. Lower mean turbidity were reported from Ponnani of Malappuram (7.6 NTU) followed by Mangad of Kollam (8.8 NTU) and Kommady of Alleppey (8.8 NTU) districts. Total solids showed a higher mean value at Vellayil of Kozhikode (13533.33 mg/l) followed by Ponnani of Malappuram (10783.33 mg/l) and Chavakkad of Thrissur (4916.67 mg/l) districts whereas, lower mean value was noticed at Mangad of Kollam (2120 mg/l) followed by Kommady of Alleppey (3133.33 mg/l) and Thoppumpady of Ernakulam (3400 mg/l) districts. Mean acidity experienced in the pre monsoon season showed a higher value at Kommady of Alleppey (41.07 mg/l) and Chavakkad of Thrissur (41.07 mg/l) followed by Thalangara of Kasaragod (38.87 mg/l) districts. Lower value of mean acidity was noticed at Vellayil of Kozhikode (19.36 mg/l) followed by Thalassery of Kannur (23.1 mg/l) and Thoppumpady of Ernakulam (23.47 mg/l) districts.

Total alkalinity showed a higher mean value at Vellayil of Kozhikode (295 mg/l) followed by Ponnani of Malappuram (260 mg/l) and Mangad of Kollam (250 mg/l) districts whereas, lower mean value of total alkalinity was reported from Kommady of Alleppey (154.17 mg/l) followed by Thoppumpady of Ernakulam (179.17 mg/l) and Chavakkad of Thrissur (183.33 mg/l) districts. Higher mean value of dissolved oxygen was reported from Kommady of Alleppey (3.54 mg/l) followed by Mangad of Kollam (2.94 mg/l) and Thirunellai of Palakkad (2.53 mg/l) districts. Dissolved oxygen showed a lower mean values at Vellayil of Kozhikode (0.91 mg/l) followed by Thalassery of Kannur (1.02 mg/l) and Chavakkad of Thrissur (1.59 mg/l) districts. Similarly total hardness showed a higher mean value at Ponnani of Malappuram (578 mg/l) followed by Vellayil of Kozhikode (442 mg/l) and Thoppumpady of Ernakulam (258.33 mg/l) districts whereas, lower mean values was noticed at Thirunellai of Palakkad (116.67 mg/l) followed by Mangad of Kollam (122 mg/l) and Chavakkad of Thrissur (126.67 mg/l) districts. Mean chloride level experienced was maximum at Thalassery of Kannur (331.33 mg/l) followed by Kommady of Alleppey (241.4 mg/l) and Manacaud of Trivandrum (204.72 mg/l) districts. Lower mean chloride value was reported from Thalangara of Kasaragod (140.82 mg/l) followed by Thirunellai of Palakkad (153.83 mg/l) and Chavakkad of Thrissur (155.02 mg/l) districts.

Table 1.10. Mean values of the physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during pre monsoon season (February 2012 to May 2012).

Sl. No	District	pH	Temperature (°C)	Turbidity (NTU)	Total Solids (mg/l)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
1	Trivandrum	7.24	27.8	12.6	4166.67	33.73	241.67	1.97	201.67	204.72
2	Kollam	7.22	27.5	8.8	2120	33.44	250	2.94	122	186.02
3	Alleppey	6.74	28.1	9.9	3133.33	41.07	154.17	3.54	180	241.4
4	Ernakulam	6.99	28.6	13.2	3400	23.47	179.17	1.97	258.33	168.03
5	Thrissur	6.79	27.4	14.7	4916.67	41.07	183.33	1.59	126.67	155.02
6	Palakkad	6.96	28.7	13.4	3433.33	34.1	200	2.53	116.67	153.83
7	Malappuram	7.48	29.0	7.6	10783.33	29.05	260	1.50	578	159.28
8	Kozhikode	7.59	28.6	10.4	13533.33	19.36	295	0.91	442	165.67
9	Kannur	7.56	27.8	24.1	8650	23.1	237.5	1.02	196.67	331.33
10	Kasaragod	7.04	27.8	10.4	4016.67	38.87	216.67	1.90	205	140.82

Table 1.11. Mean values of the physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during monsoon season (June 2012 to September 2012).

Sl. No	District	pH	Temperature (°C)	Turbidity (NTU)	Total Solids (mg/l)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
1	Trivandrum	7.14	29.0	5.7	2466.67	21.9	333.33	2.82	141	160.39
2	Kollam	7.38	29.4	4.0	1550	13.7	243.33	4.11	80	111.73
3	Alleppey	7.05	28.5	1.1	491.67	12.4	165	3.56	88.33	89.62
4	Ernakulam	7.09	28.9	2.47	975	13.5	246.67	2.59	85.33	151.87
5	Thrissur	7.09	29.3	2.3	750	12.5	158.33	3.67	88.33	215.19
6	Palakkad	7.12	28.8	1.7	933.33	13.1	228.33	4.32	109.67	91.42
7	Malappuram	6.98	28.6	1.4	1066.67	35.2	175	3.87	60.67	88.97
8	Kozhikode	7.21	28.6	2.2	1050	9.2	190	4.69	59.33	132.16
9	Kannur	7.09	28.6	1.8	1150	18.8	315	3.67	66	163.75
10	Kasaragod	7.09	29.1	2.9	1350	15.5	226.67	4.86	70.67	81.99

Table 1.12. Mean values of the physico-chemical characteristics of aquatic breeding habitats of mosquitoes experienced at all the districts during post monsoon season (October 2012 to January 2013).

Sl No	District	pH	Temperature (°C)	Turbidity (NTU)	Total Solids (mg/l)	Acidity (mg/l)	Total Alkalinity (mg/l)	Dissolved oxygen mg/l	Total Hardness (mg/l)	Chloride (mg/l)
1	Trivandrum	6.86	29.1	77.9	416.67	38.9	291.67	0.38	121.67	229.57
2	Kollam	6.99	28.6	3.7	191.67	26.0	183.33	4.96	117	250.63
3	Alleppey	7.03	28.9	17.1	850	49.9	433.33	2.75	188.33	392.87
4	Ernakulam	6.94	27.1	7.6	6450	60.9	475	2.38	180	540.78
5	Thrissur	6.97	27.8	11.2	3666.67	47.7	391.67	0.95	400	419.14
6	Palakkad	7.19	29.2	6.7	2550	35.2	533.33	1.63	316.67	256.07
7	Malappuram	7.18	27.9	11.1	1433.33	32.3	366.67	1.57	132.33	549.07
8	Kozhikode	7.44	29.4	27.3	950	16.7	250	1.57	217	444.93
9	Kannur	6.89	28.1	19.8	5500	35.9	291.67	0.37	420	534.57
10	Kasaragod	6.86	28.0	9.9	9466.67	51.3	325	1.69	471.67	228.15

The analysis of various physico-chemical attributes experienced at all the locations during monsoon season revealed that, the mean values of pH was maximum at Mangad of Kollam (7.38) followed by Vellayil of Kozhikode (7.21) and Manacaud of Trivandrum (7.14) districts. Lower values of mean pH was noticed at Ponnani of Malappuram (6.98) followed by Kommady of Alleppey (7.05) and Thoppumpady of Ernakulam (7.09) districts. Highest mean value of temperature was noticed at Mangad of Kollam (29.4 ^{o}C) followed by Chavakkad of Thrissur (29.3 ^{o}C) and Thalangara of Kasaragod (29.1 ^{o}C) districts whereas, temperature mean showed a lower value at Kommady of Alleppey (28.5 ^{o}C) followed by Ponnani of Malappuram (28.6 ^{o}C) and Vellayil of Kozhikode (28.6 ^{o}C) districts. Turbidity showed a higher mean value at Manacaud of Trivandrum (5.7 NTU) followed by Mangad of Kollam (4 NTU) and Thalangara of Kasaragod (2.9 NTU) districts. Lower mean turbidity were reported from Kommady of Alleppey (1.1 NTU) followed by Ponnani of Malappuram (1.4 NTU) and Thirunellai of Palakkad (1.7 NTU) districts. Total solids showed a higher mean value at Manacaud of Trivandrum (2466.67 mg/l) followed by Mangad of Kollam (1550 mg/l) and Thalangara of Kasaragod (1350 mg/l) districts whereas, lower mean value was noticed at Kommady of Alleppey (491.67 mg/l) followed by Chavakkad of Thrissur (750 mg/l) and Thirunellai of Palakkad (933.33 mg/l) districts.

Mean acidity experienced in the monsoon season showed a higher value at Ponnani of Malappuram (35.2 mg/l) followed by Manacaud of Trivandrum (21.9 mg/l) and Thalassery of Kannur (18.8 mg/l) districts. Lower value of mean acidity was noticed at Vellayil of Kozhikode (9.2 mg/l) followed Chavakkad of Thrissur (12.5 mg/l) and Thirunellai of Palakkad (13.1 mg/l) districts. Total alkalinity showed a higher mean value at Manacaud of Trivandrum (333.33 mg/l) followed by Thalassery of Kannur (315 mg/l) and Thoppumpady of Ernakulam (246.67 mg/l) districts whereas, lower mean value of total alkalinity was reported from Chavakkad of Thrissur (158.33 mg/l) followed by Kommady of Alleppey (165 mg/l) and Vellayil of Kozhikode (190 mg/l) districts. Higher mean value of dissolved oxygen was reported from Thalangara of Kasaragod (4.86 mg/l) followed by Vellayil of Kozhikode (4.69 mg/l) and Thirunellai of Palakkad (4.32 mg/l) districts. Dissolved oxygen showed a lower mean values at Thoppumpady of Ernakulam (2.59 mg/l) followed by Manacaud of Trivandrum (2.82 mg/l) and Kommady of Alleppey (3.56 mg/l) districts. Similarly total hardness showed a higher mean value at Manacaud of Trivandrum (141 mg/l) followed by Thirunellai of Palakkad (109.67 mg/l) and Kommady of Alleppey (88.33 mg/l) districts whereas, lower mean values was noticed at Vellayil of Kozhikode (59.33 mg/l) followed by Ponnani of Malappuram (60.67 mg/l) and Thalassery of Kannur (66 mg/l) districts. Mean chloride level experienced was maximum at Chavakkad of Thrissur (215.19 mg/l) followed by Thalassery of Kannur (163.75 mg/l) and Manacaud of Trivandrum (160.39 mg/l) districts. Lower mean chloride value was reported from Thalangara of Kasaragod (81.99 mg/l) followed by Ponnani of Malappuram (88.97 mg/l) and Kommady of Alleppey (89.62 mg/l) districts.

The analysis of various physico-chemical attributes experienced at all the locations during post monsoon season revealed that, the mean values of pH was higher at Vellayil of Kozhikode (7.44) followed by Thirunellai of Palakkad (7.19) and Ponnani of Malappuram (7.18) districts. Lower values of mean pH was noticed at Manacaud of Trivandrum (6.86) and Thalangara of Kasaragod (6.86) followed by Thalassery of Kannur (6.89) districts. Highest mean value of temperature was noticed at Vellayil of Kozhikode (29.4 ^{o}C) followed Thirunellai of Palakkad (29.2 ^{o}C) and Manacaud of Trivandrum (29.1 ^{o}C) districts whereas, temperature mean showed a lower value at Thoppumpady of Ernakulam (27.1 ^{o}C) followed by Chavakkad of Thrissur (27.8 ^{o}C) and Ponnani of Malappuram (27.9 ^{o}C) districts. Turbidity showed a higher mean value at Manacaud of Trivandrum (77.9 NTU) followed by Vellayil of Kozhikode (27.3 NTU) and Thalassery of Kannur (19.8 NTU) districts. Lower mean turbidity were reported from Mangad of Kollam (3.7 NTU) followed by Thirunellai of Palakkad (6.7 NTU) and Thoppumpady of Ernakulam (7.6 NTU) districts. Total solids showed a higher mean value at

Thalangara of Kasaragod (9466.67 mg/l) followed by Thoppumpady of Ernakulam (6450 mg/l) and Thalassery of Kannur (5500 mg/l) districts whereas, lower mean value was noticed at Mangad of Kollam (191.67 mg/l) followed by Manacaud of Trivandrum (416.67 mg/l) and Kommady of Alleppey (850 mg/l) districts. Mean acidity experienced in the post monsoon season showed a higher value at Thoppumpady of Ernakulam (60.9 mg/l) followed by Thalangara of Kasaragod (51.3 mg/l) and Kommady of Alleppey (49.9 mg/l) districts. Lower value of mean acidity was noticed at Vellayil of Kozhikode (16.7 mg/l) followed by Mangad of Kollam (26 mg/l) and Ponnani of Malappuram (32.3 mg/l) districts.

Total alkalinity showed a higher mean value at Thirunellai of Palakkad (533.33 mg/l) followed by Thoppumpady of Ernakulam (475 mg/l) and Kommady of Alleppey (433.33 mg/l) districts whereas, lower mean value of total alkalinity was reported from Mangad of Kollam (183.33 mg/l) followed by Vellayil of Kozhikode (250 mg/l) and Thalassery of Kannur (291.67 mg/l) districts. Higher mean value of dissolved oxygen was reported from Mangad of Kollam (4.96 mg/l) followed by Kommady of Alleppey (2.75 mg/l) and Thoppumpady of Ernakulam (2.38 mg/l) districts. Dissolved oxygen showed a lower mean values at Thalassery of Kannur (0.37 mg/l) followed by Manacaud of Trivandrum (0.38 mg/l) and Chavakkad of Thrissur (0.95 mg/l) districts. Similarly total hardness showed a higher mean value at Thalangara of Kasaragod (471.67 mg/l) followed by Thalassery of Kannur (420 mg/l) and Chavakkad of Thrissur (400 mg/l) districts whereas, lower mean values was noticed at Mangad of Kollam (117 mg/l) followed by Manacaud of Trivandrum (121.67 mg/l) and Thoppumpady of Ernakulam (180 mg/l) districts. Mean chloride level experienced was higher at Ponnani of Malappuram (549.07 mg/l) followed by Thoppumpady of Ernakulam (540.78 mg/l) and Thalassery of Kannur (534.57 mg/l) districts. Lower mean chloride value was reported from Thalangara of Kasaragod (228.15 mg/l) followed by Manacaud of Trivandrum (229.57 mg/l) and Mangad of Kollam (250.63 mg/l) districts.

Water temperature plays significant part in the breeding, emergence of a diverse group of mosquitoes and also on the transmission potential of diseases (Fritsch 1997). Standardization studies revealed that there will be an upsurge of larval abundance when the temperature is between 23°C and 33°C (Fritsch 1997). The results of the present study showed that, mean water temperature experienced at all the locations were ranged from 27.4 to 29^0C during pre monsoon, 28.5 to 29.4^0C during monsoon season and 27.1 to 29.4^0C during post monsoon seasons. De Meillon (1934) reported the relation between high water temperature and *Anopheles* mosquito emergence. The optimum water temperature for the development of *Culex* mosquitoes was reported to be 18 to 30^0C (Thavaselvam and Kalyanasundaram 1991). Thus it can be concluded that upon considering the different ranges of temperature, water samples from all the locations under study were found to support the breeding and emergence of different mosquito species.

pH of water is an influential attribute pertaining to the abundance of mosquito larvae (White 1926). The range of pH value noticed to ideal for the growth of mosquito larvae is 5.8 to 8.6 and *Anopheles* mosquitoes have a wider range than Culicines (White 1926). The results of the present study showed that, mean pH values experienced at all the locations were ranged from 6.74 to 7.59 during pre monsoon, 6.98 to 7.38 during monsoon season and 6.86 to 7.44 during post monsoon seasons. The ideal range of pH for the emergence of *Culex* species like *Culex quinquefasciatus* was reported to be 7.1 to 8 (Thavaselvam and Kalyanasundaram 1991). Some of the species within the genus *Armigers* can breed in water bodies where the pH values goes beyond 9 (Rajavel 1992). Water samples from most of the locations under study experienced mean pH values within these limits. This can also contribute to the breeding of different mosquito species.

Turbidity of water influences the breeding of different mosquito species. Results of the present study showed that, the mean turbidity values of different water samples collected from all the locations were ranged from 7.6

to 24.1 NTU during pre monsoon season, 1.1 to 5.7 NTU during monsoon season and 3.7 to 77.9 NTU during post monsoon season. Most of the *Anopheles* species prefers clear water for breeding except *An. gambiae* that breed in water of higher turbidity (Robert et al. 1998). Studies reported that, Culicines prefer more turbid water for breeding (Sattler et al. 2005). The turbidity values experienced at all the locations during all the seasons showed wider range from very low (1.1 NTU) to extreme high (77.9 NTU). This may aid different types of mosquito to breed in water with different turbidity optima. The lower ranges can bring the emergence of many *Anopheles* species and higher ranges are preferred by *Culex* and *Aedes* species.

Total solids are known to influence the breeding of mosquitoes. Results of the present study showed that, the mean total solids values of different water samples collected from all the locations were ranged from 2120 to 13533.33 mg/l during pre monsoon season, 491.67 to 2466.67 mg/l during monsoon season and 191.67 to 9466.67 mg/l during post monsoon season. There were reports on the positive correlation between total solids and breeding intensity of mosquitoes. The range of total solids preferred by *Armigeres* species was estimated to be 11440 to 27920 mg/l (Rajavel 1992). Also it was reported that the breeding intensity of *Culex quinquefasciatus* have positive correlation with total solids (Thavaselvam and Kalyanasundaram 1991). The high values of total solids noticed in the present study thus indicates that, many of the aquatic systems analyzed were ideal for the breeding mosquito species especially of *Culex* and *Armigeres*.

Total alkalinity influences the breeding of different species of mosquitoes in water. Results of the present study showed that, the mean total alkalinity values of different water samples collected from all the locations were ranged from 154.17 to 295 mg/l during pre monsoon season, 158.33 to 333.33 mg/l during monsoon season and 183.33 to 533.33 mg/l during post monsoon season. Most of the *Anopheles* and *Mansonia* species prefer high alkalinity for their breeding (Bashar et al. 2016). *Culex* species prefer high alkalinity and

Aedes species prefer low to moderate levels of alkalinity (Rao et al. 2011). The total alkalinity preference of *Culex quinquefasciatus* were found to be in the range of 10-1212 mg//l with optimum values of 201-300 mg/l (Thavaselvam and Kalyanasundaram 1991). The water samples from all the locations under study experienced total alkalinity values of different range, which enables so many mosquito species to use them as potential breeding grounds.

Most of the mosquito species prefer low levels of acidity in water. Results of the present study showed that, the mean acidity values of different water samples collected from all the locations were ranged from 19.36 to 41.07 mg/l during pre monsoon season, 9.2 to 35.2 mg/l during monsoon season and 16.7 to 60.9 mg/l during post monsoon season. The acidity preference of *Culex quinquefasciatus* were found to be in the range of 20-100 mg/l (Thavaselvam and Kalyanasundaram 1991). Also the acidity preference of *Armigeres* species was reported to be 24 to 124 mg/l (Rajavel 1992). Thus it can be concluded that upon considering the acidity values, water samples from all the locations under study were found to be ideal for the breeding of different mosquito species.

Generally mosquitoes prefer water with reduced dissolved oxygen (DO) content (Tennesson 1993). But, some species prefer high oxygen levels in water. Results of the present study showed that, the mean DO values of different water samples collected from all the locations were ranged from 0.91 to 3.54 mg/l during pre monsoon season, 2.59 to 4.86 mg/l during monsoon season and 0.37 to 4.96 mg/l during post monsoon season. Earlier studies on *Culex* species showed that the range at which optimum breeding take place is 1-6.2mg/l (Thavaselvam and Kalyanasundaram 1991). Also studies pertaining to *Culex* species show that, there exists a negative correlation between DO and abundance of mosquitoes (Sunish et al. 2006). The negative correlation between DO and some of the *Culex* and *Anopheles* species was also reported (Amerasinghe et al. 1995). Bashar et al. (2016) stated that, species like *Cx.*

gelidus, *Ae. aegypti*, *Ae. albopictus*, *An. vagus*, *An. peditaeniatus*, *An. barbirostris*, and *Mn. annulifera* can breed in water with high oxygen content. Upon comparing with these studies, it can be concluded that, DO values experienced at all the locations during different seasons showed wider range from very low (0.37 mg/l) to high (4.96 mg/l). This variation can bring the breeding and abundance of different mosquito species.

Hardness of water also influences the breeding of mosquitoes. Results of the present study showed that, the mean total hardness values of different water samples collected from all the locations were ranged from 116.67 to 578 mg/l during pre monsoon season, 59.33 to 141 mg/l during monsoon season and 117 to 471.67 mg/l during post monsoon season. Higher levels of total hardness in water sources enhance the breeding of *Anopheles* species (Kengluecha et al. 2005). *Culex* species also prefer higher ranges of total hardness and the optimum value for *Culex quinquefasciatus* was reported to be 178 to 647 mg/l (Thavaselvam and Kalyanasundaram 1991). In the case of *Aedes* species, lower values of total hardness were found to be ideal for larval breeding (Bashar et al. 2016). Total hardness values experienced at all the locations during different seasons showed wider range from low (59.33 mg/l) to high (578 mg/l) and enable the breeding of different mosquito species.

Chloride in water has an influence on the emergence of mosquitoes. Results of the present study showed that, the mean chloride values of different water samples collected from all the locations were ranged from 140.82 to 331.33 mg/l during pre monsoon season, 81.99 to 215.19 mg/l during monsoon season and 228.15 to 549.07 mg/l during post monsoon season. Chloride preference of mosquitoes showed varied ranges. Some of the *Culex* species can breed in water with chloride range of 21-6125 mg/l (Thavaselvam and Kalyanasundaram 1991). The optimum chloride level for the breeding of *Armigeres* species was estimated to be 198 mg/l (Rajavel 1992). The chloride preference of *Anopheles* species were comparatively less and varied between different species and habitats (Kipyab et al. 2015). The water samples from all the locations under study experienced chloride values of different range that enables different mosquito species to use them as potential breeding grounds.

Upon comparing the ranges of various parameters experienced in all the locations in the present study, it can be concluded that all the parameters are falling in an ideal range, favouring mosquito abundance. Upon comparing the results of the present study with valid literature, it can be inferred that the most influential attributes that can support maximum growth of mosquitoes were water temperature, pH, total alkalinity, dissolved oxygen and total hardness (Koehler 1996). The mean values of each of these attributes experienced at all the locations during 3 seasons were correlated with number of mf cases reported. Table 18 shows the results of the correlation studies between number of microfilaria cases reported and various physico-chemical attributes of water samples from all the locations under study.

The results revealed that the numbers of mf cases reported were positively correlated with pH during post monsoon (0.24185) and monsoon (0.39418) seasons. Water temperature showed positive correlation during monsoon season (0.62292). Positive correlation between mf cases and total alkalinity has been noticed during monsoon (0.24675) and post monsoon (0.24302) seasons. Mean values of dissolved oxygen were negatively correlated with the number of mf cases during all the seasons. Total hardness showed positive correlation only during post monsoon seasons (0.65900).

However, upon correlating the yearly mean values of all these parameters with number of mf cases reported, positive results have been noticed for water temperature (0.215664), pH (0.225064), total alkalinity (0.168761) and total hardness (0.44885). This has also supported by many other studies (Macgregor 1921; Mary and Beattie 1930; Thavaselvam and Kalyanasundaram 1991). Dissolved oxygen was found to be negatively correlated with mosquito abundance in all the aquatic habitats (Kocher and Dipthi 2012). The negative correlation noticed between number of mf cases and dissolved oxygen (-0.11061) in the present study were also indicative of conditions favoring mosquito abundance and disease prevalence.

The overall study revealed the existence of heterogeneous water sources within filarial endemic location of 10 districts of Kerala. All the water systems especially sewerage channels were capable of serving as potential breeding habitats of different mosquito species. Climatological attributes experienced at all the locations were supportive of breeding and emergence of mosquito species. Upon considering the mean values of various physico-chemical characteristics of water sources, it can be concluded that, all the parameters were ideal for the breeding of mosquito species of one genus or other. The most influential attributes that can support maximum growth of mosquitoes were water temperature, pH, total alkalinity, dissolved oxygen and total hardness. Positive correlation between number of mf cases and factors like area of sewerage systems, its open nature, water temperature, total alkalinity, dissolved oxygen and total hardness can bring upsurge in the population dynamics of filarial vector *Culex quinquefasciatus*. The upsurge of filarial vector, *Culex quinquefasciatus* by utilizing or adapting to the above mentioned environmental and climatic conditions were supposed to be the principal reason for the endemicity of filarial disease along all the locations under study.

Climatological factors like atmospheric temperature, total rain fall and relative humidity have enormous role on the abundance and emergence of mosquitoes. Total rainfall, mean maximum temperature, mean minimum temperature and mean relative humidity experienced at all the locations falling in 10 districts were procured from India meteorological department, Trivandrum. The data were analyzed with respect to pre monsoon, monsoon and post monsoon seasons. The mean values of climatological attributes experienced at all the locations under study during pre monsoon, monsoon and post monsoon seasons are depicted in Tables 13 – 15 respectively.

Table 1.13. Mean values of climatological factors experienced at all the locations during pre monsoon season (February 2012 to May 2012).

Sl No	District	Location	Total Rainfall (mm)	Mean Minimum Temperature (^{O}C)	Mean Maximum Temperature (^{O}C)	Mean Relative Humidity (%)
1	Trivandrum	Manacaud	270.6	24.7	33.2	75
2	Kollam	Mangad	490.8	21.7	35.2	92
3	Alleppey	Kommady	423.4	24.4	32.4	81
4	Ernakulam	Thoppumpady	695.8	24.5	33	74
5	Thrissur	Chavakkad	222.7	24.1	34.4	69
6	Palakkad	Thirunellai	338.4	24.4	34.7	76
7	Malappuram	Ponnani	278.5	24.6	33.0	71
8	Kozhikode	Vellayil	190.1	25.7	34.4	74
9	Kannur	Thalassery	94.2	24.1	34.7	69
10	Kasaragod	Thalangara	138.4	24.7	32.2	76

Table 1.14. Mean values of climatological attributes experienced at all the locations during monsoon season (June 2012 to September 2012).

Sl No	District	Location	Total Rainfall (mm)	Mean Minimum Temperature (^{O}C)	Mean Maximum Temperature (^{O}C)	Mean Relative Humidity (%)
1	Trivandrum	Manacaud	518.2	24.3	31.4	81
2	Kollam	Mangad	883.4	21.5	31.4	95
3	Alleppey	Kommady	1104.6	23.8	30	89
4	Ernakulam	Thoppumpady	1296.8	23.4	30.9	83
5	Thrissur	Chavakkad	1714.3	23.5	29.9	85
6	Palakkad	Thirunellai	1190.1	23.4	29.6	85
7	Malappuram	Ponnani	1653.1	23.1	29.5	83
8	Kozhikode	Vellayil	1770.2	24.3	30.8	86
9	Kannur	Thalassery	2293.1	23.9	29.9	88
10	Kasaragod	Thalangara	2252.9	24.2	28.7	84

Table 1.15. Mean values of climatological attributes experienced at all the locations during post monsoon season (October 2012 to January 2013).

Sl	District	Location	Total	Mean	Mean	Mean

No			**Rainfall (mm)**	**Minimum Temperature (^{O}C)**	**Maximum Temperature (^{O}C)**	**Relative Humidity (%)**
1	Trivandrum	Manacaud	395.4	23.6	32.2	78
2	Kollam	Mangad	379.2	22.5	34.1	85
3	Alleppey	Kommady	340	23.6	31.1	80
4	Ernakulam	Thoppumpady	520.2	23.1	32.5	73
5	Thrissur	Chavakkad	232.1	22.9	32.9	66
6	Palakkad	Thirunellai	225.8	23.8	32.2	64
7	Malappuram	Ponnani	153.1	22.8	32.4	70
8	Kozhikode	Vellayil	287.3	24.1	33.3	76
9	Kannur	Thalassery	261.4	23.7	32.7	72
10	Kasaragod	Thalangara	204.5	22.7	31.2	63

Detailed analysis of climatological attributes revealed that, in the pre monsoon season, mean total rain fall was maximum at Thoppumpady of Ernakulam (695.8mm) followed by Mangad of Kollam (490.8mm) and Kommady of Alleppey (423.4mm) districts. However, minimum values of mean total rain fall were experienced at Thalassery of Kannur (94.2mm) followed by Thalangara of Kasaragod (138.4mm) and Vellayil of Kozhikode (190.1mm) districts. Mean values of atmospheric minimum temperature were noticed to be higher at Vellayil of Kozhikode (25.7^{0}C) followed by Thalangara of Kasaragod (24.7^{0}C) and Manacaud of Trivandrum (24.7^{0}C) districts whereas, lower values were noticed at Mangad of Kollam (21.7^{0}C) followed by Chavakkad of Thrissur (24.1^{0}C) and Thalassery of Kannur (24.1^{0}C) districts. Atmospheric maximum temperature showed higher mean values at Mangad of Kollam (35.2^{0}C) followed by Thirunellai of Palakkad (34.7^{0}C) and Thalassery of Kannur (34.7^{0}C) districts. However, lower values were noticed at Thalangara of Kasaragod (32.2^{0}C) followed by Kommady of Alleppey (32.4^{0}C) and Ponnani of Malappuram (33^{0}C) districts. Mean relative humidity experienced at all the locations revealed that, Mangad of Kollam

(92%) was noticed for a higher value followed by Kommady of Alleppey (81%) and Thirunellai of Palakkad (76%) districts. Minimum values of mean relative humidity were reported from Thalassery of Kannur (69%) and Chavakkad of Thrissur (69%) followed by Ponnani of Malappuram (71%) districts.

Analysis of climatological attributes experienced at all the locations during monsoon season revealed that, mean total rain fall was maximum at the northern most districts Thalassery of Kannur (2293.1mm) followed by Thalangara of Kasaragod (2252.9mm) and Vellayil of Kozhikode (1770.2mm). However, minimum values of mean total rain fall were experienced at Manacaud of Trivandrum (518.2mm) followed by Mangad of Kollam (883.4mm) and Kommady of Alleppey (1104.6mm) districts. Mean values of atmospheric minimum temperature were noticed to be higher at Manacaud of Trivandrum (24.3^0C) and Vellayil of Kozhikode (24.3^0C) followed by Thalangara of Kasaragod (24.2^0C) districts, whereas, lower values were noticed at Mangad of Kollam (21.5^0C) followed by Ponnani of Malappuram (23.1^0C) and Thirunellai of Palakkad (23.4^0C) districts. Atmospheric maximum temperature showed higher mean values at Mangad of Kollam (31.4^0C) and Manacaud of Trivandrum (31.4^0C) followed by Kommady of Alleppey (30^0C) districts. However, lower values were noticed at Thalangara of Kasaragod (28.7^0C) followed by Ponnani of Malappuram (29.5^0C) and Thirunellai of Palakkad (29.6^0C) districts. Mean relative humidity experienced were higher at Mangad of Kollam (95%) followed Kommady of Alleppey (89%) and Thalassery of Kannur (88%) districts whereas, minimum values were reported from Manacaud of Trivandrum (81%) followed by Thoppumpady of Ernakulam (83%) and Ponnani of Malappuram (83%) districts during monsoon season.

Results of various climatological attributes experienced at all the locations during post monsoon season revealed that mean total rain fall was maximum at Thoppumpady of Ernakulam (520.2mm) followed by Manacaud of

Trivandrum (395.4mm) and Mangad of Kollam (379.2mm) districts. However, minimum values of mean total rain fall were experienced at Ponnani of Malappuram (153.1mm) followed by Thalangara of Kasaragod (204.5mm) and Chavakkad of Thrissur (232.1mm) districts. Mean values of atmospheric minimum temperature were noticed to be higher at Vellayil of Kozhikode (24.1^{0}C) followed by Thirunellai of Palakkad (23.8^{0}C) and Thalassery of Kannur (23.7^{0}C) districts whereas, lower values were noticed at Mangad of Kollam (22.5^{0}C) followed by Thalangara of Kasaragod (22.7^{0}C) and Ponnani of Malappuram (22.8^{0}C) districts. Atmospheric maximum temperature showed higher mean values at Mangad of Kollam (34.1^{0}C) followed by Vellayil of Kozhikode (33.3^{0}C) and Chavakkad of Thrissur (32.9^{0}C) districts. However, lower values were noticed at Kommady of Alleppey (31.1^{0}C) followed by Thalangara of Kasaragod (31.2^{0}C) and Manacaud of Trivandrum (32.2^{0}C) districts. Mangad of Kollam (85%) was noticed for a higher value of mean relative humidity followed by Kommady of Alleppey (80%) and Manacaud of Trivandrum (78%) districts. Thalangara of Kasaragod (63%) followed by Thirunellai of Palakkad (64%) and Chavakkad of Thrissur (66%) districts were notice for lower values of mean relative humidity during post monsoon season.

The overall results revealed that, uniform pattern of atmospheric maximum temperature has been noticed during pre monsoon and monsoon seasons, whereas monsoon season showed a slight decline. Both total rain fall and relative humidity showed higher values with respect to monsoon season than the other two seasons. Both of these attributes maintained a uniform pattern during pre monsoon and post monsoon seasons.

Atmospheric temperature have supreme role on the rate of reproduction, biting behavior, survival rate and transmissibility of mosquitoes (Gratz 1999). Increased temperature upsurges the disease transmission potential of mosquitoes. This is a result of enhanced blood meal digestion and subsequent processes related to ovarian and egg development. Such changes induce the mosquitoes to take more blood meal by feeding on their hosts (Martens et al. 1995). In the present study results of the mean maximum temperature experienced at all the locations during pre monsoon, monsoon and post monsoon seasons revealed that, all the values are coming in the range wherein, different species of mosquitoes can breed, survive and transmit diseases. The mean values of atmospheric maximum temperatures were in the range of 32.2 to 35.2^{0}C during pre monsoon, 28.7 to 31.4^{0}C during monsoon and 31.1 to 34.1^{0}C during post monsoon seasons. A high value was noticed in the pre monsoon season with a wider range followed by post monsoon and monsoon seasons. All the values of temperature were below 38^{0}C and elevated temperature around 38^{0}C may result in drastic decrease in the daily survival of mosquitoes and will lead to enhanced mortality rate (Martens et al. 1997).

A prominent upsurge in the abundance of mosquitoes around 30-100% could be reached in accordance with a fluctuation of 0.5^{0}C in the mean ambient air temperature (Pascual et al. 2006). Different months during pre monsoon season showed a temperature range from 32.2 to 35.2^{0}C and were noted to be ideal for the breeding and emergence of different mosquito species. Temperature during early months of the season was lower at all the locations under study and increased in the later months. The change of temperature around 1^{0}C during the late pre monsoon season enables more mosquito species to evolve in a short period of time. Moreover a similar pattern of variation in temperature was noticed at all the locations in the monsoon season. Early months of post monsoon season was noticed for a diminished level of temperature and were increased towards the later months.

Mosquito abundance and transmission of different pathogen by them are profoundly affected when the temperature become too low. This is due to the effect of temperature on the development and efficiency of pathogen within the mosquitoes and also by the shortening of lifespan and survivability of mosquitoes (Tsai et al. 2012). The mean atmospheric temperature experienced at all the locations under study was ranged from 21.7-25.7^{0}C, 21.5-24.3^{0}C and 22.5-24.1^{0}C during pre monsoon, monsoon and post monsoon seasons respectively. As the minimum temperature experienced at all the locations were above 20^{0}C, it can be inferred that, these locations can bring the upsurge of mosquitoes.

Studies with respect to the filarial vector, *Culex quinquefasciatus* show that, the species can breed in environments with mean temperature range of 17-36^{0}C (Thavaselvam and Kalyanasundaram 1991). The ranges of both minimum and maximum temperature at all the locations under study during different seasons of the year were coming within these limits. Thus it can be concluded that, locations studied with reference to the occurrence of filariasis were experiencing different ranges of temperature during all the seasons of the year and favors the abundance, survivability and disease transmissibility of its mosquito vector.

Rainfall has been described as the most essential physical factor as far as mosquito abundance concerned. Mosquito populations are influenced by the extent, intensity and period of rainfall (Russell et al. 1963). Rainfall creates new habitats with all possible volume in the tropical and subtropical regions and affects the reproduction and abundance of mosquitoes. In the present study, the mean total rainfall experienced at all the locations under study was ranged from and 94.2-695.8 mm, 518-2293 mm and 153.1-520.2 mm during pre monsoon, monsoon and post monsoon seasons respectively. All the locations under study availed adequate rainfall during different seasons towards the sustenance of different water sources. A significant lower pattern of total rainfall was experienced at Ponnani of Malappuram district during post monsoon season and Thalassery of Kannur district during pre monsoon season.

Relative humidity is one of the other important attributes in determining the abundance, distribution and survivability of mosquitoes. The mean relative humidity experienced at all the locations under study has ranged from and 69-

92%, 81-95% and 63-85% during pre monsoon, monsoon and post monsoon seasons respectively. Earlier studies revealed that the optimum values of relative humidity for the growth and development of mosquitoes is 65-90% (Pampana 1969). The mean values of relative humidity experienced at all the locations during 3 seasons were falling within these limits. Thus it can also be inferred that, the pattern of relative humidity was also favoring the abundance of mosquitoes in the filariasis endemic locations of 10 districts of Kerala.

From the results it can be concluded that, various climatological attributes experienced at all the locations during different seasons were favouring the abundance of mosquitoes, especially the filarial vector, *Culex quinquefasciatus* (Russell et al. 1963; Pampana 1969; Thavaselvam and Kalyanasundaram 1991; Martens et al. 1995). Even though all the parameters have vital role in mosquito emergence, their possible impact on the occurrence of filarial disease is less understood. Table 11 shows the results of correlation studies between number of microfilaria cases reported and various climatological attributes from all the locations under study.

The results revealed that, the mean values of mean total rainfall, atmospheric minimum temperature, atmospheric maximum temperature and relative humidity experienced during most seasons were noticed to be negatively correlated with the number of mf cases reported. Only the atmospheric minimum temperature during pre monsoon season (0.16762) and total rainfall during monsoon season (0.07729) were positively correlated with occurrence of filarial disease. Thus it can be concluded that, even though all these attributes have vital role in mosquito emergence and host vector interactions, no direct influence has been noticed with respect to the occurrence of filarial disease.

Summary and Conclusion

Filariasis is a group of vector - borne parasitic diseases of humans and other animals, caused by long, thread like parasitic round worms such as *Wuchereria bancrofti*, *Brugia malayi*, and *Brugia timori*. The disease, which had already been kept away by most developed countries, is still rampant in some of the coastal and non-coastal districts of Kerala. Even though much of studies have been carried out on the vector characteristics and therapeutic aspects of the disease, no reported study is available on the recent persistence and confinement of the disease in Kerala. In this context, present study is attempted to elucidate the environmental, entomological, social, occupational and cultural reasons responsible for the endemicity of filariasis in 10 locations, each falling in Trivandrum, Kollam, Alleppey, Ernakulam, Thrissur, Palakkad, Malappuram, Kozhikode, Kannur and Kasaragod districts of Kerala.

Assessment of the nature, type, number and area of all surface water sources within each location in all the ten districts were carried out and reported. Emphasis was given to sewerage channels, as they are the most ideal breeding sites of filarial vector, *Culex quinquefasciatus*. Water samples from these water sources were collected seasonally for a period of one year from February 2012 to January 2013 and subjected to the analysis of various physicochemical parameters such as pH, temperature, turbidity, total solids, acidity, total alkalinity, dissolved oxygen, total hardness and chloride. Data pertaining to various climatological attributes like mean atmospheric temperature, total rainfall and relative humidity were procured from the Meteorological department of the Government of India.

The results revealed that the water sources falling within all the locations are in the category of ponds, canals, ground pools, rice fields and sewerage channels. The nature of water sources was noticed to be different in different districts. Upon considering the number of water sources, Thoppumpady of Ernakulam district occupied highest (47) and Thalangara of Kasaragod district the lowest (19). Likewise Thoppumpady of Ernakulam district was occupied by higher area of sewerage channels (17033.5 m^2) falling in categories A, B, and E, followed by Manacaud of Trivandrum (14400.5 m^2) and Ponnani of Malappuram (10458 m^2) in categories B and D. All the districts occupied both open and closed types of sewerages. A larger area of open sewerage system was noticed at Ponnani of Malappuram district (3394 m^2) followed by Vellayil of Kozhikode (2500 m^2) and Thirunellayi of Palakkad District (2242 m^2).

The total number of microfilaria (mf) cases reported from each district has been correlated with different aspects of water sources. The total number of water sources and number of mf cases reported from all the locations were noticed to be negatively correlated (-0.00997). However, the total area of water sources and mf cases from all the locations was positively correlated but weak (0.096403). Upon correlating the number, area and types of sewerage systems with the number of mf cases in all the locations, it can be concluded that, the number of sewerage channels was noticed to be negatively correlated (-0.02948). However, a slight positive correlation has been noticed between number of mf cases and total area of sewerage systems (0.033059). The open nature of sewerage channels has supreme influence on the emergence of mosquitoes. A strong positive correlation has been noticed between the total areas of open sewerage channels and number of mf cases (0.713181).

The overall results showed that, even though all the locations hold higher number of water sources for the breeding and emergence of mosquitoes, their influence on the occurrence of filarial disease was very nominal. But, total area has been shown to influence the occurrence of the disease. Presence of sewerage channels in all the locations may enhance the emergence of filarial vector, *Culex quinquefasciatus*. All the locations under study occupied larger area of sewerage channels and a significant percentage of them were open type. Larger area of sewerage channels along with their open nature may result in the enhanced emergence and abundance of filarial vector. Dasgupta (1984) reported that by increasing the number of potential vector breeding sites due to various human activities, the spread of filarial parasite *W. bancrofti* increases. The positive correlation between the number of microfilaria cases and area of open type sewerage channels establish the fact that, such systems have enormous impact on the transmission of filariasis.

Results of analysis of various physico-chemical parameters of water collected from all the locations under study during pre monsoon, monsoon and post monsoon seasons revealed that, all the parameters showed considerable changes. As per valid literature, the most influential attributes that can support maximum growth of mosquitoes are water temperature, pH, total alkalinity, dissolved oxygen and total hardness.

The mean water temperature experienced at different locations ranged from 27.4^{0}C to 29^{0}C during pre monsoon, 28.5^{0}C to 29.4^{0}C during monsoon season and 27.1^{0}C to 29.4^{0}C during post monsoon seasons. The mean pH values experienced at all the locations ranged from 6.74 to 7.59 during pre monsoon, 6.98 to 7.38 during monsoon season and 6.86 to 7.44 during post monsoon seasons. The mean total alkalinity values of different water samples collected from all the locations ranged from 154.17 to 295 mg/l during pre monsoon season, 158.33 to 333.33 mg/l during monsoon season and 183.33 to 533.33 mg/l during post monsoon season. The mean dissolved oxygen values of different water samples collected from different locations ranged from 0.91 to 3.54 mg/l during pre monsoon season, 2.59 to 4.86 mg/l during monsoon season and 0.37 to 4.96 mg/l during post monsoon season. The mean total hardness values of different water samples collected from the locations ranged from 116.67 to 578 mg/l during pre monsoon season, 59.33 to 141 mg/l during monsoon season and 117 to 471.67 mg/l during post monsoon season.

Upon comparing the results of the present study with valid literature, it can be inferred that the most influential attributes that can support maximum growth of mosquitoes were water temperature, pH, total alkalinity, dissolved oxygen and total hardness (Koehler 1996). The mean values of each of these attributes experienced at all the locations during 3 seasons were correlated with number of mf cases reported. Upon correlating the yearly mean values of all these parameters with number of mf cases reported, positive results have been noticed for water temperature (0.215664), pH (0.225064), total alkalinity (0.168761) and total hardness (0.44885). This has also supported by many other studies (Macgregor 1921; Mary and Beattie 1930; Thavaselvam and Kalyanasundaram 1991). Dissolved oxygen was found to be negatively correlated with mosquito abundance in all the aquatic habitats (Kocher and Dipthi 2012). The negative correlation noticed between number of mf cases and dissolved oxygen (-0.11061) in the present study were also indicative of conditions favoring mosquito abundance and diseases prevalence.

The seasonal pattern of climatological attributes like atmospheric temperature, total rain fall and relative humidity pertaining to all the locations were collected. The results revealed that, mean total rainfall (1467.67 mm) and mean relative humidity (85.9%) experienced at all the locations were higher during monsoon season. The mean value of atmospheric maximum and minimum temperatures experienced at all the locations revealed a higher trend during pre monsoon season (28.6^{0}C).

Upon correlating various climatological attributes with number of microfilaria reported it can be concluded that, only atmospheric minimum temperature during pre monsoon season (0.16762) and total rainfall during monsoon season (0.07729) were positively correlated with occurrence of filarial disease. Thus it can be concluded that, even though all these attributes have vital role in mosquito emergence and host vector interactions, no significant influence was noticed with respect to the occurrence of filarial disease.

Upon considering all the factors under study, it can be concluded that, all the locations under study occupied sufficient number and volume of water sources that can support the breeding of different mosquito species. Occurrence of a large area of sewerage systems and their open nature can contribute to the breeding of filarial vector *Culex quinquefasciatus* in all the locations. Upon considering the mean values of various physico-chemical attributes of water sources, it can be concluded that, all the parameters were ideal for the breeding of mosquito species of one genus or other. The most influential attributes that can support maximum growth of mosquitoes were water temperature, pH, total alkalinity, dissolved oxygen and total hardness. The correlation studies showed that, the number of microfilaria cases were positively correlated with area of sewerage systems, its open nature, water temperature, pH, total alkalinity, dissolved oxygen and total hardness. Climatological attributes experienced at all the locations were supportive of breeding and emergence of mosquito species. All these factors might have been contributing to the upsurge in the population dynamics of filarial vector *Culex quinquefasciatus*, resulting in the endemicity of filarial disease along the locations under study.

CHAPTER II
DIVERSITY STUDIES

Introduction

Mosquitoes are the most diversified group of hematophagous insects that have distributed all over the globe. They probably have a much higher influence on human health and well-being than any other arthropod vectors. Besides the annoyance that they make, these remarkably resistant insects have been involved in the transmission of many devastating diseases. Each species contribute to the breeding of filarial vector *Culex quinquefasciatus* in all the locations. Upon considering the mean values of various physico-chemical attributes of water sources, it can be concluded that, all the parameters were ideal for the breeding of mosquito species of one genus or other. The most influential attributes that can support maximum growth of mosquitoes were water temperature, pH, total alkalinity, dissolved oxygen and total hardness. The correlation studies showed that, the number of microfilaria cases were positively correlated with area of sewerage systems, its open nature, water temperature, pH, total alkalinity, dissolved oxygen and total hardness. Climatological attributes experienced at all the locations were supportive of breeding and emergence of mosquito species. All these factors might have been contributing to the upsurge in the population dynamics of filarial vector *Culex quinquefasciatus*, resulting in the endemicity of filarial disease along the locations under study.

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Mosquitoes are the most diversified group of hematophagous insects that have distributed all over the globe. They probably have a much higher influence on human health and well-being than any other arthropod vectors. Besides the annoyance that they make, these remarkably resistant insects have been involved in the transmission of many devastating diseases. Each species prefer a particular breeding habitat that sustains adequate nutrients required for their growth. The ability to prefer a particular host and the resistance acquired against various insecticides make them unique in the area of public health.

Numerous interacting features of the environment determine the abundance of mosquitoes. Different mosquito species can sustain throughout the year and abundance of each of them directly depends on the heterogeneity and availability of breeding habitats. Heterogeneous mix of breeding grounds and enhanced rates of emergence along with survivability influences the pattern of disease transmission by mosquitoes. Mosquito diversity of a particular geographic area has got enormous impact on the health status of the people (WHO 2007). Insight on to the nature and diversity of mosquitoes in relation to environmental characteristics thus assumes significance in developing better eradication strategies.

Mosquitoes are considered among the most widely distributed and scientifically studied insects in the world. They have an almost worldwide distribution, being found throughout the tropics and temperate regions. Their distribution covers all the extremities of the globe except the area under permanently frozen condition and along few islands. They can thrive in a variety of habitats containing fresh, brackish, or other water types (clear, turbid or polluted), excluding marine habitats with high-salt concentration. Presently, under 42 genera and 140 subgenera, 3,555 species of mosquitoes have been reported from different sectors of the world (Harbach 2017). There are probably more than 1,000 species that have yet to be found and described (Rueda 1998).

Generally mosquitoes are included in class Insecta, Order Diptera, Suborder Nematocera, Family Culicidae and Sub families Anophelinae, Culicinae and Taxorhynchitinae. The order Diptera includes mainly small or even minute insects with only one pair of fore wings. The wings are reduced to club shaped vestiges called halters. The unique features of the suborder

Nematocera include subtle body with long antennae and maxillary palpi. The antennae are filamentous and palpi are flexible in nature. Presence of slender body with legs, wings and scales along with elongated proboscis are the features of the family Culicidae (Roy and Brown 1970). The family Culicidae is categorized in to three subfamilies such as Anophelinae, Culicinae, and Toxorhynchitinae (Knight and Stone 1977).

Anophelinae: The posture with respect to resting or standing is the recognizing features of this group of mosquitoes. Maxillary palpi of both sexes possess length as long as the proboscis. Evenly rounded or strap-like dorsal scutellum is present. Each egg has floats and no siphon tubes for larvae. Adults rest with their abdomen tilted forwards at 45^{o} to the surface and adult females are blood-feeders. The veins of wings are covered partially or fully by dark and pale scales. Presence of scales on the maxillary palpi and its absence on abdominal terga and sterna is another uniqueness of this group. There are three genera coming under this subfamily (Knight and Stone 1977).

Culicinae: Maxillary palpi are shorter and come around less than half as long as the proboscis and there will be a tri-lobed scutellum with setae. There are dense dark scales on wings, abdominal terga and sterna. The dark scales on veins of wings have intermittent spots of white or yellow scales. Adults rest with abdomens about parallel to the surface; larvae have a prominent siphon for respiration and the eggs that are deposited as rafts lack floats. The females are blood-feeders. There are about 34 genera coming under this subfamily (Knight and Stone 1977).

Toxorhynchitinae: Proboscis is strongly curved downwards and they are unusually large mosquitoes with metallic coloured scales. The larvae are predaceous. The adult females do not feed on blood but only on nectar and other plant juices. Only one genus has been categorized under this subfamily (Knight and Stone 1977).

Among the 3555 species of mosquitoes reported, less than 100 species belonging to 8 genera are important in terms of disease transmission (Rao

1984). The most important genera of mosquitoes that have eminent role in disease transmission are *Anopheles*, *Aedes*, *Culex* and *Mansonia*. They spread a wide array of pathogens along different sectors of the world and are responsible for 10% of all the sickness to humans (Tyagi 2003). They act as the vector of so many devastating diseases such as malaria, dengue fever, Japanese encephalitis, chikungunya and filariasis.

In terms of medical importance, *Anopheles* stands at the top among different genera of mosquitoes. *Anopheles* mosquitoes are the infamous vector of the disease malaria in the world. Estimates show that 2400 million people in more than 90 countries in the world are at risk of malaria with annual clinical and death cases amounting to 300-500 million and 1.5-2.7 million, respectively (WHO 2000). Malarial disease has both primary and secondary vectors. The most important primary vectors of malaria are *Anopheles culicifacies*, *An. stephensi*, *An. fluviatilis*, *An. dirus*, *An. sundaicus* and *An. minimus*. The secondary vectors include *An. annularis, An. philippinensis*, *An. jeyporiensis* and *An. varuna* (Rao 1984). Some of the Anopheline species are reported to be involved in the transmission of *Wuchereria bancrofti*, *Brugia malayi* and *B. timori* causing filariasis in humans (Nagpal and Sharma 1995).

The most important vector borne diseases spread through *Culex* species are Japanese Encephalitis (JE) and bancroftian filariasis. The major Culex species having supreme role in the transmission of JE are *Cx. vishnui, Cx. pseudovishnui, Cx. tritaeniorhynchus* and *Cx. gelidus*. JE transmission also occurs due to mosquito species such as *Cx. whitmorei, Cx. bitaeniorhynchus, Cx. fuscanus, Cx. infula* and *Cx. fuscocephala* (Samuel et al. 2000). The principal vector of bancroftian filariasis is *Cx. quinquefasciatus* (Mourya et al. 1989). Worldwide, there are 1.2 billion people fronting the risk of lymphatic filariasis and 128 million are known to be carriers of filarial young worms (Kumaraswami et al. 2000). Estimates in India shows that, 473 million people are exposed to the risk of bancroftian infection and of these about 348 million are estimated to be harbouring microfilaria (mf) and over 23 million suffer from filarial disease manifestations (WHO 2005).

Aedes species are involved in the transmission of a series of pathogens such as yellow fever virus, dengue fever virus, encephalitis virus, chikungunya virus and many other arboviruses. Their role in the transmission of filarial parasites such as *Wucheraria bancrofti* and *Brugia malayi* are also well established (WHO 1999). The occurrence of the diseases dengue fever and chikungunya across different sectors of the world is due to the involvement of *Ae. aegypti* and *Ae. albopictus* as primary and secondary vectors respectively (Jupp and McIntoch 1988). Also, the role of *Ae. niveus* in the transmission of dengue fever has also been reported (Huang 1979). The most important vectors involved in the transmission of yellow fever in many parts of the world are *Ae. vittatus* and *Ae.* Aegypti. *Ae. albopictus* itself is the primary principal vector of dengue fever and chikungunya in different parts of India (Kannan et al. 2009; Thenmozhi et al. 2007). *Mansonia* species such as *Ma. annulifera*, *Ma. indiana* and *Ma. uniformis* are involved in the spreading of pathogens *Brugia malayi* and *Wucheraria bancrofti* causing filariasis (Iyengar 1938).

Among different vector borne diseases by mosquitoes, filariasis is considered as the second largest painful and disfiguring one. The disease is due to the nematode worms *Wuchereria bancrofti*, *Brugia malayi* and *Brugia timori*. The disease is characterized by fever, chills, headache, and skin lesions in the early stages and, if untreated, can progress to gross enlargement of the limbs and genitalia, a condition called Elephantiasis (Ottesen 1984). Infection by *W. bancrofti* transmitted by the ubiquitous vector, *Culex quinquefasciatus* is the most common and accounts globally for approximately 90% of all infections (Anosike et al. 2005). Infection is prevalent in both urban and rural areas. *Brugia malayi* infection (10%) is mainly restricted to rural areas due to peculiar breeding habits of the vector associated with floating vegetation. *Mansonia annulifera* is the principal vector of *Brugia malayi* (Wharton 1962).

Filariasis is widespread through many tropical and subtropical parts of the world. The disfiguring disease still persists as a major social and economic burden along Africa, Asia, Western Pacific and parts of America. Endemic areas across the world occupy 1.1 billion people of which 120 million living in 73 countries are suffering from clinical manifestations. 40% of the global and 70% of the Asian prevalence of filariasis have been reported from India.

In India, Kerala has been reported as the second largest filariasis endemic state. The filarial statistics in the state shows that, the disease is endemic to certain pockets of coastal districts. The most affected endemic areas are along the Ernakulam, Alleppey and Thrissur districts (WHO 2005). Considering this, the filariasis control programmes and mass drug administration programmes are operational from 1955 and 1997, respectively. Despite years of well-managed filariasis control programmes, sporadic outbreaks continue to occur in certain pockets of the state.

In light of the above, an attempt has been carried out to evaluate the mosquito diversity for a period of one year from February 2012 to January 2013 within the filarial endemic areas falling under Trivandrum, Kollam, Alleppey, Ernakulam, Thrissur, Palakkad, Malappuram, Kozhikode, Kannur and Kasaragod districts of Kerala. Such studies will provide adequate information on the status of different medically important mosquito species, especially filarial vector *Culex quinquefasciatus*, together with their pivotal role in the transmission of the disease. Surveillance on the diversity and distribution of mosquitoes along such endemic areas will also help in developing strategies of vector control.

Review of Literature

Mosquitoes are the most important arthropod vectors involved in the transmission of many overwhelming infectious diseases such as malaria, dengue fever, Japanese encephalitis, yellow fever, chikungunya and filariasis. Mosquito diversity within a particular geographical area has got enormous impact on the health status of human beings. Data on the diversity and distribution of various mosquito species will aid in the design of species specific management strategies. The present work has been an attempt to assess the mosquito diversity in selected locations of 10 districts of Kerala with special reference to endemicity of filariasis.

Diversity studies pertaining to mosquitoes revealed that, mosquitoes are distributed all over the world except areas that are permanently frozen. Worldwide, around 3555 species of mosquitoes under 42 genera and 142 subgenera have been reported (Harbach 2017). Among these, only less than 100 species under 8 genera are supposed to be involved in the transmission of diseases. India is ranked fifth after Brazil, Indonesia, Malaysia and Thailand in terms of mosquito biodiversity and distribution (Foley et al. 2007). Reports reveal that, among 49 genera and 41 subgenera, a total number of 393 species are present in India. Subfamily Anophelinae contains 61 species in one genus, followed by subfamily Culicinae with 332 species in 11 tribes and 48 genera. Tribe Aedini of subfamily Culicinae contains the highest number of 176 species in 33 genera (Bhattacharyya et al. 2014). *Aedes*, *Anopheles, Culex* and *Mansonia* are the most important genera of mosquitoes responsible for 10% of all the sickness to humans (Tyagi 2003).

Enough studies in the context of diversity and distribution of mosquitoes have been carried out and reported from all over the world. All of them were done either in relation to the occurrence of a particular disease or depending on environmental settings of a particular area. The finding on the role of mosquitoes in the transmission of filariasis in 1877 was the first evidence for the involvement of any arthropod vector in human diseases. Years later, the involvement of mosquitoes in the transmission of malaria, yellow fever and dengue were also studied and reported. There onwards, mosquito taxonomy has got special attention and become a prominent area to work on across different parts of the world.

As far as the taxonomy of mosqutoes concerned, contributions of Christophers (1933) and Barraud (1934) are significant. Two volumes of 'Fauna of British India' on Indian Anophilines and Culicines published by Christophers and Barraud respectively described the existence of so many mosqutoes from Indian subcontient. The Anophilines record by Christophers revealed 43 species of *Anopheles* mosquitoes coming under 1 genus and 4 subgenera. Each species has been described in detail in terms of their classification, breeding ecology, global distribution and role in the transmission of different diseases. Complete monograph on Indian Culicines by Barraud revealved the existence of 245 species of mosqutoes under 16 subgenera. Among the Culicines, the genus *Aedes* are the most predominent group with 110 speceis under 12 subgenera. The medical importance of different *Aedes* and *Culex* mosquitoes have also been described.

Worldwide, there were a very few attempts on mosquito fauna after the publication of 2 volumes of Fauna of British India. Stone et al. (1959) described the global existence of 2401 species of mosquitoes under 31 genera. Based on this record, a comprehensive record of 2960 species under 34 genera was reported by Knight and Stone (1977). Studies pertaining to the description of the genus *Culex* from India revealed the occurrence of 42 species including 5 new and 37 revalidated (Sirivanakam 1976). Taxonomic studies on the sub genus *Stegomyia* under *Aedes* along oriental region revealed the occurrence of 37 species (Huang 1979).

Landscape structure is one of the important determinants of mosquito biodiversity. Overgaard et al. (2003) reported the diversity of Anopheline mosquitoes from the northern Thailand. The study was conducted to elucidate the effect of landscape structure on mosquito biodiversity. Different land forms like forests and paddy fields were analyzed for the occurrence of mosquitoes that are vectors of malarial disease. *Anopheles maculatus*, *An. minimus*, *An. aconitus* and *An. hyrcanus* were the most important species observed. With respect to seasons, the abundance of each of these mosquitoes was varied between the two land forms.

Natural phenomenon like floods may create numerous habitats for mosquitoes and eventually enhance their diversity. Diversity studies of mosquitoes were conducted before and after flooding in Brazil. Adult mosquitoes were collected at morning and evening using Shannon trap and human bait. *Aedes scapularis*, *Anopheles darlingi* and *An. Albitarsis Sensolatu* were the most important species noted. Shannon diversity index and student *t*-test explained the seasonal diversity pattern of these mosquitoes. The result showed that, there was an increase in the abundance of mosquitoes after the flood (Tubaki et al. 2004).

In certain geographical areas, seasonality has effects on the abundance rather than diversity of mosquitoes. Diversity studies in Florida of USA revealed that, mosquito abundance was maximum in the monsoon season followed by pre monsoon season. However the diversity pattern of mosquitoes was noticed to be uniform in all the seasons. The most common species recorded in all the seasons were *Anopheles atropos*, *Culex bahamensis*, *Deinocerites cancer*, and *Ochlerotatus taeniorhynchus* of which, *Ochlerotatus taeniorhynchus* was the dominant one (Hribar 2005).

Perdo and Sallum (2009) studied the spatial expansion and population structure of the malarial vector *Anopheles darlingi* along the neotropics. The diversity was varied in accordance with the physiographic nature of the region. Climatological attributes like rainfall has influence on the abundance and distribution of mosquitoes. Detailed evaluation on the abundance of mosquitoes on a seasonal basis was conducted and reported from Kenya. Immature forms of mosquitoes were collected from 24 heterogeneous habitats during wet and dry seasons. Both Anopheline and Culicines were recorded.

Anopheles gambiae, *An. funestus*, *An. coustani*, *Culex quinquefasciatus*, *Cx. duttoni* and *Aedes aegypti* were the most important species collected (Mwangangi et al. 2009).

Endemicity of malaria has resulted in the undertaking of various mosquito diversity studies across the world. Nikookar et al. (2010) studied the species composition and diversity of mosquitoes along Northern Iran. Both adult and immature forms of mosquitoes were collected. 5 species of mosquitoes belonging to 4 genera were reported and the most important species were *Anopheles plumbeus*, *Culiseta annulata*, *Culex pipiens*, and *Ochlerotatus geniculatus*. Ecological modifications like paddy fields enhance the diversity and abundance of mosquitoes. Diversity of mosquitoes was analyzed in Egypt with special reference to paddy field habitats and filariasis. A total of 8 species belonging to 4 genera have been reported from 3 villages and 1 city. The most important species were *Culex pipiens*, *Cx. antennatus*, *Cx. univittatus*, *Anopheles pharoensis*, and *An. coustani*. The diversity pattern among the study sites were analyzed in terms of Shannon weaner diversity (*H*) and evenness (*EH*). Of the 8 species, distribution and abundance of the filarial vectors *Cx. pipiens* and *Cx. antennatus* was noticed to be higher in areas wherein, irrigated lands in the form of paddy fields are prominent (Tarek et al. 2010)

Frequent updates on the distribution of mosquitoes are inevitable towards the assessment of menaces of diseases. In this background, diversity studies were reported from Cape Verde islands of West Africa. Several species of mosquitoes were reported, of which *Culex perexiguus* was an addition to the existing fauna. Size of the island had no effect on the mosquito richness whereas; it was affected by the distance of island from the mainland (Alves et al. 2010).

Mulambalah et al. (2011) evaluated the diversity of *Anopheles* species with respect to the prevalence of malaria along Western Kenya. Both larval and adult mosquitoes were collected from the area following standard methodology. For the identification of mosquitoes both morphological characters and molecular aspects were used. The most important species reported having specific role in the transmission of malaria were *Anopheles gambiae* followed by *Anopheles funestus* and *Anopheles arabiensis*.

Mwangangi et al. (2012) conducted mosquito diversity studies at Malindi, Kenya to evaluate the risk of disease transmission. Mosquitoes were collected from rural, peri-urban and urban areas during wet and dry seasons. The most important species recorded were *Aedes aegypti*, *Culex quinquefasciatus*, *Anopheles gambiae*, *Anopheles funestus* and *Anopheles coustani*. The urban and peri-urban environments have been noticed for a higher percentage of *Culex quinquefasciatus* whereas, the rural areas noticed for higher percentages of *Anopheles gambiae*, *Anopheles funestus* and *Anopheles coustani*. The higher abundance of *Culex quinquefasciatus* has been noticed as the prime reason for the increased prevalence of filarial disease in the area.

Diversity of mosquitoes may get varied along degraded and conserved areas. Diversity studies were conducted in the wild and anthropic forest areas of Brazil. Important species collected from the wild area were *Anopheles cruzii*, *Culex melanoconion* and *Aedes serratus* whereas; *Coquillettidia chrysonotum* and *Anopheles cruzii* were predominant in the anthropic area. The study showed that, upon comparing the diversity pattern between the two environments, a higher mosquito richness and evenness was noticed in the anthropic area than the wild area (Ribeiro et al. 2012).

Mosquito diversity studies at Malakand of Pakistan have been conducted to determine the species composition, relative abundance and habitat preference of mosquitoes (Ali et al. 2013). Collection of only larval mosquitoes were carried out and reared to adults. A total of 15 species belonging to 5 genera have been identified. The abundance and distribution status of different species identified showed that, *Culex quinquefasciatus* and *Anopheles stephensi* were the dominant and constant species. The subdominant species reported were *An. maculatus, Cx. theileri, Cx. tritaeni orhynchus* and *Ae.*

vittatus. The data on seasonality of mosquitoes revealed highest density in November and lowest in December.

The host pathogen relationship is affected by the loss of biodiversity and eventually results in the enhanced risk of infectious diseases. Thongsripong et al. (2013) studied the mosquito diversity across central Thailand with special reference to vector borne diseases. Collections were carried out from various environments including forest, rural and urban areas. 109 species of mosquitoes were reported. Abundance was higher in rice fields than forests. Results of the various diversity analysis indicated that mosquito diversity was higher in rural areas.

Inventory on the mosquitoes of significant level was reported from Belgium. The urban, rural and other natural areas were analyzed for adult mosquitoes. 23 species of mosquitoes including 21 indigenous and 2 exotic were reported. The abundance was correlated with the habitat type using correspondence analysis. Simpson diversity index and species richness revealed that natural areas have a higher diversity and distribution (Versteirt et al. 2013).

Mosquito menace is more prominent in rural areas than urban. Diversity studies along the rural areas of Faisalabad, Pakistan revealed that, there were 11 species of mosquitoes belonging to 3 genera. *Culex* was the most predominant group followed by *Anopheles* and *Aedes*. Irrigated lands produced more number of species. The filarial vector *Culex quinquefasciatus* was the most abundant species sampled from almost all the habitats (Attaullah et al. 2015).

Diversity studies pertaining mosquito distribution and abundance were carried out and reported from different parts of India. In 1984, following the taxonomic information provided in the Fauna of British India, Rao (1984) described most of the Anopheline species in India. Mosquito inventory from the eastern states of India revealed the occurrence of 61 species. *Anopheles*, *Aedes*, *Armigeres*, *Coquillettidia*, *Culex*, *Mansonia* and *Toxorhynchites* were the important genera reported (Nagpal and Sharma 1987).

Considerable increase in the number of studies on mosquito diversity was noticed after 2000. Most of them were carried out either with respect to a particular geographical zone or a particular group of mosquitoes. Diversity studies on mosquitoes in the Mizoram state revealed the existence of 54 species of which, *Culex*, *Anopheles* and *Aedes* were the most predominant group (Dutta et al. 2003). 34 species of mosquitoes belonging to 5 genera like *Aedes, Anopheles, Armigeres, Culex* and *Uranotaenia* were reported from tropical, subtropical and temperate phytogeographic zones of Himalayan region (Devi and Jahuri 2007). The study discussed different breeding habitats, their role in mosquito emergence and coexistence of different mosquitoes within a particular habitat.

29 species of mosquitoes were reported from two districts of Karnataka. Most of the species were noted to be having utmost medical importance (Kumar and Vijayan 2005). Dutta et al. (2010) reported the seasonal pattern of mosquito diversity at Dibru Saikhowa biosphere reserve in Assam. Under 11 genera, a total of 52 species of mosquitoes were reported. *Anopheles* was the most predominant group followed by *Culex* and *Aedes*. The prevalence of mosquitoes in the core and buffer zones of the biosphere showed variation with respect to pre monsoon, monsoon and post monsoon seasons.

Year round study on the diversity of mosquitoes along Sirumalai hills of Tamil Nadu was conducted. The study included the collection of both adult and immature forms of mosquitoes for a period of one year. 17 species of mosquitoes belonging to 4 genera were reported of which, the most important species were *Culex quinquefasciatus*, *Aedes albopictus*, *Anopheles vagus*, *Anopheles subpictus* and *Culex triteaniorhynchus*. Most of the species reported have utmost medical significance as they are involved in the transmission of many diseases (Amala et al 2011).

In the same year, Jaid et al. (2011) reported the diversity of mosquitoes with respect to 3 seasons of the year along the urban areas of Jalna district, Maharashtra state. A total of 1908 mosquitoes belonging to 4 genera have been reported of which, *Anopheles* was the predominant group followed by *Aedes*, *Culex* and *Mansonia*. Maximum number and diversity was observed during monsoon season followed by post monsoon and pre monsoon seasons.

Munirathinam et al. (2014) reported 124 mosquito species belonging to 24 subgenera and 30 genera in the phytotelmata habitats of 11 hill ranges of Western Ghats falling in three states of South India. Culicines were more prominent, followed by Anopheline. *Anopheles culicifacies, Culex pseudovishnui, Cx. whitmorei, Stegomyia aegypti* and *St. albopicta* were the important species reported, that are having medical significance.

Mosquito diversity studies from 3 cities of Warangal revealed the existence of 7 species belonging to 3 genera, *Anopheles*, *Aedes* and *Culex*. Adult mosquitoes were collected both indoor and outdoor of which outdoor was noticed for a higher percentage. The species recorded were *Anopheles culicifacies, Anopheles* stephensi, *Anopheles annularis, Culex quinquefasciatus, Culex tritaeniorhynchus, Aedes aegypti* and *Aedes albopictus.* The analysis of diversity was carried by means of Shannon wiener diversity index and Evenness (Suhasini and Sammaiah 2014).

Diversity of Anophiline mosquitoes were reported from Amravati district of Maharashtra (Nandurkar and Tayade 2014). The important species recorded were *Anopheles theobaldi, A. culicifacies, A. pallidus, A. vagus, A. minimus, A. subpictus, A. sundaicus* and *A. philippinensis*. The most important species having medical significance were *A. culicifacies* and *A. subpictus* that are involved in the transmission of malaria.

Mosquito diversity studies pertaining to three important locations of Punjab were carried out and reported. Based on the existing species of the area, a list was prepared that also included some new species. 26 species of mosquitoes belonging to 13 genera were reported of which, *Culex sitiens*, *Culex brevipalpis, Lutzia vorax* and *Mansonia indiana* were new records from all the locations (Kirti and Kaur 2014).

Description on different tree-hole mosquito species along the Kolli hills of Tamil Nadu revealed the existence of 11 species belonging to 5 genera. The most important species recorded were *Culex uniformis*, *Aedes aegypti*, *Culex quinquefasciatus*, *Orthopodomyia anopheloides* and *Ochlerostatus greenivarkanaranus*. The diversity of mosquitoes along different locations was analyzed using Simpson's index and Simpson's reciprocal index (Kumar and Jebanesan 2015).

Seasonal diversity pattern of mosquitoes along 13 locations in and around Nagpur was analyzed and reported. 19 species of mosquitoes belonging to 5 genera, *Aedes, Anopheles, Culex, Armigeres* and *Mansonia* were present. The most important mosquito species reported were *Culex quinquefasciatus*, *Armigeres subalbatus* and *Anopheles subpictus*. Diversity with respect to 3 seasons was analyzed by Shannon wiener diversity index. The results showed higher mosquito diversity during post monsoon season, followed by monsoon and pre monsoon seasons (Karlekar and Andrew 2015)

Mosquito diversity along two hill regions of Kanyakumari and Tirunelveli districts of Tamil nadu was reported. All the possible water breeding habitats within the area have been thoroughly assessed and collections of mosquito larvae were carried out. All the immature forms were reared to adults and identified. Under 21 genera and 18 subgenera, a total of 50 species were recorded. The most important mosquito species recorded from the study sites having specific role in the transmission of different diseases were *Stegomyia aegypti, S. albopicta*, *Culex bitaeniorhynchus, C. tritaeniorhynchus, Downsiomyia nivea* and *Anopheles mirans* (Munirathinam et al. 2015).

The distribution, abundance and diversity of mosquitoes with special reference to the occurrence of dengue fever along Vellore district of Tamil Nadu were reported. Both immature and adult mosquitoes were collected. Larvae were collected from all permanent and temporary water sources. The adult mosquitoes were collected using sweep nets and aspirators. A total of 696 species of mosquitoes were reported. The most important genera were

Aedes, *Anopheles* and *Culex*. The medically important species of mosquitoes that have distributed along different parts of the district were *Aedes aegypti*, *Ae. albopictus*, *Anopheles stephensi*, *Culex quinquefasciatus* and *Cx. tritaeniorhynchus* (Selvan and Jebanesan 2016).

The prevalence of different mosquito borne diseases along varied environmental pockets of Kerala has necessitated the execution of many taxonomic and diversity studies. The outcome of such studies contributed towards the control of mosquito menace along disease endemic areas. Over the years, there were reports of new species from Kerala that have been included in the Fauna of British India. The occurrence of mosquitoes in Kerala has been noticed and reported for the first time after the prevalence of malaria and Brugian filariasis.

Relevant studies in the area of mosquito taxonomy have been reported in Kerala by James, Giles and Theobald. Considerable contributions were also accomplished by James and Liston (1900) and Covell (1927). The most important report on mosquitoes from Kerala was given by Iyengar (1938). The study was conducted on the occurrence of filariasis and its epidemiology along Travancore. In addition, description of many mosquito species has also been furnished.

In the year 1939, diversity studies along Travancore state has revealed the occurrence of many *Anopheles* species (Mathew 1939). The study discussed the public health implications with special reference to malaria. In the same year, 19 species of *Anopheles* mosquitoes inclusive of some medically significant species were reported from Wayanad district (Covell and Harbhagwan 1939). The role of Mansonia group of mosquitoes (*Mansonia indiana*, *Mansonia annulifera* and *Mansonia uniformis*) in the transmittance of Brugian filariasis in Kerala and their pattern of distribution along different districts were reported (Singh et al. 1956). 13 species of mosquitoes belonging to 4 genera have been reported from the Trivandrum city (Daniel et al. 1986).

18 species of mosquitoes belonging to 6 genera have been reported from the Ernakulam and Alleppey districts of Kerala. *Aedes*, *Culex*, *Anopheles*, *Ficalbia*, *Armigeres* and *Mansonia* were the important genera reported. Special emphasis was given to the *Mansonia* group of mosquitoes *Mansonia indiana*, *Mansonia annulifera* and *Mansonia uniformis*, as they have specific role in the transmission of Brugian filariasis in the area (Sabesan et al. 1991).

In a comprehensive study by Mariappan et al. (1992, 1996) reported 35 species of mosquitoes belonging to 7 genera from Kochi and nearby areas. *Culex* was the most dominant genus with 14 species followed by *Anopheles* (7 species) and *Aedes* (3 species). Later in 2003, Hiriyan et al. (2003) reported 26 species of mosquitoes under 6 genera from the Kuttanad of Alleppey district.

Diversity studies along the mangrove forests of Kannur district revealed the existence of 17 species belonging to 7 genera (Rajavel et al. 2006). The onset of dengue fever along the hilly districts of Kerala and occurrence of *Aedes albopictus* have been studied and reported. Inclusive of the disease vector, a total of 14 species under 5 genera have been reported from the area (Thenmozhi et al. 2007).

21 species of mosquitoes belonging to 5 genera have been reported from southern Kerala of which, the most abundant genus was *Anopheles* (Sudharmini 2009). 38 species of mosquitoes under 10 genera were reported from the Kottayam and Idukki districts of Kerala (Jomon and Thomas 2014). The most abundant genus was *Culex* (16 species) followed by *Anopheles* (7 species) and *Aedes* (6 species).

Mosquito diversity studies in the Alappuzha and Kottayam districts of Kerala were conducted and reported. The diversity statistics of each district showed 44 species of mosquitoes belonging to 11 genera and 21 subgenera in Alappuzha and 21 species belonging to 9 genera and 13 subgenera in Kottayam. The most important genera with respect to Alappuzha district were *Aedes*, *Anopheles*, *Mansonia*, *Heizmannia*, *Culex*, *Ficalbia*, *Uranotaenia*, *Tripteroides*, *Armigeres*, *Coquillettidia*, and *Mimomyia* whereas, those recorded in Kottayam district were *Aedes*, *Anopheles*, *Armigeres*, *Culex*, *Heizmannia*, *Tripteroides*, *Toxorhynchites* and *Uranotaenia*. The most important species that were recorded at both districts were *Aedes aegypti*, *Aedes albopictus*, *Aedes vittatus*, *Armigeres subalbatus*, *Culex fuscanus*, *Culex quinquefasciatus*, *Culex tritaeniorhynchus*, *Heizmannia greenii*, *Heizmannia indica* and *Toxorhynchites affinis*. 22 species of mosquitoes recorded in both the districts are known vector of diseases such as malaria, dengue, Japanese encephalitis and filariasis (Balasubramanian and Nikhil 2013)

Diversity studies on mosquitoes with special reference to their breeding environments were carried out and reported from Irinjalakuda city of Thrissur district, Kerala. Collections of mosquitoes were carried out in the form of larvae and identified. There were 30 species of mosquitoes belonging to 5 genera. The genus *Culex* was the most predominant one with 12 species, followed by *Aedes* (8 species), *Anopheles* (6 species), *Mansonia* (3 species) and *Armigeres* (1 species). Important *Culex* species reported were *Cx. fascanus, Cx. quinquefasciatus, Cx.gelidus, Cx. univittatus, Cx. fuscocephala. Cx. tritaenorhynchus, Cx. whitmorei, Cx. vishnui, Cx. sinensis, Cx. bitaeniorhynchus. Cx. infula*and *Cx. pseudovishnui*. The *Aede*s species reported were *Ae. scatophagoides, Ae. pseudotoeniatus, Ae. longirostris, Ae.aegypti, Ae. vittatus, Ae. albopictus, Ae. walbus* and *Ae. vexanus*. Genus *Mansonia* comprised of *M. crassipes, M. uniformis* and *M. Indiana*. *Armigeres subalbatus* was the only species reported from the genus *Armigeres*. The potentiality of different breeding habitats in mosquito emergence along with their control strategies has also been discussed (Asha and Aneesh 2014).

Diversity of mosquitoes in Kerala with special reference to their public health significance was exhaustively reviewed and reported (Sumodan 2014). As per the report, the statistics of mosquitoes from the state was 105 species belonging to 15 genera. Malarial vectors *Anopheles culicifacies, A. fluviatilis and A. stephensi*, filarial vectors *Culex quinquefasciatus, Mansonia annularis, M. uniformis and M. indiana*, vectors of dengue and Chikungunya, *Aedes aegypti and Ae. albopictus* and vectors of Japanese encephalitis *Culex tritaeniorhynchus, C. vishnui, C. pseudovishnui, C. gelidus, C. bitaeniorhynchus* were reported from almost all the districts of Kerala. The study also discussed the essentialities of formulating management strategies based on existing mosquito inventories.

All the studies revealed that, in accordance with landscape structure, habitat heterogeneity, climatological and environmental factors, there are fluctuations in the abundance and diversity of mosquitoes. This may eventually lead to alteration in the host -pathogen, vector-pathogen and vector-host interactions. Such changes in the structure of mosquito fauna especially, that of medically relevant species may have negative impact on human health. Also it leads to the incidence of so many overwhelming diseases. Even though there are numerous diversity studies, reports on a disease background is less in number. The present study is an attempt to investigate the mosquito diversity of selected locations under 10 districts of Kerala with special reference to filariasis. The pattern of diversity and distribution of different mosquito species especially the filarial vectors, *Culex quinquefasciatus* and Mansonioides along these 10 endemic areas and their role in disease transmission have also been described.

Materials and Methods

Mosquito dominance and diversity within a particular geographic area has got enormous impact on the health status of people. As they can thrive in diverse habitats, interaction with specific pathogen can lead to heterogeneous diseases. In order to comprehend the epidemiology of different diseases in a particular area, systematic inquiries with respect to the existing mosquito fauna are vital. Such inventories will highlight possible infectious diseases that they spread. These also aid in the formulation of species specific eradication strategies. The present mosquito faunistic study is an attempt to establish the underlying reason of the endemicity of the disease filariasis in 10 districts of Kerala.

Study area

The present work was carried out on the abundance and diversity of both immature and adult forms of mosquitoes on a seasonal basis from ten districts of Kerala, ie. Trivandrum, Kollam, Alleppey, Ernakulam, Thrissur, Palakkad, Malappuram, Kozhikode, Kannur and Kasaragod, for a period of one year. The districts were selected on the basis of primary data obtained from district vector control units under health department of the Government of Kerala. Collection of primary data pertaining to the prevalence of filarial disease in the 10 districts was carried out for a period of one year from February 2012 to January 2013 to demarcate the highest endemic locations. The calendar year was divided into three seasons such as pre monsoon (February to May), monsoon (June to September) and post-monsoon (October to January) for assessing vector abundance and diversity. The location at which the present study has been carried out is given below:

1.Study sites

Sl. No	District	Locations	Latitude	Longitude
1	Trivandrum	Manacaud	8°47’19” N	76°95’18” E
2	Kollam	Mangad	8°91’49” N	76°62’11” E
3	Alleppey	Kommadi	9°51’39” N	76°33’04” E
4	Ernakulam	Thoppumpady	9°93’56” N	76°26’09” E
5	Thrissur	Chavakkad	10°58’33” N	76°01’89” E
6	Palakkad	Thirunellai	10°75’52” N	76°62’32” E
7	Malappuram	Ponnani	10°76’77” N	75°92’59” E
8	Kozhikode	Vellayil	11°26’63” N	75°77’16” E
9	Kannur	Thalassery	11°75’33” N	75°49’29” E
10	Kasaragod	Thalangara	12°48’41” N	74°99’25” E

2.Sampling of adult mosquitoes

All the 10 locations under study were visited during the three seasons for a period of one year and collections of adult mosquitoes were carried out. Prior intimation regarding the collection was given to the people within the study area for ensuring their coorperation in sample collection. The collections were carried out following standard methods (WHO 1975). Each location was visted during premonsoon, monsoon and post monsoon seasons of the year. Adult mosquitoes that were resting indoor, outdoor, biting people were collected using oral aspirators during morning and evening hours. A minimum of 2 man hours was spent at each location to ensure the collection of sufficient number of specimens. The mosquitoes collected were transferred to test tubes that are properly labeled and brought to laboratory for identification.

3.Sampling of mosquito larvae

Mosquito larvae and pupae were collected from heterogeneous water bodies in all the selected locations. The major habitats from which collections were carried out include canals, ponds, sewerages, rice fields, cement tanks, ground pools, pits, coconut shells, discarded wells and open ground water having grass cover.

Sampling was made with the help of plastic cups and jar. Approximately 500 ml to 1 litre of water samples bearing immature stages of mosquitoes were collected from 6 heterogeneous habitats of each location. As per the density of larvae, the number of dips was increased to ensure adequate collection of samples (WHO 1975).

Larvae and pupae along with the water from each site were transferred to plastic jars. All the jars containing immature stages were covered with a net of small mesh size to avoid escape of adult mosquitoes. A small hole, with control facility, was made in the net for collection of adult mosquitoes from the jars. No artificial food was given as the water from the sampling sites was noted to be rich in nutrients. Emerging adult mosquitoes were collected with the help of a manual aspirator and anesthetised with cotton swab of ethyl acetate.

Identification of all the mosquitoes collected in the premonsoon, monsoon and post monsoon seasons was carried out using a compound microscope. Standard taxonomic references followed for the identification were Christophers (1933), Barraud (1934), Das et al. (1990) and Reuben et al. (1994). Suitable specimens of all the mosquitoes identified were pinned and preserved for future references. Details pertaining to the collection and identification of mosquitoes are given in plate 2.1

The adult mosquitoes collected and identified from each location were subjected to various analyses such as Man Hour Total Density (MHTD), Intra species diversity and Intra generic diversity and the results are tabulated.

Data analysis

Man Hour Total Density (MHTD)

It is an estimate of the total number of adult mosquitoes collected in one hour by one person. A higher value denotes the mosquito abundance in the area and signifies the public health implications (Service 1980).

Man Hour Total Density is calculated as:

$$\text{Man-hour total density} = \frac{\text{Total number of mosquitoes collected}}{\text{Total time spent for collection in hours}}$$

Intra species diversity

When there are more numbers of species within a particular genus, the diversity and abundance of a single species with respect to the others are expressed as Intra species diversity. Normally it is expressed in percentage.

It is calculated as:

$$\text{Intra species diversity (\%)} = \frac{\text{Number of a particular species in a genus}}{\text{Total number of species in the genus}} \times 100$$

Intra generic diversity

When there are more number of species and genera, the diversity and abundance of a single species with respect to others species in all the genera are expressed as Intra generic diversity. Normally it is expressed in percentage.

It is calculated as:

Number of a particular species in a genus

Intra generic diversity (%) = ——————————————— X 100
Total number of species in the entire genera

Diversity indices

As mosquito communities vary with changes in environment and climate, their relative proportion and abundance provide an estimate on the possible health menace to humans. To better evaluate the diversity, various indices were worked out in the present study, which include species richness, abundance, Shannon Wiener diversity index, Simpson index and Shannon evenness index.

Species Richness

Species richness can be defined as the relative strength of each species in a community. As the number of species in a particular sample is high, the value of species richness is also high (Margalef 1958).

Shannon-Wiener Index (H')

It is the most common index used in community studies. When sampling is conducted from an indefinitely large population on a random basis, this index can be applied. This index assumes that, all the species are represented in the sample. The values may range normally from 0 to 5 and the usual pattern of 1.5-3.5 has been observed in most of the ecological studies. This index is very easy to calculate and actual site differences do not affect the values to a greater extend (Shannon and Weiner 1949: Pielou 1975).

This index can be calculated as,

$$H^i = - \Sigma (n_1/ N \text{ x } \ln n_1/ N)$$

Where, H^i is the diversity index

n_1 is the number of individuals in species of a community (individual density)

N is the total number of individuals in the community (density of all the species)

Simpson's Index (1-D)

The Simpson index (D) gives the dominance of a species and hence (1-D) represents the species diversity. This index gives the assumption that, random sampling of any two individuals from an indefinitely large population is different. The values are not affected by the richness of species but depend on the number of abundant species. It is less sensitive than Shannon-Wiener index and not affected by the number of any rare species (Simpson, 1949).

It can be calculated using the formula,

Simpson Diversity index (1-D) = $1- \Sigma\, n\,(n-1)/N\,(N-1)$

Where n = number of individual species and N = total number of individuals

Shannon's evenness index

Shannon evenness is a measure of the pattern of individuals divided among the taxa present. The normal values lies between 0 and 1 (Pielou 1975). A higher value indicates more number of species with almost an equal distribution.

It can be calculated as,

Evenness, $E = H^{i} / \ln S$

Where, H^{i} is the Shannon diversity index

S is the number of species present.

Results

As stated earlier, mosquito diversity within a particular geographical area has hot enormous impact on the health status of people as they are involved in the transmission of diverse types of diseases. Systematic approaches towards mosquito inventories can render adequate ways and means to tackle such diseases and aid in the formulation of species specific management strategies. The present study investigated the diversity of mosquitoes along selected locations falling in 10 districts of Kerala, wherein higher endemicity of filarial disease has been reported. The disease is being transmitted mainly by *Culex quinquefasciatus* and Mansonioides mosquitoes. The study provides sufficient information on the distribution pattern of different mosquitoes, especially the filarial vectors across these locations along with their public health significance.

Assessment of mosquito diversity has been carried out at Manacaud of Trivandrum district, Mangad of Kollam district, Kommadi of Alleppey district, Thoppumpady of Ernakulam district, Chavakkad of Thrissur district, Thirunellai of Palakkad district, Ponnani of Malappuram district, Vellayil of Kozhikode district, Thalassery of Kannur district and Thalangara of Kasaragod district. Collections of both adult and immature forms of mosquitoes were carried out for a period of 1 year from February 2012 to January 2013 on a seasonal basis. The immature forms were reared to adults under laboratory conditions. All the forms were identified following standard taxonomic keys.

Diversity and distribution of adult mosquitoes

Adult mosquitoes were collected from all the locations under study during premonsoon, monsoon and post monsoon seasons. Species composition of adult mosquitoes from various locations during premonsoon, monsoon and post monsoon seasons are depicted in Table 1.1, Table 1.2 and Table 1.3 respectively.

Table 2.1. Species composition of adult mosquitoes from various locations during pre monsoon season (February 2012 to May 2012).

Sl No	Name of species	Trivandrum		Kollam		Alleppey		Ernakulam		Thrissur		Palakkad		Malappuram		Kozhikode		Kannur		Kasaragod		Total
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
1	*Aedes aegypti*	-	-	-	7	-	-	3	6	-	2	-	-	-	-	-	-	-	-	-	-	18
2	*Aedes albopictus*		-	-	3	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	3
3	*Anopheles splendidus*	1	6	-	-	-	-	-	-	5	2	-	-	-	-	-	-	-	-	-	-	14
4	*Anopheles stephensi*	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-	-	-	5	1	10
5	*Anopheles theobaldi*	-	-	-	-	-	-	-	-	-	-	3	8	-	-	-	-	-	-	-	-	11
6	*Anopheles vagus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	2	9
7	*Armigeres annulipalpis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	5
8	*Culex bitaeniorhynchus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	2	-	-	-	-	6
9	*Culex fuscocephala*	-	-	-	-	-	-	2	5	-	-	-	-	-	-	-	-	-	-	-	-	7
10	*Culex gelidus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	4
11	*Culex mimeticus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	4
12	*Culex quinquefasciatus*	-	4	-	-	3	8	2	17	2	7	2	14	4	3		13	2	6	1	3	91
13	*Culex sitiens*	-	-	-	-	13	4	-	-	4	6	-	-	7	4	4	8	8	3	-	-	61
14	*Culex tritaeniorhynchus*	6	2		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	8	22
15	*Culex vishnui*	-	-	4	2	-	-	9	4	-	-	4	2	6	3	6	2	-	-	-	-	42
16	*Culex whitmorei*	2	-	-	-	-	-	7	4	-	-	-	-	-	-	-	-	-	-	-	-	13
17	*Mansonia uniformis*	-	-	-	-	7	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
Total Number		21		16		39		59		28		33		31		48		23		33		331
Number of Species		4		3		3		5		4		3		4		6		3		4		17
Number of Genera		2		2		2		2		3		2		2		2		1		2		5

Table 2.2. Species composition of adult mosquitoes from various locations during monsoon season (June 2012 to September 2012).

Sl No	Name of species	Trivandrum		Kollam		Alleppey		Ernakulam		Thrissur		Palakkad		Malappuram		Kozhikode		Kannur		Kasaragod		Total
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
1	*Aedes aegypti*	1	5	1	5	-	-	1	5	-	-	5	-	-	-	-	-	-	3	-	-	26
2	*Aedes vittatus*	-	-	-	-	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	5	10
3	*Anopheles stephensi*	-	-	3	3	-	-	-	-	-	-	-	-	-	6	-	-	5	1	-	-	18
4	*Anopheles vagus*	-	-	-	-	5	1	-	-	-	-	6	1	-	-	5	2	-	-	-	-	20
5	*Armigeres annulipalpis*	-	4	-	-	-	-	-	-	-	-	2	4	-	-	-	-	-	-	-	-	10
6	*Armigeres subalbatus*	-	-	-		-	-	2	11	-	-	-	-	-	13	-	4	-	-	-	-	30
7	*Culex bitaeniorhynchus*	-	-	-	3	-	-	-	-	-	-	-	-	-	-	1	6	-	-	-	-	10
8	*Culex gelidus*	1	4	-	-	-	-	-	-	-	-	-	-	-	-	2	7	-	-	-	-	14
9	*Culex infula*	-		-	-	1	6			2	1							-	-	-	-	10
10	*Culex quinquefasciatus*	4	9	-	-	-	9	-	6	1	8	4	7	1	10	-	4	-	7	-	3	73
11	*Culex sitiens*	-	-	-	-	-	-	-	-	2	4	-	-	1	3	-	-	4	3	1	5	23
12	*Culex univittattus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	4
13	*Culex vishnui*	-	-	-	-	-	-	1	3	-	-	3	6	2	-	-	-	-	-	-	-	15
14	*Mansonia annulifera*	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Total number		28		15		31		29		23		33		36		31		23		18		267
Number of Species		4		3		5		4		4		4		5		5		4		4		14
Number of Genera		3		3		4		3		2		3		3		3		3		2		5

Table 2.3. Species composition of adult mosquitoes from various locations during post monsoon season (October 2012 to January 2013).

Sl No	Name of species	Trivandrum		Kollam		Alleppey		Ernakulam		Thrissur		Palakkad		Malappuram		Kozhikode		Kannur		Kasaragod		Total
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
1	*Aedes aegypti*	1	4		4	-	5	-	16	-	-	-	6	-	-	-	-	-	-	-	-	36
2	*Aedes albopictus*	-	-	-	-	-	3	-	9	-	-	-	-	-	-	-	-	-	-	-	-	12
3	*Aedes vittatus*	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	6	-	-	9
4	*Anopheles splendidus*	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	5	2	10
5	*Anopheles stephensi*	-	-	-	-	-	-	-	-	-	-	-	-	9	7	-	-	-	-	-	-	16
6	*Anopheles subpictus*	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
7	*Anopheles vagus*	-	-	6	2	6	1	-	-	-	-	-	-	8	2	-	-	-	-	-	-	25
8	*Armigeres subalbatus*	2	7	-	-	-	-	-	-	-	-	2	6	-	-	-	3	-	-	-	-	20
9	*Culex bitaeniorhynchus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	7
10	*Culex pallidothorax*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	6	-	-	14
11	*Culex fuscanus*	-	-	-	-	-	-	-	3	2	9	-	-	-	-	-	-	-	-	-	-	5
12	*Culex fuscocephla*	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	4	-	-	5
13	*Culex gelidus*	-	-	-	-	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
14	*Culex mimeticus*	-	-	-	-	-	-	-	-	8	5	-	-	-	-	-	-	-	-	-	-	11
15	*Culex pseudovishnui*	-	-	2	9	1	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18
16	*Culex quinquefasciatus*	5	8	1	5	2	7	2	6	7	9	4	9	6	16	3	7	2	6		9	114
17	*Culex sitiens*	-	-	-	-	-	-	4	6	-	-	-	-	1	8	10	3	8	3	-	-	43
18	*Culex vishnui*	-	-	-	-	8	1	-	-	-	-	6	-	-	-	9	7	-	-	-	-	31
19	*Culex whitmorei*	-	-	-	-	-	-	-	-	3	6	-	-	2	-	-	-	-	-	-	-	11
20	*Mansonia annulifera*	-	-	-	-	-	-	-	-	-	-	1	4	-	-	-	-	-	-	-	-	5
21	*Mansonia indiana*	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Total number		27		33		49		46		49		44		60		46		36		23		413
Number of Species		3		5		8		5		4		7		6		5		5		3		21
Number of Genera		3		3		4		2		1		5		2		2		2		2		5

During pre monsoon season, a total of 331 adult mosquito specimens representing 17 species belonging to 5 genera were reported. *Culex* was the most predominant genus with 9 species followed by *Anopheles* (4 species), *Aedes* (2 species), *Armigeres* (1 species) and *Mansonia* (1 species). Among different species reported from all the locations, the most abundant species was *Culex quinquefasciatus* (91) followed by *Culex sitiens* (61) and *Culex vishnui* (42). Among the 10 locations under study, most number of species were reported from Vellayil of Kozhikode (6 species) followed by Thoppumpady of Ernakulam (5 species) districts. As far as abundance of mosquitoes is concerned, Thoppumpady of Ernakulam was noticed for maximum number (59) followed by Vellayil of Kozhikode (48) districts. Most number of genera (3 genera) was reported from Chavakkad of Thrissur district. The Bancroftian filarial vector *Culex quinquefasciatus* was reported from all the locations except Mangad of Kollam district. Maximum number of these vector was reported from Thoppumpady of Ernakulam (19) followed by Thirunellai of Palakkad (16) districts. The Brugian filarial vector *Mansonia uniformis* was reported from Kommadi of Alleppey district (11) only.

Data on mosquito diversity during monsoon season showed that, 267 mosquito specimens representing 14 species under 5 genera were present at all the locations under study. The most predominant genus was *Culex* with 7 species followed by *Anopheles* (2 species), *Aedes* (2 species), *Armigeres* (2 species) and *Mansonia* (1 species).Among different species reported from all the locations, the most abundant species was *Culex quinquefasciatus* (73) followed by *Armigeres subalbatus* (30) and *Aedes aegypti* (26). Among the 10 locations under study, most number of species were reported from Vellayil of Kozhikode (5 species), Ponnani of Malappuram (5 species) and Kommadi of Alleppey (5 species). Abundance of mosquitoes was maximum at Ponnani of Malappuram (36) followed by Thirunellai of Palakkad (33) districts. Most number of genera was reported from Mangad of Kollam (4 genera). Maximum numbers of *Culex quinquefasciatus* and *Mansonia annulifera* were reported from Manacaud of Trivandrum (13) and Kommadi of Alleppey (4) district respectively.

413 mosquito specimens representing 21 species under 5 genera were reported from all the locations during post monsoon season. *Culex* was the

most predominant genus with 11 species followed by *Anopheles* (4 species), *Aedes* (3 species), *Mansonia* (2 species) and *Armigeres* (1 species). Among different species reported from all the locations, the most abundant species was *Culex quinquefasciatus* (114) followed by *Culex sitiens* (43) and *Aedes aegypti* (36). Most number of mosquito species were reported from Kommadi of Alleppey (8) followed by Thirunellai of Palakkad (7) districts. Maximum abundance of mosquitoes was reported from Ponnani of Malappuram (60) followed by Kommadi of Alleppey (49) and Chavakkad of Thrissur (49) districts. Among all the locations, more genera were reported from Thirunellai of Palakkad district (5). Ponnani of Malappuram (22) and Chavakkad of Thrissur (16) districts were noticed for higher number of *Culex quinquefasciatus*. *Mansonia annulifera* was only reported from Thirunellai of Palakkad district. *Mansonia indiana* was only reported from Kommadi of Alleppey district (4).

Upon comparing the result it can be concluded that, maximum number of species and abundance were reported in the post monsoon season (21 and 413 respectively). This is followed by pre monsoon (17 and 331) and monsoon (14 and 267) seasons. Generic distribution was noticed to be uniform during all the seasons. *Culex* was the most predominant genus in all the seasons with 11 species in the post monsoon season followed by 9 species in the pre monsoon and 7 species in the monsoon season. Abundance of the filarial vectors *Culex quinquefasciatus* and Mansonioides were noticed to be higher in the post monsoon season.

The abundance of a particular species with respect to its genus (intra species diversity) and all other genera (intra generic diversity) in all the seasons were separately analyzed and reported. Intra species and intra generic diversity of total adult mosquitoes collected from all the locations during premonsoon, monsoon and post monsoon seasons are depicted in Table 2.4.

Table 2. 4. Intra species and Intra generic diversity of total adult mosquitoes collected from all the locations during pre monsoon, monsoon and post monsoon seasons (February 2012 to January 2013).

Name of species	Pre monsoon		Monsoon		Post monsoon	
	Intra species diversity (%)	Intra generic diversity (%)	Intra species diversity (%)	Intra generic diversity (%)	Intra species diversity (%)	Intra generic diversity (%)
Aedes aegypti	85.71	5.44	72.22	9.59	63.15	8.72
Aedes albopictus	14.29	0.91	-	-	21.05	2.91
Aedes vittatus	-	-	27.78	3.69	15.79	2.18
Anopheles splendidus	31.82	4.23	-	-	18.18	2.42
Anopheles stephensi	22.73	3.02	47.37	6.64	29.09	3.87
Anopheles subpictus	-	-	-	-	7.27	0.97
Anopheles theobaldi	25.00	3.32	-	-	-	-
Anopheles vagus	20.45	2.72	52.63	7.38	45.45	6.05
Armigeres annulipalpis	0	1.51	25	3.69	-	-
Armigeres subalbatus	-	-	75	11.07	0	4.84
Culex bitaeniorhynchus	2.4	1.81	6.54	3.69	2.57	1.69
Culex fuscanus	-	-	-	-	5.15	3.39
Culex fuscocephla	2.8	2.11	-	-	1.84	1.21
Culex gelidus	1.6	1.21	9.15	5.17	1.84	1.21
Culex infula	-	-	6.54	3.69	-	-
Culex mimeticus	1.6	1.21	-	-	4.78	3.15

Name of species	Pre monsoon		Monsoon		Post monsoon	
	Intra species diversity (%)	Intra generic diversity (%)	Intra species diversity (%)	Intra generic diversity (%)	Intra species diversity (%)	Intra generic diversity (%)
Culex pallidothorax	-	-	-	-	4.04	2.66
Culex pseudovishnui	-	-	-	-	6.62	4.36
Culex quinquefasciatus	36.4	27.49	47.71	26.94	41.91	27.60
Culex sitiens	24.4	18.43	17.65	9.96	15.81	10.41
Culex tritaeniorhynchus	8.8	6.65	-	-	-	-
Culex univittattus	-	-	2.61	1.48	-	-
Culex vishnui	16.8	12.69	9.80	5.54	11.40	7.51
Culex whitmorei	5.2	3.93	-	-	4.04	2.66
Mansonia annulifera	-	-	0	1.48	55.56	1.21
Mansonia indiana	-	-	-	-	44.44	0.97
Mansonia uniformis	0	3.32	-	-	-	-

In the pre monsoon season, 85.71% of the genus *Aedes* was represented by *Aedes aegypti*. 31.82% of the genus *Anopheles* and 36.4% of the genus *Culex* were represented by *Anopheles splendidus* and C*ulex quinquefasciatus* respectively. During monsoon season, *Aedes aegypti* represented 72.22% of the genus *Aedes* and *Anopheles vagus* represented 52.63% of the genus *Anopheles*. 75% of the genus *Armigeres* and 47.71% of the genus *Culex* were represented by *Armigeres subalbatus* and *Culex quinquefasciatus* respectively.

In the post monsoon season, *Aedes aegypti* represented 63.15% of the genus *Aedes* and *Anopheles vagus* represented 45.45% of the genus *Anopheles*. 41.91% of the genus *Culex* and 55.56% of the genus *Mansonia* were represented by *Culex quinquefasciatus* and *Mansonia annulifera* respectively. The overall result showed that, during all the seasons *Aedes aegypti* and *Culex quinquefasciatus* were noticed to be the most abundant species of the genera *Aedes* and *Culex* respectively.

In terms of intra generic diversity, *Culex quinquefasciatus* (27.49%), *Culex sitiens* (18.43%) and *Culex vishnui* (12.69%) were the most predominant species in the pre monsoon season. During monsoon season, the most predominant species were *Culex quinquefasciatus* (26.94%), *Armigeres subalbatus* (11.07%) and *Culex sitiens* (9.96%). During the post monsoon also *Culex quinquefasciatus* was the most abundant species (27.6%) followed by *Culex sitiens* (10.41%) and *Aedes aegypti* (8.72%).

Analysis of some of the diversity indices with respect to adult mosquitoes were carried out and reported. Total man hour density, species richness, abundance, Shannon diversity index, Shannon evenness and Simpson diversity index of adult mosquitoes were calculated during all the three seasons. District wise diversity of adult mosquitoes collected from all the locations during premonsoon, monsoon and post monsoon seasons are depicted in Table 2.5(a) to (c).

Table 2.5(a). District wise diversity of adult mosquitoes collected from all the locations during pre monsoon season (February 2012 to May 2012).

Sl No	District	Man hours of capture (Hours)	Total man hour density	Species richness	Species abundance	Shannon diversity index(H)	Shannon evenness (E)	Simpson diversity index (1-D)
1	Trivandrum	2	10.5	4	21	1.274	0.8935	0.6984
2	Kollam	2	8	3	16	1.043	0.9462	0.6328
3	Alleppey	2	19.5	3	39	1.076	0.9776	0.6509
4	Ernakulam	2	29.5	5	59	1.551	0.9433	0.7756
5	Thrissur	2	14	4	28	1.268	0.8881	0.7015
6	Palakkad	2	16.5	3	33	1.027	0.931	0.6208
7	Malappuram	2	15.5	4	31	1.327	0.9424	0.7222
8	Kozhikode	2	24	6	48	1.702	0.9138	0.803
9	Kannur	2	11.5	3	23	1.024	0.9284	0.62
10	Kasaragod	2	16.5	4	33	1.284	0.9026	0.6979

Table 2.5(b). District wise diversity of adult mosquitoes collected from all the locations during monsoon season (June 2012 to September 2012).

Sl No	District	Man Hours of Capture (Hours)	Total Man Hour Density	Species Richness	Species Abundance	Shannon diversity index(H)	Shannon evenness (E)	Simpson diversity index (1-D)
1	Trivandrum	2	14	4	28	1.272	0.8919	0.6862
2	Kollam	2	7.5	3	15	1.055	0.9572	0.64
3	Alleppey	2	15.5	5	31	1.571	0.9627	0.7846
4	Ernakulam	2	14.5	4	29	1.285	0.9035	0.6944
5	Thrissur	2	11.5	4	23	1.315	0.9313	0.7146
6	Palakkad	2	16.5	4	33	1.359	0.9735	0.7365
7	Malappuram	2	18	5	36	1.433	0.8386	0.733
8	Kozhikode	2	15.5	5	31	1.56	0.9513	0.7804
9	Kannur	2	11.5	4	23	1.34	0.9551	0.7297
10	Kasaragod	2	9	4	18	1.355	0.9691	0.7346

Table 2.5(c). District wise diversity of adult mosquitoes collected from all the locations during post monsoon season (October 2012 to January 2013).

Sl No	District	Man Hours of	Total Man Hour	Species Richness	Species Abundance	Shannon diversity	Shannon evenness	Simpson diversity

		Capture (Hours)	Density			index(H)	(E)	index (1-D)
1	Trivandrum	2	13.5	3	27	1.03	0.9341	0.6228
2	Kollam	2	16.5	5	33	1.531	0.9248	0.7677
3	Alleppey	2	24.5	8	48	2.02	0.9421	0.8605
4	Ernakulam	2	23	5	46	1.501	0.8968	0.759
5	Thrissur	2	24.5	4	49	1.364	0.9781	0.7389
6	Palakkad	2	22	7	44	1.827	0.8878	0.8202
7	Malappuram	2	30	6	60	1.485	0.7359	0.7428
8	Kozhikode	2	23	5	46	1.447	0.8498	0.7401
9	Kannur	2	18	5	36	1.558	0.9496	0.7793
10	Kasaragod	2	11.5	3	23	1.091	0.9927	0.6616

Among different locations under study during pre monsoon season, both total man hour density and abundance of mosquitoes were noticed to be higher at Thoppumpady of Ernakulam district (29.5 and 59 respectively) whereas, lower values were reported at Mangad of Kollam district (8 and 16 respectively). Species richness was noticed to be higher at Vellayil of Kozhikode (6 species) and lower at Thalassery of Kannur, Thirunellai of Palakkad, Kommadi of Alleppey and Mangad of Kollam districts (3 species each). Both Shannon and Simpson diversity indices were noticed to be higher at Vellayil of Kozhikode (1.702 and 0.803 respectively) indicating the existence of diverse group of mosquitoes along the area. However, both the indices showed lower values at Thalassery of Kannur district (1.024 and 0.62 respectively) depicting lower diversity of mosquitoes. Even though all the districts showed variation with respect to all the indices studied, a more uniform pattern of distribution has been noticed at Kommadi of Alleppey district and less at Thalassery of Kannur district. This has been evidenced by the values of Shannon evenness 0.9776 at Kommadi and 0.8881 at Thalassery.

The district wise diversity of mosquitoes during monsoon season revealed that, among different locations under study, total man hour density, abundance and richness of mosquitoes were noticed to be higher at Ponnani of Malappuram district (18, 36 and 5 respectively) whereas, lower values were reported at Mangad of Kollam district (7.5,15and 3 respectively). Higher values of species richness were also noticed at Vellayil of Kozhikode (5 species) and Kommadi of Alleppey (5) districts. Both Shannon and Simpson diversity indices were noticed to be higher at Kommadi of Alleppey (1.571 and 0.7846 respectively) and lower at Mangad of Kollam district (1.055 and 0.64 respectively).Thirunellai of Palakkad district was noticed for uniform pattern of species distribution with a Shannon evenness value of 0.9735. Even though having high abundance and richness, Ponnani of Malappuram district has been noticed for a less uniform pattern of mosquito distribution with Shannon evenness value of 0.8386.

During post monsoon season, both total man hour density and abundance of mosquitoes were noticed to be higher at Ponnani of Malappuram district (30 and 60 respectively). Species richness was higher at Kommadi of Alleppey district (8) and lower at Manacaud of Trivandrum (3) and Thalangara of Kasaragod (3) districts. Shannon and Simpson indices analyzed were noticed to be higher at Kommadi of Alleppey (2.02 and 0.86 respectively) and lower at Manacaud of Trivandrum (1.03 and 0.6228 respectively) districts. Thalangara of Kasaragod and Ponnani of Malappuram districts were reported for a higher (0.9927) and lower (0.7359) values of Shannon evenness. This in turn indicated the variation of uniformity in the mosquito distribution pattern.

The overall results showed that, upon comparing the values of diversity indices during all the seasons, the average values of total man hour density, species richness, abundance, Shannon index and Simpson index were noticed to be higher in the post monsoon season. This revealed the fact that the diversity of mosquitoes along with their distribution was more prominent in the post monsoon season. Even though monsoon season has lower values of diversity indices, a uniform pattern of species distribution has been noticed with higher average values of Shannon evenness.

Diversity and distribution of mosquito larvae

In order to evaluate the complete statistics of mosquito fauna within the locations under study, mosquitoes in the form of immature larvae were collected for a period of 1 year on a seasonal basis. Mosquito larvae were collected from heterogeneous habitats within the study areas of all the districts and reared to adults under laboratory conditions. The emerged out adult mosquitoes were identified following standard taxonomic keys. Species composition of mosquito larvae collected from all the locations under study during premonsoon, monsoon and post monsoon seasons are depicted in Table 2.6, Table 2.7 and Table 2.8 respectively.

Table 2.6. Species composition of mosquito larvae collected from the study sites during pre monsoon season (February 2012 to May 2012).

Sl No	Name of species	Trivandrum		Kollam		Alleppey		Ernakulam		Thrissur		Palakkad		Malappuram		Kozhikode		Kannur		Kasaragod		Total
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
1	*Aedes aegypti*	11	28	-	34	6	11	9	15	10	23	17	20	-	-	2	22	12	12	2	7	241
2	*Aedes vittattus*	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	1	7	13
3	*Anopheles jamessi*	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
4	*Anopheles splendidus*	3	-			-	5	-	-	7	9	10	20	14	19	-	-	-	-	1	7	95
5	*Anopheles stephensi*	22	26	7	1	3	6	31	36	7	16	4	18	10	7	-	-	-	-	9	-	203
6	*Anopheles subpictus*	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	6	2	-	-	11
7	*Anopheles theobaldi*	-	-	-	-	-	-	-	-	-	-	-	-	6	15	-	-	-	-	-	-	21
8	*Anopheles vagus*	8	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	31
9	*Armigeres annulipalpis*	-	-	4	8	12	-	12	17	4	3	7	11	-	-	42	65	5	13	-	-	203
10	*Armigeres aureolineatus*	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-	-	-	-	-	4
11	*Armigeres subalbatus*	-	-	-	-	5	9	23	23	21	22	-	-	-	-	-	-	6	12	-	-	121
12	*Culex bitaeniorhynchus*	-	-	-	-	9	4	-	-	-	-	-	-	-	-	1	5	-	-	-	-	19
13	*Culex fuscanus*	9	-	-	-	-	-	12	13	-	-	-	-	-	-	-	-	-	-	-	-	34
14	*Culex fuscocephala*	-	-	-	-	-	-	-	-	-	-	-	-	1	6	-	-	-	-	-	-	7
15	*Culex gelidus*	-	-	-	-	4	-	-	6	-	-	7	11	-	-	-	6	4	-	4	12	54
16	*Culex pallidothorax*	-	4	5	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17

Sl No	Name of species	Trivandrum		Kollam		Alleppey		Ernakulam		Thrissur		Palakkad		Malappuram		Kozhikode		Kannur		Kasaragod		Total
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
17	*Culex pseudovishnui*	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
18	*Culex quinquefasciatus*	6	14	7	9	10	25	-	38	32	44	4	41	5	28	22	46	10	36	20	39	436
19	*Culex sitiens*	6	-	3	-	-	-	-	5	6	19	13	6	11	39	4	29	7	-	9	9	166
20	*Culex tritaeniorhynchus*	5	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	13	34
21	*Culex vishnui*	-	-	16	7	5	12	-	-	-	6	-	-	15	16	20	11	-	-	-	-	108
22	*Culex whitmorei*	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	4	9	19
23	*Mansonia annulifera*	4	7	-	-	5	8	-	-	-	-	6	4	3	-	-	6	-	-	-	-	43
24	*Mansonia uniformis*	-	-	5	17	11	22	-	-	3	-	-	-	-	-	-	-	-	-	-	-	58
Total number		175		142		178		240		232		207		199		281		134		161		1949
Number of Species		10		10		12		8		9		9		9		8		8		9		24
Number of Genera		4		5		5		4		5		5		4		4		4		3		5

Table 2.7. Species composition of mosquito larvae collected from the study sites during monsoon season (June 2012 to September 2012).

Sl No	Name of species	Trivandrum		Kollam		Alleppey		Ernakulam		Thrissur		Palakkad		Malappuram		Kozhikode		Kannur		Kasaragod		Total
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
1	*Aedes aegypti*	-	-	-	-	3	6	3	10	-	-	1	10	-	-	-	7	2	7	5	8	62
2	*Aedes albopictus*	-	-	7	12	-	-	-	-	-	-	-	-	-	-	-	-	6	10	6	7	48
3	*Aedes vittatus*	-	-	-	4	-	-	-	-	-	-	3	4	-	-	-	-	-	-	4	7	22
4	*Anopheles splendidus*	1	4	-	4	4	11	-	-	4	7	-	-	10	20	-	-	-	-	-	-	65
5	*Anopheles stephensi*	4	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	1	3	5	30
6	*Anopheles subpictus*	-	-	-	-	-	-	-	-	6	2	6	10	4	8	-	-	3	8	-	-	47
7	*Anopheles vagus*	-	-	-	-	5	-	-	-	6	3	-	-	-	-	4	10	-	-	3	4	35
8	*Armigeres annulipalpis*	-	-	-	-	-	-	4	6	-	-	-	-	-	-	-	-	-	-	-	-	10
9	*Armigeres subalbatus*	13	19	4	8	-	-	7	16	8	20	6	5	-	-	7	-	10	10	2	6	141
10	*Culex bitaeniorhynchus*	-	-	-	-	4	3	-	-	3	6	-	4	4	-	13	8	-	-	4	7	56
11	*Culex gelidus*	7	4	-	-	2	12	-	-	-	-	1	3	-	-	8	4	-	3	-	-	44
12	*Culex infula*	3	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
13	*Culex mimeticus*	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	6
14	*Culex quinquefasciatus*	5	19	11	17	13	17	12	20	8	22	1	15	2	12	22	29	3	8	6	8	250
15	*Culex sitiens*	3	4	-	-	-	-	-	-	-	-	2	6	7	6	6	4	-	-	-	-	38
16	*Culex sinensis*	-	-	4	2	-	-	4	3	-	-	-	-	-	-	-	-	-	-	-	-	13
17	*Culex univittattus*	-	-	-	-	8	7	-	-	-	-	2	6	-	-	-	-	-	-	-	-	23
18	*Culex vishnui*	-	-	-	-	2	3	-	12	-	-	-	4	6	15	-	-	-	-	-	-	42
19	*Mansonia annulifera*	-	-	6	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19
Total number		102		105		100		97		101		58		94		122		78		85		958
Number of Species		7		8		8		6		7		11		6		7		7		8		19
Number of Genera		3		5		3		3		4		4		2		4		4		4		5

Table 2.8. Species composition of mosquito larvae collected from the study sites during post monsoon season (October 2012 to January 2013).

Sl No	Name of species	Trivandrum		Kollam		Alleppey		Ernakulam		Thrissur		Palakkad		Malappuram		Kozhikode		Kannur		Kasaragod		Total
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
1	*Aedes aegypti*	2	14	-	5	3	8	3	10	7	31	2	9	-	4	-	-	5	9	5	8	125
2	*Aedes albopictus*	-	-	1	6	-	-	-	6	-	6	-	-	-	-	-	-	-	-	-	-	19
3	*Aedes vittatus*	-	-	-	8	-	-	4	-	-	-	-	-	-	6	-	5	-	2	-	-	25
4	*Anopheles jamessi*	-	-	4	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
5	*Anopheles splendidus*	-	-	4	7	-	-	8	-	-	-	12	10	14	7	-	-	-	-	-	-	62
6	*Anopheles stephensi*	12	33	8	2	7	4	6	9	7	16	4	6	11	3	11	6	17	9	17	16	204
7	*Anopheles subpictus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
8	*Anopheles theobaldi*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5
9	*Anopheles vagus*	11	15	-	-	1	13	4	6	-	-	-	-	-	-	-	-	2	4	-	-	56
10	*Armigeres annulipalpis*	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	4	11	6	6	2	33
11	*Armigeres subalbatus*	4	3	12	36	-	-	-	-	4	-	-	-	7	9	-	2	-	3	6	3	89
12	*Culex bitaeniorhynchus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	18	-	-	6	4	37
13	*Culex fuscanus*	-	-	-	-	2	6	2	6	3	11	5	-	-	-	-	-	-	-	-	-	35
14	*Culex fuscocephla*	9	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	16
15	*Culex gelidus*	-	6	-	7	-	-	-	-	4	2	4	6	-	-	-	-	-	6	-	9	44
16	*Culex infula*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	8	-	-	-	-	13
17	*Culex pallidothorax*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	13	-	-	-	-	22
18	*Culex pseudovishnui*	-	-	-	-	6	2	-	-	-	-	6	3	-	-	6	4	-	-	-	-	27
19	*Culex quinquefasciatus*	9	34	12	29	6	60	8	26	6	71	6	43	13	83	3	23	9	32	14	42	529
20	*Culex sitiens*	2	10	-	-	5	11	-	-	-	2	-	4	15	6	9	21	13	7	4	-	109
21	*Culex univittattus*	-	-	4	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11

Sl No	Name of species	Trivandrum		Kollam		Alleppey		Ernakulam		Thrissur		Palakkad		Malappuram		Kozhikode		Kannur		Kasaragod		Total
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
22	*Culex vishnui*	3	-	6	-	9	4	2	9	15	6	4	9	2	-	4	6	4	-	5	-	88
23	*Culex whitmorei*	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
24	*Mansonia annulifera*	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	5
25	*Mansonia uniformis*	-	-	-	-	-	-	-	-	-	-	8	6	-	-	-	-	-	-	-	-	14
26	*Mimomyia hybrida*	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	4
Total number		167		171		147		109		197		152		188		166		139		153		1590
Number of Species		9		12		8		9		10		10		10		11		10		11		26
Number of Genera		4		4		3		3		4		4		5		4		4		4		6

A total of 1949 mosquito larvae representing 24 species and 5 genera were reported during pre monsoon season. The most predominant genus was *Culex*(11 species) followed by *Anopheles* (6 species), *Armigeres* (3 species), *Aedes* (2 species) and *Mansonia* (2 species).Among different species of mosquitoes reported from all the locations, the most abundant was *Culex quinquefasciatus* (436) followed by *Aedes aegypti* (241), *Armigeres annulipalpis* (203) and *Anopheles stephensi* (203). Among 10 locations under study, most number of species were reported from Kommadi of Alleppey (12 species) followed by Manacaud of Trivandrum and Mangad of Kollam districts (10 species each). Abundance of mosquitoes was maximum at Vellayil of Kozhikode (281) followed by Thoppumpady of Ernakulam (240) districts. However, lower abundance was noticed at Thalassery of Kannur district (134). As far as the filarial vectors concerned, Chavakkad of Thrissur district has been reported for higher abundance of *Culex quinquefasciatus* (76) followed by Vellayil of Kozhikode district (68). Both *Mansonia annulifera* and *Mansonia uniformis* were noticed to be abundant at Kommadi of Alleppey district (13 and 33 respectively).

During monsoon season, a total of 958 mosquito larvae representing 19 species and 5 genera were reported from all the locations under study. *Culex* was the most predominant genus with 11 species followed by *Anopheles* (4 species), *Aedes* (3 species), *Armigeres* (2 species) and *Mansonia* (1 species). Among different locations under study, mosquito abundance was noticed to be higher at Vellayil of Kozhikode (122) followed by Mangad of Kollam (105) districts whereas, lower abundance was reported at Thirunellai of Palakkad district (58). Among different species of mosquitoes reported from all the locations, the most abundant was *Culex quinquefasciatus* (250) followed by *Armigeres subalbatus* (141) and *Anopheles splendidus* (65). Maximum number of genera was reported at Mangad of Kollam and species richness was higher at Thirunellai of Palakkad district (11). Abundance of the filarial vector *Culex quinquefasciatus* was noticed to higher at Vellayil of Kozhikode (49) followed by Thoppumpady of Ernakulam (32) districts.

Mangad of Kollam district was reported for a higher abundance of *Mansonia annulifera* (19).

Results of the collection and identification of mosquito larvae during post monsoon season revealed that, a total of 1590 mosquito larvae representing 26 species and 6 genera were reported from all the locations. The most predominant genus was *Culex* (12 species) followed by *Anopheles* (6 species), *Aedes* (3 species), *Armigeres* (2 species), *Mansonia* (2 species) and *Mimomyia* (1 species). Most number of species were reported from Mangad of Kollam (12) followed by Vellayil of Kozhikode (11) and Thalangara of Kasaragod (11) districts. Ponnani of Malappuram district has been noticed for maximum number of genera (5). Among different locations under study, mosquito abundance was higher at Chavakkad of Thrissur (197) followed by Ponnani of Malappuram (188) districts whereas, lower abundance was noticed at Kommadi of Alleppey district (109). Among different species of mosquitoes reported from all the locations, the most abundant was *Culex quinquefasciatus* (529) followed by *Anopheles stephensi* (204) and *Aedes aegypti* (125). Abundance of *Culex quinquefasciatus* was higher at Ponnani of Malappuram (96) followed by Chavakkad of Thrissur (77) and Kommadi of Alleppey (66) districts. The Brugian filarial vectors, *Mansonia annulifera* and *Mansonia uniformis* were reported only from Thirunellai of Palakkad district (5 and 14 respectively).

The overall result showed that, mosquito larval abundance was higher during pre monsoon season followed by post monsoon and monsoon seasons. Post monsoon season has been noticed for higher species richness followed by pre monsoon and monsoon seasons. The mosquito species found to be abundant during all the seasons were *Culex quinquefasciatus*, *Anopheles stephensi*, *Aedes aegypti* and *Armigeres subalbatus*. Abundance of *Culex quinquefasciatus* was in accordance with the total mosquito abundance in which, higher value has been reported during post monsoon season followed by pre monsoon and monsoon seasons. Abundance of the *Mansonia* mosquitoes was noticed to be higher during pre monsoon season followed by both post monsoon and monsoon seasons. Results of the abundance of mosquitoes along all the locations during different seasons revealed that, Vellayil of Kozhikode district during pre monsoon season has been noticed for a higher value and Thirunellai of Palakkad during monsoon for a lower value.

Both intra species and intra generic diversity of total larval mosquitoes were analyzed and reported. Intra species and intra generic diversity of total mosquito larvae collected from all the locations during pre monsoon, monsoon and post monsoon seasons are depicted in Table 2.9.

Table 2.9.Intra species and Intra generic diversity of total mosquito larvae collected from all the locations during pre monsoon, monsoon and post monsoon seasons (February 2012 to January 2013).

Name of species	Pre monsoon		Monsoon		Post monsoon	
	Intra species diversity (%)	Intra generic diversity (%)	Intra species diversity (%)	Intra generic diversity (%)	Intra species diversity (%)	Intra generic diversity (%)
Aedes aegypti	94.88	12.37	46.97	6.47	71.46	7.86
Aedes albopictus	-	-	36.36	5.01	10.86	1.19
Aedes vittatus	5.12	0.67	16.67	2.30	14.29	1.57
Anopheles jamessi	0.55	0.10	-	-	4.37	0.94
Anopheles splendidus	26.17	4.87	36.73	6.78	18.08	3.90
Anopheles stephensi	55.92	10.42	16.95	3.13	59.48	12.83
Anopheles subpictus	3.03	0.56	26.55	4.91	0.29	0.06
Anopheles theobaldi	5.79	1.08	-	-	1.46	0.31
Anopheles vagus	8.54	1.59	19.77	3.65	16.33	3.52
Armigeres annulipalpis	61.89	10.42	6.62	1.04	27.05	2.08
Armigeres aureolineatus	1.22	0.21	-	-	-	-
Armigeres subalbatus	36.89	6.21	93.38	14.72	72.95	5.60
Culex bitaeniorhynchus	2.10	0.97	11.69	5.85	3.97	2.33
Culex fuscanus	3.77	1.74	-	-	3.75	2.20
Culex fuscocephala	0.78	0.36	-	-	1.71	1.01
Culex gelidus	5.98	2.77	9.19	4.59	4.72	2.77
Culex infula	-	-	1.46	0.73	1.39	0.82
Culex mimeticus	-	-	1.25	0.63	-	-
Culex pallidothorax	1.88	0.87	-	-	2.36	1.38

Name of species	Pre monsoon		Monsoon		Post monsoon	
	Intra species diversity (%)	Intra generic diversity (%)	Intra species diversity (%)	Intra generic diversity (%)	Intra species diversity (%)	Intra generic diversity (%)
Culex pseudovishnui	1.00	0.46	-	-	2.89	1.70
Culex quinquefasciatus	48.28	22.37	52.19	26.10	56.70	33.27
Culex sitiens	18.38	8.52	7.93	3.97	11.68	6.86
Culex sinensis	-	-	2.71	1.36	-	-
Culex tritaeniorhynchus	3.77	1.74	-	-	-	-
Culex univittattus	-	-	4.80	2.40	1.18	0.69
Culex vishnui	11.96	5.54	8.77	4.38	9.43	5.53
Culex whitmorei	2.10	0.97	-	-	0.21	0.13
Mansonia annulifera	42.57	2.21	0	1.98	26.32	0.31
Mansonia uniformis	57.43	2.98	-	-	73.68	0.88
Mimomyia hybrida	-	-	-	-	0	0.25

The results revealed that, *Aedes aegypti* represented 94.88%, 46.97% and 71.46% of the genus *Aedes* during pre monsoon, monsoon and post monsoon seasons respectively. The dominant species under the genus *Anopheles* was *An. stephensi* that represented 55.92% during pre monsoon and 59.48% during post monsoon seasons. During monsoon season, *An. splendidus* was the dominant species (36.73%). *Armigeres subalbatus* was the dominant species under the genus *Armigeres* during monsoon (93.38%) and post monsoon (72.95%) seasons whereas, *Armigeres annulipalpis* was dominant in the pre monsoon season. Among the genus *Culex*, the most abundant species during all the seasons was *Culex quinquefasciatus* (48.28%, 52.19% and 56.70%). *Mansonia uniformis* represented maximum number in the genus *Mansonia* during pre monsoon (57.43%) and post monsoon (73.68%) seasons.

Intra generic diversity status of all the species during different seasons revealed that, *Culex quinquefasciatus* (22.37%) and *Aedes aegypti* (12.37%) were the dominant species during pre monsoon season. Higher abundance of *Culex quinquefasciatus* (26.1%) and *Armigeres subalbatus* (14.72%) during monsoon season and *Culex quinquefasciatus* (33.27%) and *Anopheles stephensi* (12.83%) during post monsoon seasons has also been noticed.

Species richness, abundance, Shannon diversity index, Shannon evenness and Simpson diversity index of total mosquito larvae collected from all the locations during all the 3 seasons were calculated and reported. District wise diversity of mosquito larvae during pre monsoon, monsoon and post monsoon seasons are depicted in Table 2.10(a) to (c).

Table 2.10 (a). District wise diversity of mosquito larvae collected from all the locations during pre monsoon season (February 2012 to May 2012).

Sl No	District	Species Richness	Species Abundance	Shannon diversity index(H)	Evenness (E)	Simpson diversity index (1-D)
1	Trivandrum	10	175	1.989	0.7311	0.8321
2	Kollam	10	142	2.078	0.799	0.8564
3	Alleppey	12	178	2.296	0.8276	0.8823
4	Ernakulam	8	240	1.859	0.802	0.8237
5	Thrissur	9	232	1.865	0.7176	0.8102
6	Palakkad	9	207	1.94	0.773	0.8346
7	Malappuram	9	199	1.94	0.7729	0.8373
8	Kozhikode	8	281	1.655	0.6538	0.7581
9	Kannur	8	134	1.823	0.7738	0.8023
10	Kasaragod	9	161	1.932	0.767	0.8086

Table 2.10 (b). District wise diversity of mosquito larvae collected from all the locations during monsoon season (June 2012 to September 2012).

Sl No	District	Species Richness	Species Abundance	Shannon diversity index(H)	Evenness (E)	Simpson diversity index (1-D)
1	Trivandrum	7	102	1.763	0.8327	0.8008
2	Kollam	8	105	1.89	0.8276	0.8288
3	Alleppey	8	100	1.908	0.8425	0.8274
4	Ernakulam	6	97	1.659	0.8756	0.7858
5	Thrissur	7	101	1.757	0.828	0.7974
6	Palakkad	11	58	2.066	0.7179	0.8329
7	Malappuram	6	94	1.654	0.871	0.7888
8	Kozhikode	7	122	1.69	0.7744	0.7653
9	Kannur	7	78	1.834	0.8945	0.8271
10	Kasaragod	8	85	2.051	0.9721	0.8681

Table 2.10 (c). District wise diversity of mosquito larvae collected from all the locations during post monsoon season (October 2012 to January 2013).

Sl No	District	Species Richness	Species Abundance	Shannon diversity index(H)	Evenness (E)	Simpson diversity index (1-D)
1	Trivandrum	9	167	1.888	0.7342	0.8162
2	Kollam	12	171	2.109	0.6869	0.8366
3	Alleppey	8	147	1.744	0.7152	0.7526
4	Ernakulam	9	109	2.005	0.825	0.8358
5	Thrissur	10	197	1.816	0.6144	0.7783
6	Palakkad	10	152	2.025	0.7579	0.8296
7	Malappuram	10	188	1.64	0.5155	0.699
8	Kozhikode	11	166	2.183	0.8063	0.8733
9	Kannur	10	139	1.958	0.7086	0.827
10	Kasaragod	11	153	1.926	0.6237	0.7955

Among different locations under study during pre monsoon season, richness of mosquito larvae was higher at Kommadi of Alleppey (12) and lower at Thoppumpady of Ernakulam (8), Vellayil of Kozhikode (8) and Thalassery of Kannur (8) districts. Abundance of mosquito larvae was noticed to be higher at Vellayil of Kozhikode (281) and lower at Thalassery of Kannur (134) districts. The Shannon diversity index, Shannon evenness and Simpson index values were found to be higher at Kommadi of Alleppey (2.296, 0.8276 and 0.8823 respectively) and lower at Vellayil of Kozhikode (1.655, 0.6538 and 0.7581 respectively) district. The result showed that, even though Vellayil of Kozhikode possessed higher mosquito abundance, a more uniform pattern of distribution has been noticed at Kommadi of Alleppey district.

Data on diversity indices of mosquito larvae during monsoon season showed that, higher species richness was reported at Thirunellai of Palakkad (11) and lower at Thoppumpady of Ernakulam (6) and Ponnani of Malappuram (6) districts. Among different locations under study, Vellayil of Kozhikode (122) and Thirunellai of Palakkad (58) have been noticed for higher and lower mosquito abundance respectively. Shannon diversity index value was high at

Thirunellai of Palakkad (2.066) and low at Ponnani of Malappuram (1.654) district. Both Simpson index and Shannon evenness values were higher at Thalangara of Kasaragod district (0.8681 and 0.9721 respectively). However, both the indices showed lower values at Vellayil of Kozhikode (0.7653) and Thirunellai of Palakkad (0.7179) districts respectively.

During post monsoon season, Chavakkad of Thrissur district and Thoppumpady of Ernakulam districts were noticed for higher (197) and lower (109) mosquito abundance respectively. As far as species richness concerned, Mangad of Kollam was reported for a higher value (12) and Kommadi of Alleppey for a lower value (8). Both Shannon and Simpson diversity indices were noticed to higher at Vellayil of Kozhikode (2.183 and 0.8733 respectively) and lower at Ponnani of Malappuram (1.64 and 0.699 respectively) districts. Among all the locations, Shannon evenness was higher at Thoppumpady of Ernakulam (0.825) and lower at Chavakkad of Thrissur (0.6144) districts.

Upon comparing the diversity indices, it can be concluded that mosquito abundance and richness were noticed to higher at Vellayil of Kozhikode (281) and Kommadi of Alleppey (12) districts respectively during pre monsoon season. Both indices were noticed to lower at Thirunellai of Palakkad (58) and Thoppumpady of Ernakulam (6) districts during monsoon season. Higher values of Shannon and Simpson diversity indices were noticed at Kommadi of Alleppey district during pre monsoon season (2.296 and 0.8823 respectively). However, both the indices showed lower values at Ponnani of Malappuram district during post monsoon season (1.64 and 0.699 respectively). Thalangara of Kasaragod during monsoon season has been noticed for higher value of Shannon evenness (0.9721) whereas, lower value was noticed during post monsoon season at Chavakkad of Thrissur district (0.6144).

Diversity and distribution of total mosquitoes

In order to avail information on the entire mosquito fauna along all the locations under study, total adult and larval mosquitoes collected during all the seasons were combined.

Table 2.11. Species composition of total mosquitoes collected from the study sites during pre monsoon season (February 2012 to May 2012).

Sl No	Species	Total No.	Intra species diversity (%)	Intra generic diversity (%)
1	*Aedes aegypti*	259	94.18	11.36
2	*Aedes albopictus*	3	1.09	0.13
3	*Aedes vittatus*	13	4.73	0.57
4	*Anopheles jamessi*	2	0.49	0.09
5	*Anopheles splendidus*	109	26.78	4.78
6	*Anopheles stephensi*	213	52.33	9.34
7	*Anopheles subpictus*	11	2.70	0.48
8	*Anopheles theobaldi*	32	7.86	1.40
9	*Anopheles vagus*	40	9.83	1.75
10	*Armigeres annulipalpis*	208	62.46	9.12
11	*Armigeres aureolineatus*	4	1.20	0.18
12	*Armigeres subalbatus*	121	36.34	5.31
13	*Culex bitaeniorhynchus*	25	2.17	1.10
14	*Culex fuscanus*	34	2.95	1.49
15	*Culex fuscocephala*	14	1.21	0.61
16	*Culex gelidus*	58	5.03	2.54
17	*Culex mimeticus*	4	0.35	0.18
18	*Culex pallidothorax*	17	1.47	0.75
19	*Culex pseudovishnui*	9	0.78	0.39
20	*Culex quinquefasciatus*	527	45.71	23.11
21	*Culex sitiens*	227	19.69	9.96
22	*Culex tritaeniorhynchus*	56	4.86	2.46
23	*Culex vishnui*	150	13.01	6.58
24	*Culex whitmorei*	32	2.78	1.40
25	*Mansonia annulifera*	43	38.39	1.89
26	*Mansonia uniformis*	69	61.61	3.03
	Total number	2280		
	Number of Species	26		
	Number of Genera	5		

The aggregate of both forms were analyzed in terms of different diversity indices and reported. Species composition of total mosquitoes collected from the study sites during premonsoon, monsoon and post monsoon seasons are depicted in Table 2.11, Table 2.12 and Table 2.13 respectively.

Table 2.12. Species composition of total mosquitoes collected from the study sites during monsoon season (June 2012 to September 2012).

Sl No	Species	Total No.	Intra species diversity (%)	Intra generic diversity (%)
1	*Aedes aegypti*	88	52.38	7.16
2	*Aedes albopictus*	48	28.57	3.91
3	*Aedes vittatus*	32	19.05	2.60
4	*Anopheles splendidus*	65	30.23	5.29
5	*Anopheles stephensi*	48	22.33	3.91
6	*Anopheles subpictus*	47	21.86	3.82
7	*Anopheles vagus*	55	25.58	4.48
8	*Armigeres annulipalpis*	20	10.47	1.63
9	*Armigeres subalbatus*	171	89.53	13.91
10	*Culex bitaeniorhynchus*	66	10.44	5.37
11	*Culex gelidus*	58	9.18	4.72
12	*Culex infula*	17	2.69	1.38
13	*Culex mimeticus*	6	0.95	0.49
14	*Culex quinquefasciatus*	323	51.11	26.28
15	*Culex sitiens*	65	10.28	5.29
16	*Culex sinensis*	13	2.06	1.06
17	*Culex univittattus*	27	4.27	2.20
18	*Culex vishnui*	57	9.02	4.64
19	*Mansonia annulifera*	23	0	1.87
Total number		1225		
Number of Species		19		
Number of Genera		5		

Table 2.13. Species composition of total mosquitoes collected from the study sites during postmonsoon season (October 2012 to January 2013).

Sl No	Name of species	Total No.	Intra species diversity (%)	Intra generic diversity (%)
1	*Aedes aegypti*	161	71.24	8.04
2	*Aedes albopictus*	31	13.72	1.55

3	*Aedes vittatus*	34	15.04	1.70
4	*Anopheles jamessi*	15	3.77	0.75
5	*Anopheles splendidus*	72	18.09	3.59
6	*Anopheles stephensi*	220	55.28	10.98
7	*Anopheles subpictus*	5	1.26	0.25
8	*Anopheles theobaldi*	5	1.26	0.25
9	*Anopheles vagus*	81	20.35	4.04
10	*Armigeres annulipalpis*	33	23.24	1.65
11	*Armigeres subalbatus*	109	76.76	5.44
12	*Culex bitaeniorhynchus*	44	3.65	2.20
13	*Culex fuscanus*	49	4.07	2.45
14	*Culex fuscocephla*	21	1.74	1.05
15	*Culex gelidus*	49	4.07	2.45
16	*Culex infula*	13	1.08	0.65
17	*Culex mimeticus*	13	1.08	0.65
18	*Culex pallidothorax*	33	2.74	1.65
19	*Culex pseudovishnui*	45	3.73	2.25
20	*Culex quinquefasciatus*	643	53.36	32.10
21	*Culex sitiens*	152	12.61	7.59
22	*Culex univittattus*	11	0.91	0.55
23	*Culex vishnui*	119	9.88	5.94
24	*Culex whitmorei*	13	1.08	0.65
25	*Mansonia annulifera*	10	35.7	0.50
26	*Mansonia indiana*	4	14.3	0.20
27	*Mansonia uniformis*	14	50.0	0.70
28	*Mimomyia hybrida*	4	0	0.20
	Total number	2003		
	Number of Species	28		
	Number of Genera	6		

In the pre monsoon season, a total of 2280 mosquito specimens representing 26 species under 5 genera were reported from all the locations. The most abundant and diverse genus was *Culex* with 12 species. The least abundant genus was *Mansonia* with 2 species. The intra generic diversity percentage values revealed that, among different mosquito species reported, the most abundant species were *Culex quinquefasciatus* (527), *Aedes aegypti* (259) and *Culex sitiens* (227). The least abundant species reported were *Anopheles jamessi* (2), *Aedes albopictus* (3), *Armigeres aureolineatus* (4) and *Culex mimeticus* (4). Under the genus *Aedes*, the most abundant species was *Aedes aegypti* (94.14%) whereas, *Anopheles stephensi* was the dominant species under the genus *Anopheles* (52.33%). *Culex quinquefasciatus* (45.71%), *Armigeres annulipalpis* (62.46%) and *Mansonia uniformis* (61.61%) have been noticed as the dominant species under the genera *Culex*, *Armigeres* and *Mansonia* respectively.

A total of 1225 mosquito specimens representing 19 species under 5 genera were reported from all the locations under study during monsoon season. *Culex* was the most abundant genus with 9 species whereas, the least abundant genus was *Mansonia* with 1 species. Among different mosquito species reported, the most abundant species were *Culex quinquefasciatus* (323, 26.28%), *Armigeres subalbatus* (171, 13.91%) and *Aedes aegypti* (88, 7.16%). The least abundant species reported were *Culex mimeticus* (6), *Culex sinensis* (13) and *Culex infula* (17). Under the genus *Aedes*, the most abundant species was *Aedes aegypti* (52.38%) whereas, *Anopheles splendidus* was the dominant species under the genus *Anopheles* (30.23%). *Culex quinquefasciatus* represented 51.11% of the genus *Culex*. The most dominant species under the genus *Armigeres* was *Armigeres subalbatus* (89.53%).

During post monsoon season, a total of 2003 mosquito specimens representing 28 species under 6 genera were reported from all the locations. The most abundant genus was *Culex* with 13 species and least abundant was *Mansonia* with 3 species. The intra generic diversity percentage values revealed that, among different mosquito species reported, the most abundant species were *Culex quinquefasciatus* (643), *Anopheles stephensi* (220), *Aedes aegypti* (161) and *Culex sitiens* (152). The least abundant species reported were *Mimomyia hybrida* (4), *Mansonia indiana*(4), *Anopheles subpictus* (5) and *Anopheles theobaldi* (5). Under the genus *Aedes*, the most abundant species was *Aedes aegypti* (71.24%) whereas, *Anopheles stephensi* was the dominant species under the genus *Anopheles* (55.28%). The dominant species under the genera *Culex*, *Armigeres* and *Mansonia* were *Culex quinquefasciatus* (53.36%), *Armigeres subalbatus* (76.76%) and *Mansonia uniformis* (50%).

The overall result showed that, post monsoon season has been noticed for a higher mosquito abundance, number of species and number of genera followed by pre monsoon and monsoon seasons. *Culex* was the predominant genus during all the seasons with more species in the post monsoon and less in the monsoon seasons. *Culex quinquefasciatus* was the most abundant species during all the seasons. *Aedes aegypti* has also been noticed as a dominant species during all the seasons. The abundance of the genus *Mansonia* has also been noticed to be higher during post monsoon season followed by pre monsoon and monsoon seasons.

The total numbers of mosquitoes collected during different seasons inclusive of both adult and larval forms were subjected to various diversity analyses. The district wise diversity of total mosquitoes collected from all the locations during premonsoon, monsoon and post monsoon seasons are depicted in Table 2.14 (a) to (c).

Table 2.14 (a). District wise diversity of total mosquitoes collected from all the locations during pre monsoon season (February 2012 to May 2012).

Sl No	District	Species Richness	Species Abundance	Shannon diversity index(H)	Shannon evenness (E)	Simpson diversity index (1-D)
1	Trivandrum	11	196	2.096	0.7391	0.852
2	Kollam	11	158	2.089	0.7343	0.8501
3	Alleppey	13	217	2.317	0.7803	0.8778
4	Ernakulam	11	299	2.109	0.7489	0.8567
5	Thrissur	9	160	1.868	0.7194	0.8125
6	Palakkad	11	240	2.068	0.7193	0.8448
7	Malappuram	9	230	1.909	0.7499	0.8305
8	Kozhikode	8	329	1.728	0.7035	0.7828
9	Kannur	9	157	1.902	0.7442	0.8117
10	Kasaragod	10	194	2.028	0.7595	0.8284

Table 2.14 (b). District wise diversity of total mosquitoes collected from all the locations during monsoon season (June 2012 to September 2012).

Sl No	District	Species Richness	Species Abundance	Shannon diversity index(H)	Shannon evenness (E)	Simpson diversity index (1-D)
1	Trivandrum	9	130	1.917	0.7557	0.8194
2	Kollam	11	120	2.163	0.7903	0.8633
3	Alleppey	11	131	2.157	0.7858	0.8524
4	Ernakulam	6	126	1.628	0.8493	0.7792
5	Thrissur	10	124	1.985	0.7278	0.8206
6	Palakkad	14	91	2.344	0.7443	0.8815
7	Malappuram	9	130	1.927	0.8588	0.8398
8	Kozhikode	7	153	1.732	0.8077	0.7881
9	Kannur	8	101	1.978	0.9034	0.8531
10	Kasaragod	10	103	2.219	0.9202	0.8838

Table 2.14 (c). District wise diversity of total mosquitoes collected from all the locations during post monsoon season (October 2012 to January 2013).

Sl No	District	Species richness	Species Abundance	Shannon diversity index(H)	Shannon evenness (E)	Simpson diversity index (1-D)
1	Trivandrum	9	194	1.9	0.7429	0.8192
2	Kollam	15	204	2.34	0.6921	0.8663
3	Alleppey	11	196	1.987	0.6633	0.8042
4	Ernakulam	10	155	2.096	0.8133	0.8511
5	Thrissur	12	246	1.982	0.6045	0.8016
6	Palakkad	13	196	2.184	0.6835	0.8436
7	Malappuram	13	248	1.77	0.4514	0.7299
8	Kozhikode	11	212	2.171	0.7971	0.8698
9	Kannur	12	175	2.118	0.6931	0.8449
10	Kasaragod	12	176	1.991	0.6099	0.8026

Analysis of various diversity indices during pre monsoon revealed that, among different locations under study Kommadi of Alleppey has been noticed for higher species richness (13). Higher diversity in this location has also been evidenced by the values of Shannon and Simpson indices (2.317 and 0.8778 respectively). A more uniform pattern of mosquito distribution has also been noticed at Kommadi with a Shannon evenness value of 0.7803. However, Vellayil of Kozhikode was reported for lower value of species richness (8), Shannon index (1.728), Shannon evenness (0.7035) and Simpson index (0.7828). As far as abundance concerned, Vellayil of Kozhikode was noticed for higher value (329) followed by Thoppumpady of Ernakulam (299) district. Lower mosquito abundance was reported from Thalassery of Kannur district (157).

Result of the district wise diversity of total mosquitoes collected during monsoon season showed that, higher and lower values of species richness were reported from Thirunellai of Palakkad (14) and Vellayil of Kozhikode (7) respectively. Mosquito abundance was higher at Vellayil off Kozhikode (153) and lower at Thirunellai of Palakkad (91) districts. Higher and lower values of Shannon diversity index were reported at Thirunellai of Palakkad (2.344) and Thoppumpady of Ernakulam (1.628) districts respectively. Thalangara of Kasaragod district has been noticed for higher values of Shannon evenness (0.9202) and Simpson index (0.8838) whereas, lower values of both indices were reported from Chavakkad of Thrissur (0.7278) and Thoppumpady of Ernakulam (0.7792) districts.

During post monsoon season, among the various locations under study, Mangad of Kollam (15) and Manacaud of Trivandrum (9) were noticed for higher and lower species richness. Abundance of mosquitoes was higher at Ponnani of Malappuram (248) followed by Chavakkad of Thrissur (246) and lower at Thoppumpady of Ernakulam (155) districts. Higher values of Shannon diversity index, Shannon evenness and Simpson index were noticed at Mangad of Kollam (2.34), Thoppumpady of Ernakulam (0.8133) and Vellayil of Kozhikode (0.8698) districts respectively. Lower values of all these indices (1.77, 0.4514 and 0.7299 respectively) were noticed at Ponnani of Malappuram district.

Upon comparing the diversity indices of total mosquitoes collected from all the locations during different seasons, it can be concluded that, the average values of species richness was higher during post monsoon season followed by pre monsoon and monsoon seasons. However, higher mosquito abundance has been noticed during pre monsoon season followed by post monsoon and monsoon seasons. Among different locations under study, Mangad of Kollam district during post monsoon and Thoppumpady of Ernakulam during monsoon seasons have been noticed for higher and lower species richness respectively. Similarly, higher mosquito abundance was noticed at Vellayil of

Kozhikode during pre monsoon season and lower at Thirunellai of Palakkad during monsoon season. The average value of Shannon diversity index was higher during post monsoon season followed by pre monsoon and monsoon season whereas, values of both Shannon evenness and Simpson index were higher during monsoon season.

The result of the present study revealed that, there were occurrences of a diverse group of mosquitoes along all the locations under study. A total of 5508 specimens of mosquitoes representing 31 species belonging to 6 genera and 11 subgenera were recorded from all the locations during different seasons. The 6 genera recorded were *Aedes*, *Anopheles*, *Armigeres*, *Culex*, *Mansonia* and *Mimomyia*. Genus *Culex* was reported with 15 species under 4 subgenera and *Anopheles* with 6 species under 2 subgenera. 2 species under 2 subgenera were noticed for both *Aedes* and *Armigeres*. The genus *Mansonia* was reported for 3 species under 1 subgenus. The lowest number was reported for the genus *Mimomyia* with 1 species under 1 subgenus. A revised classification of mosquitoes has been proposed recently. Accordingly some of the subgenera have been grouped in to new genera. List of total mosquito species recorded from all the locations under study during all the seasons are depicted in Table 2.15.

Table 2.15. List of total mosquito species recorded from all the locations under study during all the seasons (February 2012 to January 2013).

Sl No.	Name of Species with author citation	Family	Subfamily	Genus	Subgenus	New classification
1	*Aedes aegypti* (Linnaeus 1762)	Culicidae	Culicinae	*Aedes*	*Stegomyia*	*Stegomyia (Stegomyia) aegypti*
2	*Aedes albopictus* (Skuse 1895)	Culicidae	Culicinae	*Aedes*	*Stegomyia*	*Stegomyia albopicta*
3	*Aedes vittatus* (Bigot 1861)	Culicidae	Culicinae	*Aedes*	*Fredwardsius*	*Fredwardsius vittatus*
4	*Anopheles jamesii* (Theobald 1901)	Culicidae	Anophelinae	*Anopheles*	*Cellia*	
5	*Anopheles splendidus* (Koidzumi 1920)	Culicidae	Anophelinae	*Anopheles*	*Cellia*	
6	*Anopheles stephensi* (Liston 1901)	Culicidae	Anophelinae	*Anopheles*	*Cellia*	
7	*Anopheles subpictus* (Grassi 1899)	Culicidae	Anophelinae	*Anopheles*	*Cellia*	
8	*Anopheles theobaldi* (Giles 1901)	Culicidae	Anophelinae	*Anopheles*	*Cellia*	
9	*Anopheles vagus* (Dönitz 1902)	Culicidae	Anophelinae	*Anopheles*	*Cellia*	
10	*Armigeres subalbatus* (Coquillett 1898)	Culicidae	Culicinae	*Armigeres*	*Armigeres*	
11	*Armigeres aureolineatus* (Leicester 1908)	Culicidae	Culicinae	*Armigeres*	*Armigeres*	
12	*Armigeres annulipalpis* (Theobald 1910)	Culicidae	Culicinae	*Armigeres*	*Leicesteria*	
13	*Culex bitaeniorhynchus* (Giles 1901)	Culicidae	Culicinae	*Culex*	*Culex*	*Culex (Oculeomyia) bitaeniorhynchus*
14	*Culex pallidothorax* (Theobald 1905)	Culicidae	Culicinae	*Culex*	*Culiciomyia*	
15	*Culex fuscanus* (Wiedemann 1820)	Culicidae	Culicinae	*Culex*	*Lutzia*	*Lutzia (Metalutzia) fuscana*
16	*Culex fuscocephala* (Theobald 1907)	Culicidae	Culicinae	*Culex*	*Culex*	
17	*Culex gelidus* (Theobald 1901)	Culicidae	Culicinae	*Culex*	*Culex*	
18	*Culex infula* (Theobald 1901)	Culicidae	Culicinae	*Culex*	*Culex*	*Culex (Oculeomyia) infula*
19	*Culex mimeticus* (Noe 1899)	Culicidae	Culicinae	*Culex*	*Culex*	

Sl No.	Name of Species with author citation	Family	Subfamily	Genus	Subgenus	New classification
20	*Culex pseudovishnui* (Colless 1957)	Culicidae	Culicinae	*Culex*	*Culex*	
21	*Culex quinquefasciatus* (Say 1823)	Culicidae	Culicinae	*Culex*	*Culex*	
22	*Culex sinensis* (Theobald 1903)	Culicidae	Culicinae	*Culex*	*Oculeomyia*	
23	*Culex sitiens* (Wiedemann 1828)	Culicidae	Culicinae	*Culex*	*Culex*	
24	*Culex tritaeniorhynchus* (Giles 1901)	Culicidae	Culicinae	*Culex*	*Culex*	
25	*Culex univittatus*(Theobald 1901)	Culicidae	Culicinae	*Culex*	*Culex*	
26	*Culex vishnui* (Theobald 1901)	Culicidae	Culicinae	*Culex*	*Culex*	
27	*Culex whitmorei* (Giles 1904)	Culicidae	Culicinae	*Culex*	*Culex*	
28	*Mansonia annulifera* (Theobald 1901)	Culicidae	Culicinae	*Mansonia*	Mansonioides	
29	*Mansonia indiana* (Edwards 1930)	Culicidae	Culicinae	*Mansonia*	Mansonioides	
30	*Mansonia uniformis* (Theobald 1910)	Culicidae	Culicinae	*Mansonia*	Mansonioides	
31	*Mimomyia hybrida* (Leicester 1908))	Culicidae	Culicinae	*Mimomyia*	*Mimomyia*	

Table 2.16. Generic composition of total mosquitoes collected from all the locations under study

Sl No	Genus	No. of Species	Total No. of specimens collected	Percentage
1	*Aedes*	3	669	12.14
2	*Anopheles*	6	1020	18.51
3	*Armigeres*	3	664	12.08
4	*Culex*	15	2990	54.25
5	*Mansonia*	3	161	2.95
6	*Mimomyia*	1	4	0.07
	TOTAL	**31**	**5508**	**100**

Data on generic composition showed that, genus *Culex* was the most predominant in terms of diversity and abundance. 54.25% of the total collections were belonged to this group. This is followed by *Anopheles* (18.51%) and *Aedes* (12.14%). These 3 genera constituted 91.27% of the total mosquitoes collected. *Mimomyia* (0.07%) and *Mansonia* (2.95%) represented the lowest percentage values to the total collection. Generic composition of total mosquitoes collected from all the locations under study is depicted in Table 2.16.

Studies on medically important mosquitoes

Frequent outbreaks of mosquito borne diseases have been considered as a major public health issue in Kerala. For the past several decades, some of the vector borne diseases like malaria, dengue fever, Japanese encephalitis, chikungunya, filariasis etc. has resulted in immense suffering on human beings. Incidence of such diseases along certain geographical locations of Kerala indicates the fact that those areas are serving as the breeding grounds of different mosquito vectors. Systematic analysis of the mosquito biodiversity and distribution will help in the formulation of species specific management strategies that eventually minimize the risk of mosquito borne diseases.

The total mosquitoes enlisted in the present study revealed that, there were existences of a wide array of medically important mosquitoes along all the locations under study. Among 31 mosquito species reported, 19 species are known to transmit various diseases. List of medically important mosquito species recorded from all the locations during different seasons are depicted in Table 2.17.

Table 2.17. Medically important mosquitoes

Sl. No	**Name of species**	**Total No.**	**Relative abundance (%)**
1	*Aedes aegypti*	508	12.56
2	*Aedes albopictus*	82	2.03
3	*Aedes vittatus*	79	1.95
4	*Anopheles splendidus*	246	6.08
5	*Anopheles stephensi*	481	11.89
6	*Anopheles subpictus*	63	1.56
7	*Culex bitaeniorhynchus*	135	3.34
8	*Culex fuscanus*	83	2.05
9	*Culex fuscocephla*	35	0.87
10	*Culex gelidus*	165	4.08
11	*Culex infula*	30	0.74
12	*Culex pseudovishnui*	54	1.34
13	*Culex quinquefasciatus*	1493	36.92
14	*Culex tritaeniorhynchus*	56	1.38
15	*Culex vishnui*	326	8.06
16	*Culex whitmorei*	45	1.11
17	*Mansonia annulifera*	76	1.88
18	*Mansonia indiana*	4	0.10
19	*Mansonia uniformis*	83	2.05

Aedes aegypti and *Ae. albopictus* are known to act as potent vectors of dengue fever and chikungunya along different parts of the world whereas, *Ae. vittatus* is one of the principal vectors of yellow fever. 10 species under the genera *Culex* are known to transmit many diseases. *Culex* vishnui, *Cx. pseudovishnui*, *Cx. tritaeniorhynchus* and *Cx. gelidus* are the common vectors of Japanese encephalitis. *Cx. fuscanus*, *Cx. fuscocephla*, *Cx. infula*, *Cx. quinquefasciatus*, *Cx. bitaeniorhynchus* and *Cx. whitmorei* are also reported to have role in the transmission of Japanese encephalitis along different parts of the world. *Cx. quinquefasciatus* is the major vector of lymphatic filariasis along tropical and sub-tropical countries. *Anopheles subpictus*, *An. stephensi* and *An. splendidus* are the primary and secondary vectors of malaria. The species under the genus, *Mansonia* such as *Mansonia indiana*, *Ma. annulifera* and *Ma. uniformis* are the principal vectors of Brugian filariasis. Among different medically relevant mosquitoes collected, the most predominant species were filarial vector *Cx. quinquefasciatus* (36.92%), vector of chikungunya and dengue fever, *Ae. aegypti* (12.56%) and malarial vector *An.stephensi* (11.89%).

Diversity and distribution of filarial vectors

There are 2 types of lymphatic filariasis in Kerala that are known to be endemic along different coastal and non-coastal districts of Kerala. The major vector of Bancroftian filariasis in Kerala is *Culex quinquefasciatus* and that of Brugian filariasis are *Mansonia indiana*, *Ma. annulifera* and *Ma. uniformis*. The abundance and distribution of these vector mosquitoes may have enormous role in the transmission of diseases. In this context, analysis of the abundance and distribution of filarial vectors along endemic areas falling under 10 districts of Kerala have been carried out on seasonal basis. Distribution of filarial vector *Culex quinquefasciatus* in all the locations during premonsoon, monsoon and post monsoon seasons are depicted in Table 18 (a) to (c). Similarly distribution of the *Mansonia* mosquitoes along all the location during premonsoon, monsoon and post monsoon seasons are depicted in Table 2.19 (a) to (c).

Table 2.18 (a). Distribution of filarial vector *Culex quinquefasciatus* in all the locations during pre monsoon season (February 2012 to May 2012).

Sl No	District	Total no. of mosquitoes	No. of *Culex quinquefasciatus*	Relative abundance

		collected		(%)
1	Trivandrum	196	24	12.24
2	Kollam	158	16	10.13
3	Alleppey	217	46	21.20
4	Ernakulam	299	57	19.06
5	Thrissur	260	85	32.69
6	Palakkad	240	61	25.42
7	Malappuram	230	40	17.39
8	Kozhikode	329	81	24.62
9	Kannur	157	54	34.39
10	Kasaragod	194	63	32.47
Total		**2280**	**527**	**23.11**

Table 2.18 (b). Distribution of filarial vector *Culex quinquefasciatus* in all the locations during monsoon season (June 2012 to September 2012).

Sl No	District	Total no. of mosquitoes collected	No. of *Culex quinquefasciatus*	Relative abundance (%)
1	Trivandrum	128	37	28.91
2	Kollam	107	28	26.17
3	Alleppey	131	39	29.77
4	Ernakulam	126	38	30.16
5	Thrissur	119	39	32.77
6	Palakkad	127	27	21.26
7	Malappuram	130	25	19.23
8	Kozhikode	153	55	35.95
9	Kannur	101	18	17.82
10	Kasaragod	103	17	16.50
Total		**1225**	**323**	**26.37**

Table 2.18 (c). Distribution of filarial vector *Culex quinquefasciatus* in all the locationsduring post monsoon season (October 2012 to January 2013).

Sl No	District	Total no. of mosquitoes collected	No. of *Culex quinquefasciatus*	Relative abundance (%)
1	Trivandrum	194	56	28.87
2	Kollam	204	47	23.04
3	Alleppey	196	75	38.27
4	Ernakulam	155	42	27.10
5	Thrissur	247	93	37.65
6	Palakkad	196	62	31.63

7	Malappuram	248	118	47.58
8	Kozhikode	212	36	16.98
9	Kannur	175	49	28.00
10	Kasaragod	176	65	36.93
Total		**2003**	**643**	**32.1**

Table 2.19 (a).Distribution of *Mansonioides* in all the locations during pre monsoon season (February 2012 to May 2012).

Sl No	**District**	**Total no. of mosquitoes collected**	**No. of *Mansonioides***	**Relative abundance (%)**
1	Trivandrum	196	11	5.61
2	Kollam	158	22	13.92
3	Alleppey	217	57	26.26
4	Ernakulam	299	-	-
5	Thrissur	260	3	1.15
6	Palakkad	240	10	4.17
7	Malappuram	230	3	1.3
8	Kozhikode	329	6	1.82
9	Kannur	157	-	-
10	Kasaragod	194	-	-
Total		**2280**	**112**	**4.91**

Table 2.19 (b).Distribution *Mansonioides* in all the locations during monsoon season (June 2012 to September 2012).

Sl No	District	Total no. of mosquitoes collected	No. of *Mansonioides*	Relative abundance (%)
1	Trivandrum	128	-	-
2	Kollam	107	19	15.83
3	Alleppey	131	2	3.05
4	Ernakulam	126	-	-
5	Thrissur	119	-	-
6	Palakkad	127	-	-
7	Malappuram	130	-	-
8	Kozhikode	153	-	-
9	Kannur	101	-	-
10	Kasaragod	103	-	-
Total		**1225**	**21**	**1.71**

Table 2.19 (c).Distribution of *Mansonioides* in all the districts during Post monsoon season (October 2012 to January 2013).

Sl No	District	Total no. of mosquitoes collected	No. of *Mansonioides*	Relative abundance (%)
1	Trivandrum	194	-	-
2	Kollam	204	-	-
3	Alleppey	196	4	2.04
4	Ernakulam	155	-	-
5	Thrissur	247	-	-
6	Palakkad	196	19	9.69
7	Malappuram	248	-	-
8	Kozhikode	212	-	-
9	Kannur	175	-	-
10	Kasaragod	176	-	-
Total		**2003**	**23**	**1.15**

During pre monsoon season, 23.11% of the total mosquitoes collected were *Culex quinquefasciatus*. Among different locations under study, most number of *Culex quinquefasciatus* was recorded at Chavakkad of Thrissur (85) followed by Vellayil of Kozhikode (81) and Thalangara of Kasaragod (63) districts. However, least number has been reported at Mangad of Kollam (16) and Manacaud of Trivandrum (24) districts. Details on the relative abundance values showed that, 34.39% of the total mosquitoes collected from Thalassery of Kannur district during the season were *Culex quinquefasciatus*.

During monsoon season, 323 specimens of *Culex quinquefasciatus* representing 26.37% of the total collection have been reported. Higher relative abundance was noticed at Vellayil of Kozhikode (35.95%) followed by Chavakkad of Thrissur (32.77%) and lower values at Thalangara of Kasaragod (16.5%) and Thalassery of Kannur (17.82%) districts.

643 specimens of *Culex quinquefasciatus* has been reported during post monsoon season representing 32.1% of the total collection. Among different locations under study, relative abundance was higher at Ponnani of Malappuram (47.58%) followed by Kommadi of Alleppey (38.27%) and Chavakkad of Thrissur (37.65%) districts. Least abundances were reported at Vellayil of Kozhikode (16.98%) and Mangad of Kollam (23.04%) districts. Among different seasons, abundance of the filarial vector, *Culex quinquefasciatus* was noticed to be higher at post monsoon season followed by monsoon and pre monsoon seasons.

The most important mosquito vectors of Brugian filariasis in Kerala are belonging to the genus *Mansonia*. The species under this genus are *Ma. indiana*, *Ma. annulifera* and *Ma. uniformis*. Data on the distribution of these mosquitoes along various locations showed that, a total of 112 specimens were recorded during pre monsoon season. Kommadi of Alleppey has been noticed for higher abundance (57) followed by Mangad of Kollam district (22). During monsoon season, a total of 21 *Mansonioides* were reported from Mangad of Kollam (19) and Kommadi of Alleppey (2) districts. A total of 23

Mansonia mosquitoes were reported from Kommadi of Alleppey (4) and Thirunellai of Palakkad (19) districts during post monsoon season.

Upon correlating the number of filarial vectors with number of mf cases in all the districts, it can be stated that there is a positive correlation between abundance of *Culex quinquefasciatus* and mf cases (0.433649). Increase in the number of filarial vector increases the number of mf cases and thus disease endemicity. The correlation between number of *Mansonia* mosquitoes and mf cases was noticed to be less significant (-0.41854).

Discussion

To have an assessment on the effect of mosquitoes on the occurrence and endemicity of filariasis, evaluation of their species composition, abundance and diversity has been carried out at disease endemic locations of Kerala, falling in 10 districts. Collection and identification of both adult and larval stages of mosquitoes were carried out seasonally for a period of one year from February 2012 to January 2013 and the results are represented.

A total of 5508 specimens of mosquitoes, representing 31 species belonging to 6 genera and 11 subgenera were recorded from all the locations during different seasons. Photographs depicting diversity of mosquitoes in the present study is given in plates 2.2 to 2.9. The 6 genera recorded were *Aedes*, *Anopheles*, *Armigeres*, *Culex*, *Mansonia* and *Mimomyia*. Genus *Culex* was reported with 15 species under 4 subgenera and *Anopheles* with 6 species under 2 subgenera. 2 species under 2 subgenera were noticed for both *Aedes* and *Armigeres*. The genus *Mansonia* was reported with 3 species under 1 subgenus. The lowest number was reported for the genus *Mimomyia* with 1 species under 1 subgenus.

Upon comparing the results of the present study with earlier reports, similarity between numbers of genera have been noticed. The previous diversity studies reported from Kerala were; 13 species belonging to 4 genera from Trivandrum city (Daniel et al. 1986), 18 species belonging to 6 genera from Ernakulam and Alleppey districts (Sabesan et al. 1991), 35 species belonging to 7 genera from Kochi and nearby areas (Mariappan et al. 1992, 1996), 26 species under 6 genera from the Kuttanad of Alleppey district (Hiriyan et al. 2003), 17 species belonging to 7 genera from Kannur district (Rajavel et al. 2006), 14 species under 5 genera from hilly districts (Thenmozhi et al. 2007), 21 species belonging to 5 genera from southern Kerala (Sudharmini 2009), 44 species belonging to 11 genera from Alappuzha and 21 species belonging to 9 genera from Kottayam (Balasubramanian and Nikhil 2013), 38 species under 10 genera from Kottayam and Idukki districts (Jomon 2014), 30 species belonging to 5 genera from Irinjalakuda (Asha and Aneesh 2014). All the studies were carried out either along coastal or non-coastal districts. Present study also includes coastal or non-coastal districts and all the species recorded in the present study were already reported species from different parts of Kerala (Mariappan et al. 1992, 1996; Hiriyan et al. 2003; Thenmozhi et al. 2007; Jomon and Thomas 2014).

Even though many studies have reported from Kerala, most of them relied on mosquito faual diversity in the background of diseases such as chikungunya and dengue fever. However, diversity study with respect to the occurrence of filariasis is very limited. The presnt study has been an attempt to elucidate the species composition, diversity and abundance of mosquitoes at selected locations in 10 districts of Kerala with special reference to endemicity of filariasis. A total of 31 species of mosquitoes belonging to 6 genera from all the locations were reported. The recent literature reported a total of 50 species from differ environments of Kerala (Jomon and Thomas 2014). Among these, results of the present study shared a total of 25 species. It has also been noticed that, 6 species reported in the present study were not listed by any of the above studies.

Among the total mosquitoes, 1011 specimens (18.36%) were collected as adult and 4497 (81.64%) as larvae. Diversity of adult mosquitoes revealed higher species richness (21) and abundance (413) in the post monsoon season followed by pre monsoon (17 and 331) and monsoon seasons (14 and 267). The most abundant species of mosquitoes collected as adults during all the seasons were *Culex quinquefasciatus*, *Cx. sitiens*, *Cx. vishnui* and *Aedes aegypti*. Similarly, diversity and distribution with respect to mosquito larvae showed their higher abundance during pre monsoon season (1949) followed by post monsoon (1590) and monsoon (958) seasons. Post monsoon season has been noticed for higher species richness (26 species) followed by pre monsoon (24 species) and monsoon (19 species) seasons. The mosquito species found to be abundant during all the seasons were *Culex* *quinquefasciatus*, *Anopheles stephensi*, *Aedes aegypti* and *Armigeres subalbatus*.

The overall results revealed that the post monsoon season has higher number of species (28) and genera (6) followed by pre monsoon (26 and 5) and monsoon seasons (19 and 5). However, mosquito abundance was higher during pre monsoon season (2280), followed by post monsoon (2003) and monsoon seasons (1225). Such pattern of mosquito distribution among the 3 seasons has also been reported by other researchers (Jomon and Thomas 2014). The possible explanation could be attributed to excessive summer shower received during the pre monsoon season of study period. Increased rainfall might have attributed to the decreased population dynamics of mosquitoes during monsoon season, excessive rain may flush off the mosquito larvae.

Among different locations under study, Mangad of Kollam district during post monsoon and Thoppumpady of Ernakulam during monsoon seasons have been noticed for higher and lower species richness respectively. Similarly, higher mosquito abundance was noticed at Vellayil of Kozhikode during pre monsoon season and lower at Thirunellayi of Palakkad during monsoon season. With respect to adult mosquitoes, higher abundance during the entire season has been noticed at Thoppumpady of Ernakulam (134) and lower at Mangad of Kollam (64) district. Species richness was reported to be higher at Kommady of Alleppey district (13). During all the seasons, higher abundance with respect to mosquito larvae has been noticed at Vellayil of Kozhikode (569) and lower at Thalasserry of Kannur (335) districts. Species richness was higher at Mangad of Kollam (20) and lower at Thalasserry of Kannur (11) districts.

The overall result showed that, post monsoon season has been noticed for a higher mosquito abundance, number of species and number of genera followed by pre monsoon and monsoon seasons. *Culex* was the predominant genus during all the seasons with more species in the post monsoon and less in the monsoon seasons. *Culex quinquefasciatus* was the most abundant species during all the seasons. *Aedes aegypti* has also been noticed as a dominant species during all the seasons. These two species has also been reported as predominant species by previous studies (Balasubramanian and Nikhil 2013; Asha and Aneesh 2014; Sumodan 2014).

A survey on the diversity of mosquitoes in the present study revealed that 19 species out of 31 are vectors of diseases like Malaria **(***Anopheles subpictus*, *An. stephensi* and *An. splendidus*), dengue fever (*Aedes aegypti* and *Ae. albopictus*), chikungunya (*Ae. aegypti* and *Ae. albopictus*), yellow fever (*Ae. vittatus*), Japanese encephalitis (*Culex vishnui*, *Cx. pseudovishnui*, *Cx. tritaeniorhynchus*, *Cx. gelidus*, *Cx. fuscanus*, *Cx. fuscocephla*, *Cx. infula*, *Cx. quinquefasciatus*, *Cx. bitaeniorhynchus* and *Cx. whitmorei*), lymphatic filariasis (*Cx. quinquefasciatus*) and Brugian filariasis (*Mansonia indiana*, *Ma. annulifera* and *Ma. uniformis*).

Among different medically relevant mosquitoes collected, the most predominant species were *Culex quinquefasciatus* (36.92%), *Aedes aegypti* (12.56%) and malarial vector *Anopheles stephensi* (11.89%). *Cx. quinquefasciatus* is primary vector for bancroftian filariasis and suspected vector of JE (Mourya, 1989). *Ae. aegypti* is known as primary vector of dengue fever and chikungunya in different parts of India, including Kerala (WHO 1999; Jupp and McIntosh 1988).

Study on the diversity and distribution of filarial vector *Cx. quinquefasciatus* revealed that their presence during premonsoon, monsoon and post monsoon seasons were 23.11%, 26.37% and 32.1% respectively. A total of 1493 specimens of this mosquito have been collected from all the locations during different seasons. Among all the locations, Chavakkad of Thrissur district (217) has been noticed for a higher abundance, followed by Ponnani of Malappuram district (183). Least abundance has been noticed at Mangad of Kollam district (91). Data on the distribution of *Mansonia* mosquitoes revealed that, they represented 4.91%, 1.71% and 1.15% of the total mosquitoes collected during premonsoon, monsoon and post monsoon seasons respectively. A total of 156 specimens were reported from all the locations. Kommady of Alleppey district (63) has been noticed for higher abundance.

Studies reported that, in the urban systems, 70% of the mosquito larvae and adults are emerging from drains and sewers with stagnant flow of water. The most important categories of mosquitoes preferring these systems are *Culex, Anopheles and Armigeres* (Castro et al. 2010). All the locations under study were coming under unban or semi urban environments wherein, enhanced production of daily sewage occurs. All the districts under study were reported for significant percentages of filarial vector, *Cx. quinquefasciatus* during different seasons. This may be due to the presence of significant area of water sources along all the locations. The water source contribution in the form of sewerages has also been noticed to be high. A significant share of the sewerage channels was noticed to be open type. All these factors might have contributed to the increased abundance *Cx. quinquefasciatus*.

Hyma et al. (1989) reported that, due to poor sanitation, prevalence of filariasis was greater in the slums of urban areas in India. Most of the locations under study were urban or semi urban types. Dasgupta (1984) reported that, domestic and agricultural practices enhance the number of potential breeding sites and abundance of *Culex quinquefasciatus*. This in turn enhances the spreading of *Wucheraria bancrofti* and subsequent prevalence of filariasis. All such factors have been well exposed by the results of present study. Upon correlating the number of filarial vectors with number of mf cases in all the districts, it can be stated that there is a positive correlation between the abundance of *Culex quinquefasciatus* and mf cases (0.433649). Increase in the number of filarial vectors might have attributed to the increase in the number of mf cases and thereby disease endemicity.

Summary and Conclusion

To elucidate the species composition of mosquitoes and their resultant influence on the occurrence / persistence of filarial disease, studies pertaining to their diversity and abundance have been carried out in all endemic areas falling in all the 10 districts of Kerala State. Collections of both adult and larval stages of mosquitoes were carried out seasonally for a period of one year from February 2012 to January 2013 and identified following standard manuals.

A total of 5508 specimens of mosquitoes, representing 31 species belonging to 6 genera and 11 subgenera were recorded from all the locations during different seasons. The 6 genera recorded were *Aedes*, *Anopheles*, *Armigeres*, *Culex*, *Mansonia* and *Mimomyia*. Genus *Culex* was reported with 15 species under 4 subgenera and *Anopheles* with 6 species under 2 subgenera. 2 species under 2 subgenera were noticed for both *Aedes* and *Armigeres*. The genus *Mansonia* was reported with 3 species under 1 subgenus. The lowest number was reported for the genus *Mimomyia* with 1 species under 1 subgenus.

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Upon correlating the number of filarial vectors with number of mf cases in all the districts, it can be stated that there is a positive correlation between abundance of *Culex quinquefasciatus* and mf cases (0.433649). Increase in the number of filarial vector increases the number of mf cases and thus disease endemicity. The correlation between *Mansonioides* and mf cases was noticed to be less significant (-0.41854).

All the districts under study were reported for significant percentages of filarial vector, *Culex quinquefasciatus* during different seasons. This may be due to the presence of significant area of water sources along all the locations. The water source contribution in the form of sewerages has also been noticed to be high. A significant share of the sewerage channels was noticed to be of open type. All these factors might have contributed to the increased abundance *Culex quinquefasciatus*. This in turn enhances the spreading of *Wucheraria bancrofti* and subsequent prevalence of filariasis. Increase in the number of filarial vector increases the number of mf cases and thus disease endemicity.

CHAPTER 3

SOCIO-ECONOMIC CAUSE OF FILARIASIS& IMPACT OF THERAPEUTIC PRACTICES

Introduction

Lymphatic filariasis (LF) is one of the major vector borne diseases in the world. It is the second most common vector-borne parasitic disease after malaria and has been considered as one of the leading cause of human abundance *Culex quinquefasciatus*. This in turn enhances the spreading of *Wucheraria bancrofti* and subsequent prevalence of filariasis. Increase in the number of filarial vector increases the number of mf cases and thus disease endemicity.

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Introduction

Lymphatic filariasis (LF) is one of the major vector borne diseases in the world. It is the second most common vector-borne parasitic disease after malaria and has been considered as one of the leading cause of human deformities. The disease is prevalent in over 80 tropical and subtropical countries. India is the most endemic country for LF contributing more than 40% to the global share (WHO 2005). In India, indigenous LF cases are reported from 21 states/Union Territories and at present the disease is endemic in 255 districts and the population at risk is over 600 million. Both *Wuchereria bancrofti* and *Brugia malayi* are endemic in India. *W. bancrofti* causes the predominant infection, while *B. malayi* is confined to the western coast of Kerala and few pockets in six other states (WHO 2005).

LF causes a wide spectrum of clinical and subclinical disease manifestations. Approximately two-third of infected individuals shows no overt evidence but on clinical trials, show some degree of parasite-associated immuno-suppression and evidences of renal dysfunction. The remaining one- third suffers from the chronic manifestations of LF such as lymphoedema, elephantiasis and hydrocele of the legs or arms resulting in disability, social stigma, and economic consequences (Ottesen et al. 1997).

The paucity of socio-cultural data is a common feature of many of the neglected tropical diseases. Filariasis leads to irreversible chronic manifestations which are responsible for severe physical disability, social stigma and considerable economic loss. The chronic patients with huge elephantoid swellings are often segregated from the society. Acute attacks of filariasis frequently traumatize the patients with transient episodes of disability, often confining the patients to bed (Williams and Jones 2004). Filariasis causes long-term suffering and morbidity to individuals, communities and the nation. Since filariasis is not a direct cause of mortality, it has been given a less priority by the planners and policy makers. It has been estimated that, the annual economic loss due to the disease is very high and may affect the economic stature of many developing countries (Ramaiah et al. 2000). Estimation of the socio-economic reasons for the disease is important to understand the extent of burden and to realize the need for compliance and to accept the mitigating strategies.

The chronic manifestations of filariasis can have significant and often very negative social impacts. The chronic disabling manifestations of this disease including lymphodema of the limbs, breasts and external genitalia, have a profoundly detrimental effect on the quality of life of affected individuals (WHO 2002). The degree of social disability varies between cultural settings but, the degree of stigmatization appears to be directly correlated with the severity of visible disease (Evans et al. 1993). In conservative contexts, affected individuals avoid seeking treatment for fear of drawing attention to their condition. Failure to treat the disease results in recurrent acute febrile attacks and progressive damage to the lymphatic system. Without access to simple hygiene advice, sufferers are unable to prevent further progression of the outwardly visible complications of LF (Dreyer et al. 1999).

However, to enhance the success of elimination strategies, socio-cultural understandings of affected population in the community are pivotal. Early evidences suggest that, long-term efforts to eliminate the disease may fall short in areas wherein, community acceptance replaced by distrust engendered by misguided communication and vertical management programme delivery (WHO 2002). Strategies with respect to understanding the sociocultural aspects of affected communities have key roles in reversing this trend and also in addressing the disability burden. If disability is detected early and correctly managed, the negative economic and psycho-social consequences may be averted. Thus it can be concluded that, sociocultural factors play significant role both in the transmission and on the endemicity of filariasis. Their analysis must be brought into the mainstream for the proper elimination of the disease and to minimize the negative impacts of the disease in future generations.

In order to eliminate lymphatic filariasis globally by 2020, the World Health Assembly passed a resolution in 1997 (Molyneux and Zagaria 2002). Subsequently, a global program to eliminate lymphatic filariasis (GPELF) was launched (WHO 2004). The strategy is known as mass drug administration (MDA), aimed to reduce microfilaria (mf) load in the community and lower the transmission since mf is the essential stage for transmission of infection and disease. This includes different stages and each stage targets a particular category of people such as carriers or diseased cases.

The first step in this program includes mapping of filarial endemic areas and distribution of drugs among entire population. The combination of drugs implemented include Di ethylcarbamazine citrate (DEC) plus albendazole. Each of these drugs has specific actions as, the former kills microfilaria and latter the adult worms. Children below 2 years, pregnant women and seriously sick persons are exempted from taking the medicines. The second phase includes the awareness on the disease and to provide effective morbidity management to reduce human suffering. This is followed by providing guidelines for vector management (Ottesen 2000).

India launched the National Filarial Control Program (NFCP) in 1955 covering about 40 million populations, mainly in urban areas. The treatment strategy involved selective chemotherapy (DEC 6 mg kg^{-1} day^{-1} for 12 days) to individuals tested positive for the parasite through night blood survey (WHO 1984).

Later, World Health Organization recommended that a single dose of DEC is as effective as 12 spaced doses. The introduction in the late 1990's of mass treatment with single dose of DEC and subsequently in combination with albendazole has become a landmark in the treatment and control of lymphatic filariasis. The single dose combination of DEC (6 mg/kg body weight) and albendazole (400 mg) is now accepted as the treatment of choice for mass drug administration (Ottesen 2000).

The first pilot project of MDA using DEC was launched in India in 1996 and covered 13 districts in 7 states based on mf prevalence data collected between 1958 and 1975 (Sabesan et al. 2010). In 2004, the National Vector Borne Disease Control Program launched MDA in 202 districts out of 593, based on the filaria map of 1995 (NVBDCP 2009). On the basis of reports received from different states, 250 districts were designated as endemic for filariasis by 2006 and the MDA program has been scaled up in these districts.

Under the national policy, MDA is administered with a target of minimum 85% compliance rate. The impact of the program is monitored once a year (about one month prior to and after the program) by screening the population from sentinel sites along with an equal number of random sites. 20 μL of finger prick blood samples from a minimum of 500 persons will be examined at each location for availing the rate of microfilaraemia (NVBDCP 2009). This is also evaluated on the basis of studies carried out in vector mosquitoes. Both strategies will reveal the microfilaria rate along with infection and infectivity rates. If any of the strategies reveal endemicity rates more than 1%, such location will be treated as endemic. The filarial endemic areas are thus exposed and MDA campaigning will be initiated. After successful completion of MDA, the effectiveness of the programme can be evaluated by conducting the above two approaches. Endemicity rates evaluated before and after MDA will be compared to assess the effectiveness of the program.

Xenomonitoring is defined as the monitoring of parasite within vectors. By this method, vector mosquitoes are collected and examined for the presence of parasite (dissection) or parasite material (Polymerase Chain Reaction) using molecular technique. Presence of infective stage larva of LF is considered as an indication of current risk of transmission. Presence of larva in the vector indicates the presence of microfilaria carriers in the community. This is a passive method without samples from human.

Xenomonitoring of parasites within the mosquito vectors helps to decide whether to continue or to stop MDA and for assessing the success and progress of LF elimination programs. Dissection enables the quantification of infection rate (the proportion of mosquitoes positive for any of the larval stages of *W. bancrofti*) and infectivity rate (the proportion of mosquitoes positive for the infective L3 stage of W. bancrofti).

Considering the above facts, it can be concluded that, various socio-economic factors along with knowledge on disease and it’s mode of transmission are known to have supreme role on the prevalence of filariasis. Evidences for the influence of such factors on various approaches towards successful elimination of the disease are also prominent. In view of the above reflections, an attempt is made in the present study to examine different socio-economic and occupational characteristics of filarial patients residing at endemic locations of 10 districts of Kerala. Consideration of such social descriptions and their meaningful interpretations may reveal the most vital entity that causes intact disease. Seeking any sort of medical attention is a positive thought towards eliminating the disease. Impacts of such therapeutic practices are also subjected to thorough assessment for the carry-over or stoppage of government level drug administration protocols. Xenomonitoring of mosquitoes for parasites has also been carried out at the higher endemic districts such as Palakkad and Malappuram. Such practices may reveal the current status of the disease along the locations and impact of therapeutic practices.

Review of Literature

Lymphatic filariasis (LF) is an important public health and socio-economic problem worldwide. Although LF does not leads to immediate mortality, the associated severe morbidity has resulted in being recognized it as the second leading cause of disability. Two most common chronic manifestations of the disease are hydrocele and lymphoedema, cause socio-psychological problems to patients and their families (Ramaiah et al. 2014).

Various socio-economic and cultural factors are known to be responsible for the prevalence and endemicity of lymphatic filariasis. Studies reported that, perception, beliefs, awareness and traditional practices related to the disease, quality of life, health care behavior and deprivation and social exclusion are some of the most important factors that may lead to the spreading of the disease (Dreyer et al. 1999). There are many reports on the negative impact of such factors on the transmission of filarial disease and its elimination strategies.

Studies pertaining to the awareness on reasons for Brugian filariasis and its control were conducted and reported from Shertallai taluk of Kerala state, India. The authors recorded that, 60.8% of the individuals know correctly about the cause and method of control of filariasis and 8% had correct knowledge about the role of mosquitoes in the disease. The rest of the individuals have divergent incorrect views or no opinion (Chandrasekharan et al. 1979). The study as a whole discussed the prospects of such information in formulating the disease management strategies.

Studies pertaining to the evaluation of knowledge and beliefs of the people about the filariasis and its transmission have also been reported. Carme et al. (1979) conducted a study concerning the belief of 127 patients in French Polynesia about the origin of filarial disease. The result revealed that, only 13% of the patients were aware that mosquito is the cause of the disease. The role of sanitation in disease transmission was not at all considered as a probable determinant by the victims.

Studies on the age of people prone to the disease in Papua New Guinea revealed that, age specific prevalence of filariasis was higher in males of age above 40 years. This pattern was not observed among females. There was a rise in the prevalence up to 40 years and after that a plateau has been noticed (Kazura et al. 1984).

The gender specificity for the filarial disease was studied by many researchers. Studies carried out in different regions of Africa indicated that, generally the prevalence of microfilaria and disease was higher in males than females. Studies from Liberia and Tanzania showed that, the disease prevalence was lower in females than males (Brabin 1990). Similar findings have also been reported from Indian sub continent and South East Asia. Gender-specific estimates indicated that prevalence of *W. bancrofti* infection and clinical manifestations in males was 10% more than that in females (WHO 1994). However, studies from Srilanka reported a higher prevalence among females (Wijesinghe et al. 2007).

As vector-borne diseases are transmitted even in households, housing pattern has a direct influence on their transmission dynamics (Webb 1985). Similar studies conducted by Baruah and Rai (2000) in Varanasi have reported the role of house design in the transmission of filariasis. It has also been reported that, house structure with cross ventilation, white painted walls, meshed doors and windows are most likely to reduce indoor biting and could have a significant effect on reducing the incidence of vector borne diseases (Kolstrup et al. 1981). Crowded living conditions, housing quality, inadequate waste disposal and sanitation facilities have also resulted in an increased prevalence of filariasis (Mak 1986).

Community participation is treated as a prerequisite for successful filarial disease control programs which is moreover based on integrated vector control. Important social factors reported as barriers for the lack of community participation in filariasis control are, perception that the disease is not a serious and fatal one, slow progression of the disease towards chronic manifestations, absence of hope for clinical cure among victims, lack of awareness of the cause of the disease particularly in urban areas, that governmental agencies should themselves solve public health problems without community involvement (Panicker et al. 1992).

Studies have been conducted on the role of individuals and communities in the control of filariasis. The results have revealed the relationship between social and economic factors such as occupation on the transmission and control of lymphatic filariasis (Evans et al. 1993). Ramaiah et al. (1996) reported that, key informant approach would serve as an important tool for identifying the endemic pockets of filariasis. Such approaches also may reveal the social and occupational status of people and its impact on the transmission of disease.

Eberhard et al. (1996) studied the knowledge, attitude and perceptions of lymphatic filariasis victims among residents in an endemic area in Haiti. The victims were noticed to be suffering from lymphodema and hydrocele. Fewer than 50% of residents had heard of filariasis and only 6 % of those surveyed knew that, it was transmitted by mosquitoes. In contrast, all victims were well aware of the clinical conditions of hydrocele and elephantiasis. Awareness on the transmission of filariasis and its prevention among community using a semi structured questionnaire has been conducted from South India. The study concluded that, the knowledge of people about transmission and prevention of filariasis was very poor (Ramaiah et al. 1996).

Filarial disease has a significant impact on the economic status of community and nation. This has been evidenced by several studies across the world. Gyapong et al. (1996) investigated the economic burden of lymphatic filariasis in rural community of northern Ghana. The disease also has impact on the growth and development of people. Ramu et al. (1996) studied the impact of lymphatic filariasis on the productivity of male weavers in a South

Indian village. Ramaiah et al. (1997) studied the functional impairment caused by lymphatic filariasis in a rural area of South India and observed that occupational activities are hampered by affliction of the disease. Dash et al. (1997) reported the economic implications of filarial disease in coastal districts of Orissa. The study reported that, most of the victims were from lower socio-economic backgrounds and incidence of the disease has affected their occupational characteristics.

A qualitative analysis on the socio-cultural and behavioral aspects of lymphatic filariasis in Thailand was carried out and reported. The factors examined included traditional knowledge and cultural beliefs concerning etiology, transmission and symptomatology, perceived susceptibility and severity, social stigma, social support in disease prevention and control and behavioral risk factors and illness behaviors. Data were collected through a multi-method, predominantly qualitative approach, including rapid survey and mapping, group interviews, focus group discussions, in-depth interviews, and participant observation. Results indicated that, poor knowledge, indigenous and traditional beliefs have contributed to a high risk towards disease transmission among populations (Rauyajin et al. 1995).

Study has been carried out to describe the physical disability and psycho-social impact associated with chronic lymphoedema patients attending filariasis clinics in the Colombo district, Sri Lanka. Data were collected using a pre-tested, interviewer-administered questionnaire and the results revealed that, majority of the patients had swellings on lower limbs and there was a significant association with difficulty in walking. Swelling on legs affected occupational status of patients. The study revealed that, 25 % and 6 % of the reported cases were facing problems in interacting with the community and family. The study as a whole concluded that, lymphoedema significantly affected the physical, psychological and social functioning status of disease victims (Wijesinghe et al. 2007).

Filariasis has been a major public health problem in India, only next to malaria. National Filaria Control Programme (NFCP) was launched in the country in 1955 with the objective of delimiting the problem and to undertake control measures in endemic areas. In order to eliminate lymphatic filariasis globally by 2020, the World Health Assembly launched a global program known as mass drug administration. The impact of the program is monitored once a year by various approaches like night blood smears and xenomonitoring of vector mosquitoes. Presence of larva in the vector indicates the presence of microfilaria carriers in the community (WHO 2004).

Monitoring of vectors for filarial larvae is an important diagnostic tool for LF elimination programs. A study in Sri Lanka suggested that the examination of recently fed house-resting populations of *Cx. quinquefasciatus* could be a sensitive method for measuring the prevalence of mf in the human population (Jayasekera et al. 1991).

Studies on mosquito vectors have been carried out and reported from different parts of World to evaluate the filarial infection rates and effectiveness of MDA programs. Entomological data were collected from 9 villages in Tirukoilur, South India, to determine the impact of annual single mass drug administration. All potential resting places were thoroughly searched with the help of torchlight and the mosquitoes were collected with an oral aspirator. These collections were carried out at 3- or 4-week intervals. All the collected specimens were transported to the laboratory for further identification and dissection, and for determination of the individual vector infection status. The study showed that, intervention strategies implemented like MDA markedly influenced the transmission of the disease (Sunish et al. 2003).

Studies pertaining to knowledge, attitude and practices showed that direct interaction with community played an important role in controlling many mosquito borne diseases. Though many epidemiological studies have been carried out to describe the dynamics of filarial disease transmission across different countries, the social and economic factors that have influence on the transmission of disease in Kerala are least understood. Any control program that does not recognize the crucial role of these factors is not likely to achieve the goal of complete disruption of transmission. Thus, for evaluating the transmission dynamics of infection role of each of these factors need to be assessed at the community level. The present study has been attempted in this direction and evaluated the social, occupational status of filarial victims along endemic locations falling in 10 districts of Kerala. Patient's awareness on reasons for the disease, its mode of transmission and management strategies has also been discussed.

In Kerala, the recent reports of district vector control units revealed highest endemicity of filariasis in Palakkad and Malappuram districts. Seeking any sort of health care measure can bring down the incidence of filarial disease and its clinical manifestations. In pursuit of assessing the effect of such therapeutic practices, a mosquito based study has been conducted at Palakkad and Malappuram districts of Kerala. Thus the objectives of the present study can be summarized as:

Assessment of the socio-economic and occupational characteristics of people who are victims of filariasis in disease endemic areas of Kerala and,

Identification of filarial parasite within the mosquito vectors from the diseases endemic areas and evaluation of the impact of therapeutic practices.

Materials and Methods

1. Survey using questionnaire for the evaluation of social and occupational reasons for disease transmittance and the role of such factors in management measures.

Details pertaining to the filarial victims residing in endemic areas of all the 10 districts of Kerala have been collected from respective district vector control units, after obtaining permission. All the victims were identified on the basis of the addresses provided and the nature and purpose of the study was explained to them, for ethical reasons. The filarial victims (swelling cases) were interviewed with a structured questionnaire for the period 2015-16. Information pertaining to the social, occupational and cultural status of the victims, their awareness on disease and health care measures adopted were collected and reported, without revealing their identity.

The questionnaire (Annexure I) included five sections. The first section recorded the personal information of the victim including age, gender, number of family members, family reports of filariasis and dietary pattern. The second section included pre-infection status of the victims like occupation, housing pattern, use of mosquito repellents and occurrence of any other diseases. Post infection status of the victims like occupation, years of disease suffering, associated diseases, body part affected and incidences of secondary infection were recorded in the third section. Details regarding health care measures like years under treatment and mode of treatment were included in the fourth section. Awareness on the cause of disease and its management were included in the fifth section. Analysis of the data was carried out and the results are expressed in percentage.

Annexure I. Questionnaire on the_social and health status of victims of filariasis

1	**General Information**		
a	Age	30-45 Years	
		46-60 Years	
		61-75 Years	
		76-90 Years	
b	Gender	Male	
		Female	
c	Blood group	A	
		B	
		AB	
		O	
d	Marital status	Married	
		Unmarried	
e	Total number of family members	Below 5 Years	
		6-20 Years	
		21-60 Years	
		61 Years above	
	Gender	Male	
		Female	
g	Family reports of filariasis	Yes	
		No	
h	Dietary pattern	Vegetarian	
		Non-vegetarian	
2	**Pre infection history**		
a	Residence	Native	
		Migrant	
b	Occupation	Professional	
		Skilled labourer	
		Unemployed	
c	Nature of house	Kacha	
		Pakka	
d	Use of mosquito repellents/nets	Yes	
		No	
e	Other diseases	Yes	
		No	
3	**Post infection status**		
a	Occupation	Professional	
		Skilled labourer	
		Unemployed	

b	Body part affected	Legs	
		Genetalia	
		Both	
c	Years of disease suffering	0-10 Years	
		11-20 Years	
		21-30 Years	
		31-40 Years	
d	Fever	Yes	
		No	
e	Secondary infections	Yes	
		No	
f	Other diseases	Yes	
		No	
4	**Health care measures**		
a	Under treatment	Yes	
		No	
b	Period of treatment	0-5 Years	
		6-10 Years	
		11 above	
c	Mode of treatment	Government filarial clinic	
		Private clinic	
d	Betterment of disease	Yes	
		No	
5	**Disease awareness**		
a	Reason/ disease causing parasite	Yes	
		No	
b	Means of disease transmission	Yes	
		No	
c	Knowledge on mosquitoes larvae	Yes	
		No	
d	Disease management	Yes	
		No	
		Partial	

2. Xenomonitoring of parasites in mosquito vectors

Xenomonitoring is defined as the monitoring of parasite with in vector mosquitoes. Mosquitoes are collected, dissected and examined for the presence of parasites. Presence of larva in the vector indicates the presence of microfilaria carriers in the community and the current risk of disease transmission. This is a passive method without samples from human.

a. Collection of mosquitoes

Adult *Culex quinquefasciatus* mosquitoes were collected from 6 locations, each falling in Thirunellai of Palakkad district and Ponnani of Malappuram district during pre MDA period (September 2015 to October 2015) and post MDA perid (December 2015 to January2016). Details pertaining to the distribution of drugs and its consumption in each location were collected from the district vector control units. Collection of vectors was carried out before and after the implementation of a single dose of MDA. Adult *Culex quinquefasciatus* mosquitoes resting indoor were collected in the morning (6 am to 9 am) using oral aspirators. All the mosquitoes were transferred to test tubes and anesthetized with cotton swab of ethyl acetate (WHO 1962)

b. Dissection of mosquitoes

The anesthetized mosquitoes were placed on a glass slide. All the leg and wings were removed. Using needle, the entire body was segmented in to head, thorax and abdomen. Each segment was placed in a drop of physiological saline and macerated using needles. The slide was then observed under the microscope to find out the presence of filarial parasites. Head, thorax and abdominal parts of each dissected mosquito were examined separately. The slides which were positive for filarial parasites were kept separate and allowed to dry partially in air (WHO 1962).

c. Staining procedure

A few drops of Leishman's stain (0.15 gm Leishman powder dissolved in 100 ml of acetone free methyl alcohol) were applied on the slide containing 3 separate parts i.e. head, thorax and abdomen and was allowed to act for 30 seconds. Added double the volume of distilled water and mixed well. Kept for 10 minutes and washed in running tap water. The slides were then dried in air.

d. Observation

After staining, each slide was examined under compound microscope to identify stage of filarial parasites. Different life stages of parasites and infected part of the mosquito (head, thorax and abdomen) was noted. The proportion of mosquitoes positive for any of the larval stages of *W. bancrofti* was noted as infection rate. The proportion of mosquitoes positive for the infective L3 stage of W. bancrofti was noted as infectivity rate.

Results

Studies have been carried out to evaluate the social, occupational and cultural characteristics of filarial victims residing at endemic locations in 10 districts of Kerala for the period 2015-16. The evaluation was based on survey with the help of a structured questionnaire and personal interview. A total of 72 victims were visited to have an assessment on their demographic characteristics, pre infection and post infection status. Results of the demographic characteristics are depicted in Tables 3.1.

Demographic characteristics

Results of the assessment of demographic characteristics revealed that, most of the victims are falling in the age group 61-75 years. This trend was more evident in Kollam (100%), Alleppey (64.64%), Palakkad (63.75%) and Malappuram (63.75%) districts. Also, a significant percentage of the victims were in the age group of 41-60 years. Data from Kasaragod (66.67%), Kannur (50%), Kozhikode (60%) and Ernakulam (50%) districts showed such a pattern. The number of victims coming in the age groups of 30-45 and 76-90 years were noticed to be less in all the districts. It was also noticed that, males are victims of this pathogen and are remaining as patients. Higher percentages of male patients were surveyed from Ponnani of Malappuram (75%), Chavakkad of Thrissur (70%) and Thalangara of Kasaragod (66.67%) districts.

Different blood groups of the victims noticed were A+ve, B+ve, AB+ve and O+ve. No negative group has been noticed from any of the districts. A major share of the victims has B+ve as their blood groups. This trend was more prominent in Manacaud of Trivandrum (60%) and Thalassery of Kannur (50%) districts. A+ve was the major blood group of victims from Thalassery of Kannur district (50%). AB+ve have been noticed as the major blood group of victims from Thalangara of Kasaragod district (66.67%). O+ve was the major blood group of victims from Ponnani of Malappuram district (37.5%).

Table 3.1.Demographic characteristics of filarial victims in all the districts under study

I	General information		Trivandrum	Kollam	Alleppey	Ernakulam	Thrissur	Palakkad	Malappuram	Kozhikode	Kannur	Kasaragod	Mean with SD
1	Age	30-45 Years	0	0	9.09	0	0	6.25	6.25	0	0	0	2.159 ± 3.38
		46-60 Years	40	0	27.27	50	30	25	25	60	50	66.67	37.394± 18.86
		61-75 Years	40	100	64.64	50	60	63.75	63.75	40	50	33.33	56.547± 18.00
		76-90 Years	20	0	0	0	10	0	0	0	0	0	3± 6.40
2	Gender	Male	60	50	54.55	50	70	50	75	60	50	66.67	58.622±8.83
		Female	40	50	45.45	50	30	50	25	40	50	33.33	41.378± 8.83
3	Blood group	A+ve	0	0	0	25	10	16.67	25	0	50	0	12.667± 15.89
		B+ve	60	50	36.36	25	30	41.67	12.5	40	50	33.33	37.886± 13.03
		AB+ve	0	50	27.28	50	30	25	25	20	0	66.67	29.395±20.24
		O+ve	40	0	36.36	0	30	16.67	37.5	40	0	0	20.053± 17.56
4	Marital status	Yes	100	100	100	100	100	100	100	100	100	100	100±0
		No	0	0	0	0	0	0	0	0	0	0	0
5	Family members	Below 5 Years	12.5	11.11	25.37	17.65	23.91	11.47	25.37	23.08	14.29	11.76	17.651± 5.84
		6-20 Years	20.83	22.22	17.91	17.65	19.57	18.03	17.91	15.38	14.29	17.64	18.143± 2.21

I	General information		Trivandrum	Kollam	Alleppey	Ernakulam	Thrissur	Palakkad	Malappuram	Kozhikode	Kannur	Kasaragod	Mean with SD
		21-60 Years	37.5	44.45	35.82	47.06	41.3	54.1	35.82	46.16	50	47.06	43.927± 5.87
		61 Years above	29.17	22.22	20.9	17.65	15.22	16.4	20.9	15.38	21.42	23.54	20.28±4.09
	Gender	Male	45.83	55.56	58.2	64.71	41.72	60.66	58.2	34.62	57.14	54.55	53.119± 8.90
		Female	54.17	44.44	41.8	35.29	58.28	39.34	41.8	65.38	42.86	45.45	46.881± 8.90
6	Family reports of filariasis	Yes	0	0	18.18	0	10	0	18.75	20	0	0	6.693±8.57
		No	100	100	81.82	100	90	100	81.25	80	100	100	93.307± 8.57
7	Dietary pattern	Vegetarian	25	0	27.27	0	0	25	0	0	25	0	10.227± 12.54
		Non – vegetarian	75	100	72.73	100	100	75	100	100	75	100	89.773± 12.54

All the victims from different districts were married and leading family life. Major share of their family members are in the age group of 21 to 60 years. Results from all the districts showed such a trend. Among all the districts under study, number of family members in the above age group was more prominent in Thirunellai of Palakkad (54.1%) and Thalassery of Kannur (50%) districts. Significant number of family members in the age group of 61 years and above has also been recorded from all the districts. Data on the gender ratio revealed that, major share of the victim's family members were males. Such a trend has been noticed from all the districts under study except, Manacaud of Trivandrum, Chavakkad of Thrissur and Vellayil of Kozhikode wherein higher percentages of the family members were females.

Most of the victims do not have family history of filariasis. Among different districts under study, 18.18%, 10% and 18.75% of victims residing at Kommady of Alleppey, Chavakkad of Thrissur and Ponnani of Malappuram districts respectively were noticed for having family history of filariasis. It has been noticed that, victims residing at all other districts does not have any family history of filariasis. Major share of the victims are following non-vegetarian type of dietary pattern. A fewer number of victims residing at 4 districts under study only followed vegetarian type of food habits.

The overall result from the entire districts showed that, most of the victims are falling in the age group 61-75 years (56.547 +/- 18). It has been noticed that males (58.622 +/- 8.83) are the victims of this pathogen and are remaining as patients. It has also been noticed that a major share of the victims (37.886 +/- 13.03) have a blood group B+ve. As the victims are of higher age group, 100 % of them are married and are associated with a family system. Higher share of their family members are in the age group 21 to 60 years (43.927 +/- 5.87) and are mostly males (53.119 +/- 8.9). A major share of the victims (93.307 +/- 8.57) does not have family history of filariasis. Major share of the victims (89.773 +/- 12.54) are following non-vegetarian type of dietary pattern.

Pre infection history

To elucidate the role of occupational, social and other factors that have influence on transmission of diseases, data pertaining to the pre infection period were collected. Results of the pre infection history of the filarial victims in all the districts under study are depicted in Table 3.2.

Data on the pre infection history of patients revealed that most of the victims are residents and have not migrated from any place. This was evident in almost all the districts except, Thoppumpady of Ernakulam and Thirunellai of Palakkad where, 25% and 16.67% of people respectively were migrants from other states.

The occupational characteristics of victims were grouped in to three categories and evaluated. They are professionals (those working in government and private sectors), skilled labourer (cooly, fishermen, store keepers) and unemployed. Major shares of the victims were engaged in skilled labourer category of occupations. This trend was prominent in Mangad of Kollam, Kommady of Alleppey and Chavakkad of Thrissur districts wherein, almost all the victims were skilled labourers. Only 31.25% of victims at Ponnani of Malappuram and 25% at Thalassery of Kannur district were engaged in professional occupation category.

Two types of housing patterns have been noticed at all the locations and they are Pucca and Kutcha. 87.383% victims were living in pucca type of houses. Kutcha type of housing pattern has been noticed along the coastal areas of Malappuram, Alleppey, Kozhikode and Kannur districts. Rural areas at Thirunellai of Palakkad district has also been noticed for Kutcha type of housing pattern. A significant percentage of the victims were not in the habit of using mosquito repellents or nets in routine life. Such attitude has more pronouncedly shown by victims residing at Mangad of Kollam, Thirunellai of Palakkad, Vellayil of Kozhikode and Thalangara of Kasaragod districts.

Table 3.2.Pre infection history of the filarial victims in all the districts under study

II	Pre infection history		Trivandrum	Kollam	Alleppey	Ernakulam	Thrissur	Palakkad	Malappuram	Kozhikode	Kannur	Kasaragod	Mean with SD
1	Resident	Native	100	100	100	75	100	83.33	100	100	100	100	95.833±8.54
		Migrant	0	0	0	25	0	16.67	0	0	0	0	4.167±8.54
2	Occupation	Professional	0	0	0	0	0	0	31.25	0	25	0	5.625±11.34
		Skilled labourer	80	100	100	75	90	50	43.75	60	25	66.67	69.042±23.54
		Unemployed	20	0	0	25	10	50	25	40	50	33.33	25.333±17.44
3	Nature of house	Kutcha	0	0	9.09	0	20	33.33	18.75	20	25	0	12.617±6.51
		Pucca	100	100	90.91	100	80	66.67	81.25	80	75	100	87.383±11.74
4	Use of mosquito repellents/nets	Yes	40	0	36.36	25	20	0	37.5	0	25	0	18.386±16.12
		No	60	100	63.64	75	80	100	62.5	100	75	100	81.614±16.12
5	Other diseases	Yes	40	100	54.55	75	70	33.33	43.75	80	100	0	59.663±29.88
		No	60	0	45.45	25	30	66.67	56.25	20	0	100	40.337±29.88

Before getting the filarial disease, most of the victims were suffering from many other diseases. The diseases noted were, cardiac diseases, diabetes mellitus, hypertension, arthritis, asthma, etc. This trend was more prominent at Mangad of Kollam, Vellayil of Kozhikode and Thalassery of Kannur districts wherein, all the victims were suffering from other diseases.

The overall result showed that, 95.883% (+/- 8.53) of victims are residents and have not migrated from / to any place. 69.042% (+/- 23.54) of people were skilled labourers in the pre infection stage. 87.383% (+/- 11.74) people were living in pucca type of houses. 59.663 %(+/- 29.88) of people does not have other diseases and 81.614% (+/- 16.11) of them were not in the habit of using mosquito repellents or nets in routine life.

Post infection status

Filariasis is regarded as the second leading cause of permanent disability in the world. In addition to various clinical manifestations, the disease has been resulting in so many negative impacts on socio-economic and occupational factors. Details on the post infection status of filarial patients such as occupation, clinical manifestation and occurrence of other diseases residing at all the locations were collected and reported. Results of the post infection status of the filarial victims in all the districts under study are depicted in Table 3.3.

Results of the post infection status of filarial patients revealed that major share of them are leading a sedentary sort of life and are unemployed. This has been evidenced by the higher percentages of unemployed victims residing at all the locations except Kommady of Alleppey where, the prevalence of the disease does not affected the occupational characteristics. Even after getting disease, 54.555% of the victims have been engaged in various occupations of the skilled labourer category.

Table 3.3.Post infection status of the filarial victims in all the districts under study

III	Post infection status		Trivandrum	Kollam	Alleppey	Ernakulam	Thrissur	Palakkad	Malappuram	Kozhikode	Kannur	Kasaragod	Mean with SD
1	Occupation	Professional	0	0	0	0	0	0	6.25	0	0	0	0.625±1.88
		Skilled labourer	20	50	54.55	0	10	25	18.75	20	25	0	22.33±17.29
		Unemployed	80	50	45.45	100	90	75	75	80	75	100	77.045±17.27
2	Body part affected	Legs	100	100	93.75	100	100	91.67	93.75	100	100	100	97.917±3.23
		Genetalia	0	0	0	0	0	0	0	0	0	0	0
		Both	0	0	6.25	0	0	8.33	6.25	0	0	0	2.083±3.23
3	Years of suffering disease	0-10	40	0	18.18	0	40	41.67	62.5	60	75	33.33	37.068±24.02
		11-20	40	50	36.36	100	30	50	12.5	40	0	66.67	42.553±26.30
		21-30	20	50	18.18	0	20	0	12.5	0	25	0	14.568±10.72
		31-40	0	0	18.18	0	0	0	12.5	0	0	0	3.068±6.27
		40 above	0	0	9.09	0	10	8.33	0	0	0	0	2.742±4.21
4	Fever	Yes	20	100	63.64	75	40	58.33	56.25	60	50	66.67	58.989±21.88
		No	80	0	36.36	25	60	41.67	43.75	40	50	33.33	41.011±21.88
5	Secondary infections	Yes	60	100	45.45	75	50	50	37.5	40	50	0	50.795±24.49
		No	40	0	54.55	25	50	50	62.5	60	50	100	49.205±24.49
6	Other	Yes	0	0	36.36	50	50	8.33	25	0	0	25	19.469±19.

	diseases												62
		No	100	100	63.64	50	50	91.67	75	100	100	75	80.531±19.62

The clinical manifestations of the disease include fever, chills, headache and skin lesions in the early stages and enlargement of the limbs and genitalia (condition known as hydrocele) in later stages. A major share of the victims is suffering from clinical manifestations in the form of swelling on legs. Such a pattern has been noticed in all the districts under study. 1111111111111111

Few cases have been noticed with swelling on both legs. In addition to swelling on lower limbs, signs of hydrocele have been noticed in victims residing at Kommady of Alleppey (6.25%), Thirunellai of Palakkad (8.33%) and Ponnani of Malappuram (6.25%) districts. All the victims have been suffering from the clinical manifestations of the disease for varied period of time. Most of the patients under study are suffering from the disease for the last 11 to 20 years. Victims who have been suffering from the effects of the disease for more than 30 years has also been reported from sites like Kommady (Alleppey), Thirunellai (Palakkad) and Ponnani (Malappuram).

Intermittent occurrence of fever and chills are unique nature of filarial diseases. Most of the patients from all the districts experienced such clinical signs. If the swollen legs and genetalia are not managed properly, bacterial and fungal infection are noticed as secondary infections. More than half of the victims from all the districts have been noticed for secondary bacterial infections. After getting filarial disease, majority of the patients were not suffering from any other diseases. In addition to the clinical signs of filariasis, most of them sustained diseases that were prevalent during pre infection period.

The overall study revealed that a major share of patients (77.045 +/- 17.27) are leading a sedentary sort of life and were not engaged in any occupation. 97.917 % (+/- 3.23) of the victims were suffering from clinical manifestations in the form of swelling on legs. Most of the patients (42.553 +/- 26.29) are suffering from disease for the last 11 to 20 years. Intermittent occurrence of fever was experienced by 58.989% (+/-21.88). Secondary infections were noticed to be prominent among 50.795 % (+/-24.49) of victims. After getting filarial disease, majority of the patients (80.531 +/-19.62) were not suffering from any other diseases.

Health care measures

Utmost medical care and strict follow up are inevitable for the betterment of clinical manifestations of filariasis. Delicacy in seeking any medical care may aggravate the symptoms and leads to secondary infections. Details of patients related to their medical attention have been collected and reported from all the districts. Results of the health care measures adopted by the victims in all the districts under study are depicted in Table 3.4.

The results revealed that most of the victims are not adopting any medical care. Such a trend has been noticed from all the districts except Kommady of Alleppey and Chavakkad of Thrissur districts wherein, most of the victims are following regular treatment practice. Even though most of the patients were suffering from the disease for longer periods, many of them started seeking medical care only for the last 5 years. Most of the patients are depending on private clinics for the treatment. This was the case with all the districts except Alleppey, Thrissur and Malappuram where, significant share of the victims are visiting government filarial clinics on a regular interval. Even after adopting treatment, major share of the victims have not attained any betterment in the clinical manifestations. However, patients at Ponnani of Malappuram, Vellayil of Kozhikode and Thalangara of Kasaragod districts have been reported to attained cure.

The overall results revealed that, majority of them (58.72 ± 13.64) are not following any treatment practice. A major share (82.273 ± 23.78) of the patients is depending on private clinics for the treatment rather than any government facility. Among the victims seeking medical attention, 69.667 % (± 34.49) has not attained any cure.

Table 3.4.Health care measures adopted by the victims in all the districts under study

IV	Health care measures		Trivandrum	Kollam	Alleppey	Ernakulam	Thrissur	Palakkad	Malappuram	Kozhikode	Kannur	Kasaragod	Mean with SD
1	Under treatment	Yes	20	50	63.64	25	60	33.33	37.5	40	50	33.33	41.28±13.65
		No	80	50	36.36	75	40	66.67	62.5	60	50	66.67	58.72±13.65
2	Period under treatment	0-5 Years	100	100	100	100	50	100	87.5	100	50	100	88.75±19.72
		6-10 Years	0	0	0	0	33.33	0	0	0	50	0	8.333±17.08
		11 above	0	0	0	0	16.67	0	12.5	0	0	0	2.917±5.91
3	Mode of treatment	Government filarial clinic	0	0	27.27	0	66.67	0	33.33	50	0	0	17.727±23.78
		Private clinic	100	100	72.73	100	33.33	100	66.67	50	100	100	82.273±23.78
4	Betterment of disease	Yes	0	0	20	0	0	25	83.33	50	25	33.33	23.666±25.69
		No	100	100	80	100	100	75	16.67	50	75	0	69.667±34.49

Awareness on disease

In order to evaluate the influence of patient's knowledge on filariasis in the transmission of disease and its management, data has been collected and reported. Results on the awareness on the reason for disease and its management in all the districts under study are depicted in Table 3.5.

The results from all the districts showed that, most of the patients were not aware of the parasite, *Wuchereria bancrofti* as the causative organism of the disease. This has been evidenced by the total ignorance from all the districts except Ponnani of Malappuram where, 12.5% of the patients are aware of the parasite. Most of the victims do not know the role of mosquitoes in the transmission of disease. However, Manacaud of Trivandrum district (60%) has been noticed for higher number of patients who are aware of the means of disease transmission. Significant share of the patients from all the districts even do not know about mosquito larvae. Most of the patients from all the districts were totally unaware about disease management.

The overall results of the patient's awareness on filarial disease revealed that 98.75% (±3.75) of the patients were not aware about the disease causing parasite. A major share of the patients (83.299 ± 18.58) was unaware about the involvement of mosquitoes as the mode of disease transmission. Even 67.023% (± 16.89) of the patients don't know about mosquito larvae. As far as disease management is concerned, 54.295% (± 18.29) of the victims were noticed to be totally unaware.

Table 3.5. Awareness on the reason for disease and its management in all the districts under study

V	Disease awareness		Trivandrum	Kollam	Alleppey	Ernakulam	Thrissur	Palakkad	Malappuram	Kozhikode	Kannur	Kasaragod	Mean with SD
1	Reason/ disease causing parasite	Yes	0	0	0	0	0	0	12.5	0	0	0	1.25±3.8
		No	100	100	100	100	100	100	87.5	100	100	100	98.75±3.8
2	Means of disease transmission	Yes	60	0	9.09	0	30	16.67	32.25	20	0	0	16.801±18.6
		No	40	100	90.91	100	70	83.33	68.75	80	100	100	83.299±18.6
3	Knowledge on mosquitoes larvae	Yes	40	0	27.27	25	30	33.33	37.5	20	50	66.67	32.977±16.9
		No	60	100	72.73	75	70	66.67	62.5	80	50	33.33	67.023±16.9
4	Disease management	Yes	20	0	36.36	25	20	0	50	20	50	33.33	25.469±16.6
		No	40	100	45.45	50	60	66.67	37.5	60	50	33.33	54.295±18.3
		Partial	40	0	18.18	25	20	33.33	12.5	20	0	33.33	20.234±12.8

From the results it can be concluded that, a congested pattern of life style, poor knowledge on disease parasite and vector mosquitoes along with poor disease management has been noticed as the supreme reasons for the endemicity of disease in these regions. Even though all the victims were residing in Pucca type of houses, a congested life resulted in exposure to more unhygienic conditions might have played a crucial role in disease confinement. Mosquito menace was never a concern to them, as most of them were not used to any repellents. The data also revealed that regular medical follow-up has brought down clinical manifestations.

Xenomonitoring of parasites in mosquito vectors

Pre MDA period

The recent report of the district vector control units revealed that, prevalence of filariasis is higher at filariasis at Palakkad and Malappuram districts of Kerala. Seeking any sort of health care can bring down the incidence of filarial disease and its clinical manifestations. The government level Mass Drug Administration on a yearly basis is supposed to reduce the risk of disease occurrence. In pursuit of assessing the effect of such therapeutic practices, a mosquito based study has been conducted at Thirunellai of Palakkad and Ponnani of Malappuram districts of Kerala for the period 2015-16. This is a passive method without obtaining samples from human beings.

The vector mosquitoes, *Culex quinquefasciatus* were collected prior to and after Mass Drug Administration (MDA) from two locations falling in Palakkad and Malappuram districts of Kerala. All the specimens were dissected to find out the occurrence of filarial parasites. Results of the mosquito dissection studies carried out at endemic locations of Palakkad and Malappuram districts during Pre MDA period are depicted in Table 3.6 and Table 3.7 respectively.

Table 3.6. Results of the vector mosquito dissection studies at Palakkad district during Pre MDA period (September 2015 to October 2015).

Site	No. of mosquitoes collected and dissected	Occurrence of parasites		
		No. of parasites observed	**Growth stage of the parasites**	**Body part of mosquito where in parasites observed**
1	20	0	-	-
2	24	1	Microfilaria	Abdomen
3	15	0	-	-
4	19	1	L2 larva	Abdomen
5	15	0	-	-
6	16	1	Microfilaria	Abdomen

Table 3.7. Results of the vector mosquito dissection studies at Malappuram district during Pre MDA period (September 2015 to October 2015).

Site	No. of mosquitoes collected and dissected	Occurrence of parasites		
		No. of parasites observed	**Growth stage of the parasites**	**Body part of mosquito where in parasites observed**
1	16	0	-	-
2	21	1	Microfilaria	Abdomen
3	24	0	-	-
4	14	0	-	-
5	17	0	-	-
6	23	0	-	-

The results revealed that, during Pre MDA period, a total of 109 adult mosquitoes were collected from 6 random sites in Thirunellai of Palakkad district. Of the total mosquitoes collected, 101 were (92.66%) filarial vector, female *Culex quinquefasciatus*. The other species collected were *Armigeres subalbatus* and *Aedes aegypti*. Total man hour density calculated was 13.47. Mosquitoes collected from 3 sites have been noticed for harboring filarial parasites.

A total of 3 filarial worms have been observed in mosquitoes under microscope after dissection (Plate 3.1). The filarial worms observed in mosquitoes from 2 sites were in the microfilaria stages. Positive result reported from the third site was mature larvae in the L2 stage. All parasites have been noticed in the abdomen of mosquitoes. On the basis of occurrence of these parasites, the disease infection and infectivity rates have been calculated and reported. The result showed that, the disease infection rate at the entire location was 2.97%. As, there were no L3 stage of parasite, the infectivity rate was 0.

A total of 115 adult mosquitoes were collected from Ponnani of Malappuram district. Of the collected mosquitoes, 113 (98.26%) were female *Culex quinquefasciatus*. The remaining two specimens were *Aedes aegypti*. The total man hour density calculated was 15.07.

The results revealed that, filarial parasite was present in collected mosquitoes. 1 microfilaria has been noticed in the abdominal region of mosquitoes (Plate 3.1). The disease infection rate was estimated to be 0.88%, indicating the presence of filarial parasites in the community within the study area. The disease infectivity rate at the location was 0.

The overall results revealed that the mosquitoes collected from endemic areas of Palakkad and Malappuram districts during pre MDA period were harboring filarial worms in the stages of microfilaria and L2 larva. All the worms were observed in the abdominal region of mosquitoes. The disease infection rates were estimated to be 2.97% at Palakkad and 0.88% at Malappuram districts. Presence of parasites in the mosquitoes indicated the incidence of filarial infested people along the location.

Post MDA period

During Post MDA period, a total of 97 adult mosquitoes were collected from Thirunellai of Palakkad district. Of the total mosquitoes collected, 94 (96.91%) specimens were female *Culex quinquefasciatus*. Results of the vector mosquito dissection studies at Palakkad and Malappuram districts during Post MDA period are depicted in Table 3.8 and Table 3.9 respectively.

Table 3.8. Results of the vector mosquito dissection studies at Palakkad district during Post MDA period (December 2015 to January 2016).

Site	No. of mosquitoes collected and dissected	Occurrence of parasites		
		No. of parasites observed	Growth stage of the parasites	Body part of mosquito where in parasites observed
1	18	0	-	-
2	15	0	-	-
3	14	0	-	-
4	17	0	-	-
5	17	0	-	-
6	16	0	-	-

Table 3.9. Results of the vector mosquito dissection studies at Malappuram district during Post MDA period (December 2015 to January 2016).

Site	No. of mosquitoes collected and dissected	Occurrence of parasites		
		No. of parasites observed	Growth stage of the parasites	Body part of mosquito where in parasites observed
1	17	0	-	-
2	18	0	-	-
3	18	0	-	-
4	16	0	-	-
5	17	0	-	-
6	20	0	-	-

The results revealed that, no parasites have been present in the vector mosquitoes collected. Of the total 106 adult mosquitoes collected from Ponnani of Malappuram district, 102 specimens (96.23%) were female *Culex quinquefasciatus*. Result of the dissection studies showed that, no mosquitoes were harboring any form of filarial parasites. Both disease infection and infectivity rates of the location were 0.

The overall study revealed that, no parasites were observed in mosquitoes collected from the 2 districts during post MDA period. This indicated that, the MDA program implemented in both the districts were effective in controlling the parasites within the community.

The overall result revealed that, Thirunellai of Palakkad district and Ponnani of Malappuram district have been reported for highest endemicity of filarial diseases. This fact has been established by the result of the present study. The disease infection rates recorded in terms of dissection studies necessitated the campaigning of mass drug administration in the areas. The effectiveness of the program was assessed by xenomonitoring studies during Post MDA period. Absence of parasites in the mosquitoes collected during this period has highlighted the successful implementation of the program in both locations.

The survey results of the present study revealed that, seeking any sort of medical care can bring down the increased prevalence of filarial disease. Lack of awareness of the disease, inadequate knowledge on its management including role of chemotherapy has also been noticed as the reasons for disease incidence. It has also been noticed that, compliance to chemotherapy with DEC and albendazole resulted in the change in clinical status of filarial victims. Thus it can be stated that, MDA with DEC and albendazole is an unavoidable entity as far as the management and elimination of filariasis is concerned. The effectiveness of the program has very well exposed by the present xenomonitoring studies.

Discussion

Lymphatic filariasis commonly known as elephantiasis is a painful and profoundly disfiguring disease that has major social and economic impact in Asia, Africa, Western Pacific and parts of America (Ottesen et al. 1997). Estimation of the socio-economic reasons for the disease is important to understand the extent of burden and to realize the need for compliance and to accept the mitigating strategies. A questionnaire survey has been carried out among the filarial patients residing at endemic locations of 10 districts in

Kerala to have an assessment of their socio-economic and occupational characteristics responsible for disease confinement. This was followed by a xenomonitoring on vectors with respect to the effectiveness of Mass Drug Administration in two districts having higher endemicity of filariasis.

Understanding the gender and age distribution of lymphatic filariasis victims is important in identifying the target group for intervention. Earlier reports revealed that the prevalence of the disease has been noticed to be high among people of age above 40 years (Kazura et al. 1984). The results of the present study have also revealed that most of the victims are falling in the age group 61-75 years (56.547 ± 18). It indicates that, the patients got the infection at the ages of above 40 years and evidences of clinical symptoms have started after 60 years. It has also been noticed that in the present study, males (58.622 ± 8.83) are victims of this pathogen and are remaining as patients. Such pattern of gender specificity of the disease has already been reported by many researchers. Brabin (1990) has reported a lower prevalence of the disease in females than males. Studies from Pondicherry have also reported the same pattern (Das et al. 1992). Gender-specific estimates from Indian sub continent and South East Asia indicated that prevalence of *W. bancrofti* infection and clinical manifestations in males was 10% more than that in females (WHO 1994). The result of the present study has revealed 22.22% higher disease prevalence in males than females and underlines the fact that males are more prone to the disease.

Size of the family is an important determinant of quality of life, especially those in low socio-economic status. Crowded living conditions, housing quality and inadequate waste disposal and sanitation facilities have resulted in an increased prevalence of filariasis (Mak 1986). The results of the present study showed that all the victims are leading a family life and family members are of different age groups. Higher share of their family members are in the age group 21 to 60 years (43.927 ± 5.87) and are mostly males (53.119 ± 8.9). The congested pattern of life might have created low sanitary conditions that resulted in the exposure to mosquito vectors and pathogens. A major share of the victims (93.307 ± 8.57) in the present study does not have family history of filariasis. This indicated the fact that, even within a congested life, family history has no impact on the transmission of diseases.

In the present study, filarial patients had 3 categories of occupations in the pre infection period. The result revealed that, most of them were skilled labourers. Those engaged in fishing and agricultural practices have been noticed as prominent group. Such occupational status might have exposed them to so many unsanitary conditions especially of water. Due to their living and working conditions, they might have been greatly exposed to repeated mosquito bites and thus yielded to infection.

Lymphatic filariasis imposes an economic burden on infected individuals, their households and the communities in which they live. Results of the post infection status of filarial victims revealed that, major share of them are leading a sedentary sort of life and are unemployed. Most of the patients in the present study were suffering from clinical manifestations in the form of swelling on legs. Occupational activities are hampered by affliction of the disease. This has been reported by many researchers (Ramaiah et al. 1997; Dash et al. 1998). Generally, filarial patients are forced to change to a less strenuous occupation due to swelling on the legs (Kumari et al. 2005). Such trends have been reported by the present study. The study as a whole revealed that swelling on legs in the form of lymphoedema has affected the occupation of majority of the victims.

Most of the patients under study are suffering from the disease for the last 11 to 20 years. Longer duration of disease suffering has been noticed in the age group of 61-75 years and shorter duration in 46-60 years. This might be due to various cumulative effects in the affected persons. Similar views have also been reported by Michael et al. (1996). Even though the post infection status of the victims have no effect on the transmission of diseases, such details are useful to manage the disease and to minimize the disease’s negative impacts on future generations. There were no significant relation noticed between incidence of other diseases and filariasis. Depending on the patient's immunity, intermittent occurrence of fever has been noticed among majority of the patients.

In conservative contexts, filarial affected individuals avoid seeking treatment for the fear of drawing attention to their condition (Rauyujin et al. 1995). Studies in India show that 46%-100% of persons with filarial lymphoedema sought treatment from health care centers (Ramaiah et al. 1999). However in the present study, majority of victims are not following any treatment practice. Studies showed that, compliance with a prescribed, simple regime of self-care practices including leg hygiene, exercise and self-examination may bring down the clinical manifestation of the disease (Dreyer et al. 2000). Studies have also been carried out to explain the role of health care measure on disease management (Kanda 2004). Because of distance to health facilities and the physical strain and pain associated with swelling, many patients do not seek treatment outside their home. Failure to treat the disease results in recurrent acute febrile attacks and progressive damage to the lymphatic system (Dreyer et al. 1999). A major share of the patients is depending on private clinics for the treatment rather than any government facility. In the present study, victims seeking government filarial units have been found to get more cure than those depending private clinics.

Awareness on disease got utmost importance in minimizing mosquito contact for preventing infection (Evans et al. 1993). Earlier studies reported from Kerala have shown that most of the patients residing at Shertallai taluk are well aware of the cause of the disease and its control measures (Chandrasekharan et al. 1979). However, data pertaining to patient's awareness on filarial disease in the present study revealed that most of them were not aware about the disease causing parasite. A major share of the patients was unaware about the role of mosquitoes as the mode of disease transmission. Such a trend has also been reported by many researchers (Wynd 2007; Ahorlu et al. 1999; Carme et al. 1979). Significant percentage of the patients in the present study doesn't know about mosquito larvae. As far as disease management concerned, most of the victims were noticed to be totally unaware. This might have resulted in the infrequent use of mosquito net and repellents by the victims during pre-infection stage. It has also been noticed that mosquito breeding sites were poorly controlled towards the control of disease control.

Thus from all the results it can be concluded that, a congested pattern of life style, poor knowledge on disease parasite and vector mosquitoes along with poor disease management has been noticed as the supreme reason for the disease endemicity. Results of the study has confirmed that, successful control of disease, community wide awareness, understanding and support are inevitable. To attain community participation and develop socially acceptable control strategies, people’s knowledge, beliefs and their perception towards the disease are also very essential.

The government level Mass Drug Administration (MDA) on a yearly basis is supposed to reduce the risk of filarial disease. Xenomonitoring of parasites within the mosquito vectors helps to decide whether to continue or stop MDA and for assessing the success and progress of elimination programs. In pursuit of assessing the effect of such therapeutic practices, a mosquito based study has been conducted at Thirunellai of Palakkad and Ponnani of Malappuram districts of Kerala state.

The result of the study during Pre MDA period revealed that, the filarial vector *Culex quinquefasciatus* collected from both district were harboring filarial parasites. The infection rates were estimated to be 2.97% and 0.88% in Palakkad and Malappuram districts respectively. As per WHO, when the infection rate goes beyond 1%, such locations should be treated as endemic (WHO 1999). Thirunellai of Palakkad district has been noticed for disease infection rate of 2.97% signifying the presence of filarial parasites within the community.

The government level monitoring have also reported a higher endemicity rate along these locations. On such background, MDA program have successfully initiated and completed at both locations. No parasites were observed in mosquitoes collected from the two districts during post MDA period. This indicated that, the MDA program implemented in both districts were effective to eliminate the filarial parasites within the people and thereby in mosquitoes.

Di Ethylcarbamazine Citrate (DEC) is an effective microfilaricide widely used in the treatment of lymphatic filariasis. An important drawback of chemotherapy with DEC is the associated side effects in microfilanae carriers during therapy. The adverse reactions of DEC limit its total acceptance by the population. But in the present study, the results showed that the MDA program implemented with DEC has been completely accepted by the population. This might have lead to complete elimination of filarial worms in the community and in mosquitoes.

Summary and Conclusion

Lymphatic filariasis (LF) is an important public health and socio-economic problem worldwide. Various socio-economic and cultural factors are known to be responsible for the prevalence and endemicity of lymphatic filariasis. Community participation is treated as a prerequisite for successful filarial disease control programs, which is moreover based on integrated vector control.

A survey has been carried out to assess the demographic characteristics of filarial victims from all the 10 districts of Kerala for the period 2015-16. The survey revealed that most the victims are falling in the age group 61-75 years (56.547 ± 18). It is also noticed that mostly male (58.622 ± 8.83) are victims of this pathogen and are remaining as patients. Higher share of their family members are in the age group 21 to 60 years (43.927 ± 5.87) and are mostly male (53.119 ± 8.9). A major share of the victims (93.307 ± 8.57) does not have family history of filariasis.

An inquiry into the pre infection history of patients revealed that 95.883% (± 8.53) of people are residents and have not migrated from any place. 69.042% (± 23.54) of people were skilled labourers in the pre infection stage. 87.383% (± 11.74) people were living in pucca type of houses. 59.663 % (± 29.88) of people does not have other diseases and 81.614% (± 16.11) of them were not in the habit of using mosquito repellents or nets in routine life.

Details on the post infection status of filarial patients revealed that major share of them (77.045 ± 17.27) are leading a sedentary sort of life and are unemployed. 97.917 % (± 3.23) of the victims are suffering from clinical manifestations in the form of swelling on legs. Intermittent occurrence of fever was experienced by 58.989% (± 21.87). Secondary infections were noticed to be prominent among 50.795 % (±24.49) of victims. After getting filarial disease, majority of the patients (80.531±19.62) were not suffering from any other diseases.

Details of patients with respect to medical attention reveal that majority of them (58.72 ± 13.64) are not following any treatment practice. A major share (82.273 ± 23.78) of the patients is depending on private clinics for the treatment rather than any government facility. Among the victims seeking medical attention, 69.667 % (± 34.49) has not attained any cure.

Data pertaining to patient’s awareness on filarial disease revealed that 98.75% (±3.75) of the patients were not aware about the disease causing parasite. A major share of the patients (83.299 ± 18.58) was unaware about the involvement of mosquitoes as the mode of disease transmission. Even 67.023% (± 16.89) of the patients are unaware about mosquito larvae. As far as disease management concerned, 54.295% (± 18.29) of the victims were noticed to be totally unaware.

From the results it can be concluded that, a congested pattern of life style, poor knowledge on disease parasite and vector mosquitoes along with poor disease management has been noticed as the supreme reason for the disease endemicity. Even though all the victims were residing in Pucca type of houses, a congested life resulted in exposure to more unhygienic conditions might have played a crucial role in disease confinement. Mosquito menace was never a concern to them, as most of them were not used to any repellents. The data also revealed that regular medical follow-up has brought down clinical manifestations. Though several significant improvements in the tools to control this disease have become available, successful control of lymphatic filariasis depends on community wide awareness, understanding and support. Therefore, in order to attain community participation and develop socially acceptable control strategies, people's knowledge, beliefs and their perception towards the disease are very essential.

Seeking any sort of health care measure can bring down the incidence of filarial disease and its clinical manifestations. The government level Mass Drug Administration on a yearly basis is supposed to reduce the risk of disease occurrence. In pursuit of assessing the effect of such therapeutic practices, a mosquito based study has been conducted at two district of Kerala for the period 2015-16. This is a passive method without obtaining samples from human beings.

The vector mosquito, *Culex quinquefasciatus* were collected prior to and after Mass Drug Administration (MDA) from two locations falling in Palakkad and Malappuram districts of Kerala. All the specimens were dissected to find out the occurrence of filarial parasites.

The results revealed that the mosquitoes collected from the endemic areas of Palakkad and Malappuram districts during pre MDA period were harboring filarial worms in the stages of microfilaria. All the worms were observed in the abdominal region of mosquitoes. The disease infection rates were estimated to be 2.97% in Palakkad and 0.88% in Malappuram districts. Presence of parasites in the mosquitoes indicated the incidence of filarial infested people along the location. No parasites were observed in mosquitoes collected from the two districts during post MDA period. This indicated that the MDA program implemented at both districts were effective to eliminate the filarial parasites within the people and thus within mosquitoes. The results showed that the MDA program implemented with DEC has been completely accepted by the population. This might have lead to complete elimination of filarial worms in the community and in mosquitoes.

The overall results showed that lack of adequate knowledge on disease, its transmission and management strategies have been noticed as the major reasons for the persistence of the disease along different locations under study. Non compliance of health care measures like MDA has noted to be a major reason for disease persistence.

GENERAL CONCLUSION

From all the results it can be stated that heterogeneous types of water sources are present at all the filarial endemic areas. Selected water quality parameters with optimum ranges have enabled the proliferation of mosquito vectors. The number and area of sewerage system were also noticed to higher and a significant percentage of such systems were open type. This might have been the reason for enhanced emergence of filarial vector *Culex quinquefasciatus* along all the locations under study. The area of total water sources, area and openness of sewerage systems and abundance of *Culex quinquefasciatus* were noted to be positively correlated with number of mf cases. These three factors along with the lack of adequate knowledge on diseases, its transmission and management strategies have been noticed as the major reasons for the persistence of the disease along different locations under study. Noncompliance of health care measures like MDA has noted to be a major reason for disease persistence.

The overall results showed that lack of adequate knowledge on disease, its transmission and management strategies have been noticed as the major reasons for the persistence of the disease along different locations under study. Non compliance of health care measures like MDA has noted to be a major reason for disease persistence.

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