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Study on mosquito (Diptera: Culicidae) diversity in Ernakulam district of The Kerala state, South India

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Abstract
The present study was conducted to know the diversity of mosquito species in Ernakulam district of Kerala state. The study was undertaken for a period of 11 months (October 2017 to August 2018). Larvae and adults mosquito survey were carried out to generate information on the current mosquito species diversity in the district. 26 species of mosquitoes belonging to 6 genera was recorded in the study namely, *Anopheles*, *Culex*, *Aedes*, *Mansonia*, *Armigeres* and *Toxorhynchites*. *Anopheles* (11) was the dominant genus followed by *Culex* (6), *Aedes* (5), *Mansonia* (2), *Armigeres* (1), and *Toxorhynchites* (*1*) respectively. *Ae. albopictus*, *Cx. tritaeniorhynchus*, *Cx. gelidus*, *Cx. quinquefasciatus* and *Mn. uniformis* were found throughout the study period. Vectors of malaria, dengue, chikungunya, Japanese encephalitis and filariasis were recorded in the present study.

Keywords: Mosquito fauna, *Anopheles*, *Aedes*, *Culex*, vector diversity, Ernakulam, Kerala

1. Introduction
Mosquitoes belonging to the family Culicidae of the order Diptera are considered as the most important vectors for the transmission of various protozoan and viral pathogens which effects human and animal health [1, 2]. The diversity of mosquito fauna and rate of transmission of mosquito borne diseases can be altered significantly by the influence of global changes such as change in climate, land use, population movements and urbanization [3]. Understanding the diversity and faunal richness in the area is essential for an effective and efficient mosquito control program by the local authorities. The diversity and abundance of mosquito species is influenced directly by the environmental and ecological changes in the area. Vector borne diseases are one of the major public health problems challenging the health systems of Kerala. The rapid urbanization has resulted in altering factors affecting the vector fauna of the state. Ernakulam district being the commercial capital of Kerala hosts the highest number of international and domestic tourists in the state. An effective vector surveillance and control programs is vital in preventing outbreaks of vector borne disease such as Malaria, Filariasis, Dengue, Japanese encephalitis and Chikungunya [4]. Information on the mosquito fauna of Ernakulam district of Kerala is scantly recorded. Being the commercial capital of Kerala, Ernakulam district hosts the highest number of international and domestic tourists in the state. The district is surrounded by Thrissur District to the north, Coimbatore District of Tamil Nadu to the north-east, Idukki District to the east, Alappuzha and Kottayam districts to the south and Lakshadweep Sea to west. Owing to the international airport, water ways, railways, and road ways, Ernakulam is one of the most strategically connected districts in the state. The study area is an important cultural, educational and commercial centre comprised of various types of human settlement and varying number of cattle and other animals that favors the mosquito population. The diversity among the mosquito species gives an insight on the density of vector species during the peak seasons and this understanding helps the authorities in instigating better prevention and control strategies to prevent the outbreak of diseases in the area [5]. These studies can help in understanding the diversity and distribution of vector species in the area. The present study was undertaken to understand the current status on the distribution and species diversity of vector mosquitoes in Ernakulam district.

2. Materials and methods

2.1 Study area

The present study was carried out at Ernakulam a district of Kerala state, India situated in the central part of that state. Spanning an area of about 3,068 km^2 located on the Western Coastal Plains of India and home to over 12% of Kerala's population. The district can be divided geographically into highland, midland and coastal area. The district has a moderate climate, and mostly falls within the Malabar Coast moist forests ecoregion, while the highlands are part of the South Western Ghats moist deciduous forests ecoregion.

2.2 Study Period

The study was carried out for the period of 11 months from October 2017 to August 2018. The survey sites were selected with an intention to cover entire topography of the district. The study sites comprised of various types of human settlement and varying number of cattle and other animals that favors the mosquito population.

2.3 Mosquito collection

Different methods were employed to collect the mosquitoes during the survey. The habitats sampled include containers, stagnant pools, discarded tires, rock pools, domestic runoffs and tree holes etc. Habitat evaluation method as described by Service M W (1993) was adopted in collecting the larvae from different habitats [6]. These were then transferred to plastic vials for their transportation to the laboratory for identification. The adult mosquitoes were collected with the help of suction tube and sweep net. Biting adult female mosquito collections were carried out at dawn (06:00-08:30) and dusk (18:30-21:30) hours from human dwellings and cattle sheds using a suction tube and torch light [7]. All the sampling sites were visited periodically to record the diversity of mosquitoes.

2.4 Identification of Mosquito Species

The collected larvae and pupae were kept in the laboratory for adult emergence. The wild caught mosquitoes and emerged adults were morphologically identified to species level by the Entomology Consultant in Zonal Entomology Unit Ernakulam, Kerala, using standard key and catalogues [8, 9, 10].

2.5 Biodiversity Index

The degree of biodiversity was evaluated by estimating the mosquito diversity using alpha diversity or species richness index [11]. The following formula was adopted in the analysis [12].

$$\alpha = 1 - \sum \left(\frac{X1}{t}\right)^2 + \left(\frac{X2}{t}\right)^2 + \cdots + \left(\frac{Xn}{t}\right)^2$$

Where,
α = Species richness index
t = Total number of mosquitoes of all species
X = Number of each species

3. Results and Discussion

The present study recorded a diversity of 26 species of mosquitoes belonging to 6 genera namely *Aedes*, *Anopheles*, *Armigeres*, *Culex Mansonia and Toxorhynchites*. *Aedes* genus was represented by 5 species belonging to 3 subgenera; *Aedimorphus*, *Stegomyia*, *Fredwardsius.* The genera anopheles was predominant of all the genera with 11 species belonging to two subgenera *Anopheles* and *Cellia*. The genus *Culex* was represented by 6 species in single subgenera *Culex.* In the present study genus *Armigeres and Toxorhynchites* was represented by single species each. Of the 26 species recorded in the study the team could identify larval breeding habitats of 13 species whereas other species were obtained only as adults. Both the species of Mansonia namely *Mansonia annulifera* and *Mansonia uniformis* were found only as adults. Even though the adult density of the species was higher in the area, larval survey on the waterbodies with water plants could not yield any larvae of Mansonia species. *Aedes albopictus*, *Culex quinquefasciatus* and *Aedes aegypti* were the predominant vector species in the dawn collection. Blood fed females of these species were collected from human dwellings during the study period. *Anopheles karwari* and *Anopheles tessellatus* were found in higher densities in hilly and forest fringe areas of the study areas. *Anopheles vagus* and *Anopheles subpictus* were present throughout the costal belt of Ernakulam district. *Anopheles karwari* was found breeding in rock pools near forest fringe areas during the survey. Arboviral vector *Aedes albopictus* was found throughout the study area in higher density than *Aedes aegypti*, breeding in almost all types of fresh water holding containers. Polythene sheets were a major source of *Aedes albopictus* breeding the rural areas of the study area. *Aedes albopictus* was dominant than *Aedes aegypti* in rural areas of the study areas whereas *Aedes aegypti* was present in considerable higher densities in urban areas. Plastic containers were the predominant breeding habitat found in the study (Table 1).

The species collected during the study are all of potential medical importance. Major vectors for diseases such as Dengue, chikungunya, malaria, Japanese encephalitis and filariasis were identified from the study sites. *Aedes albopictus* potential vector for dengue [13] and chikungunya [14], *Cx. tritaeniorhynchus*, *Cx. gelidus* vectors for Japanese encephalitis [15,16] *Cx. quinquefasciatus* vector for Bancroftian and *Mn. uniformis* vector for Japanese encephalitis [17] and brugian filariasis was found throughout the study period. The presence of urban malaria vector *Anopheles stephensi* during the months of April, May, July August 2018 is a potential risk of malaria transmission in the area [9].

The changes in the local ecosystems and microclimatic conditions results in the altered preference of mosquito species in their breeding and feeding behaviors [18].*Anopheles stephensi* was found to be breeding of in plastic containers as reported in previous studies [19, 20]. *Anopheles stephensi* represented 0.75% of the total anopheline female mosquitoes collected in the study whereas *Anopheles vagus* was the most represented species with 26% of total anopheline females. *Culex gelidus* (21.5%) was predominant among all the species collected in the study which plays as secondary vector for Japanese encephalitis virus [21, 22] The cohabitation of *Aedes albopictus* and *Aedes aegypti* was seen in the urban environments whereas the rural breeding habitats favor the breeding of *Aedes albopictus* and resulted in the exclusion of *Aedes aegypti* as described in other previous studies [23].

In the present study the species richness was found to be high during the month of April 2018 (16 species) followed by July (15 species), January and March 2018 with 14 species each. Moderate species richness was found during the months of October 2017 (11 species), December 2017, (10 species),

February 2018 (13 species), May 2018(13 species), and August 2018(11 species). Minimum number of species was recorded during the month of November 2017 and June 2018 with 7 species each (Table 2).

Understanding the dynamics of mosquito population in the area can delivers substantial evidence for assessing the potential risk for a probable outbreak of vector borne diseases [6, 24]. Previous studies on the relationship between the species diversity and disease risk [25] suggest that the potential for transmission of diseases is higher with lower biodiversity [26]. Suggesting that higher biodiversity can reduce the risk of vector borne disease in human population [27].

The study area had a diverse mosquito profile with 26 species of mosquitoes. *Aedes aegypti* dominance in the urban areas possesses a threat for outbreak of dengue fever in the urban areas. *Anopheles stephensi* was identified from urban and rural areas of the study area; breeding in diverse habitats including plastic containers, water tanks and polythene sheets shows its adaptation to proliferate in these areas. This increase in the distribution of *Anopheles stephensi* supports the indigenous transmission of malaria in the area where they can acquire parasite from the migrant works that comes from malaria endemic areas of the country. The need for surveillance of migrant workers for malaria parasite is inevitable to prevent local transmission of the disease. Faster rate of emergence and reemergence of infectious diseases with decline in biodiversity can change the epidemiology of the transmission of vector borne diseases in the area. The biodiversity index was higher (0.86) during the month of January and August 2018. Followed by 0.83 in April (2018) and 0.81 during November (2017), February (2018), March (2018) and June (2018). Lowest biodiversity was observed in October (2017) with 0.76.

Change in the land use pattern, deforestation and rapid urbanization results in the proliferation of vector species thereby promoting infectious diseases transmission [28, 29]. The changes in the environments due to human activities are of importance to health authorities since the risk of diseases transmission is altered by these activities. It's high time to monitor these changes and its impact on potential diseases transmission. Furthermore, it is crucial to monitor the establishment and distribution of these species in the district, in order to design and implement interventions targeting to control of vector borne diseases. The present study showed that the greatest diversity of mosquitoes occurs in the district's rural area, whereas diversity is relatively low in its urban area. The difference in the distribution of mosquito species during the study period may be influenced by various environmental factors in the area. Studies on the ecological and environmental factors can contribute to a better understanding on the distribution and diversity of vector species in the area. These finding serve as a warning to local health authorities to initiate better surveillance of vector species to prevent their proliferation and introduction of disease in the human population.

Table 1: Diversity of mosquito species recorded in study area (Ernakulam district) during the study period (October 2017 - August 2018)

S. No	Species	Types Of Habitats Positive For Larval Breeding										
		PC	TY	OHT	GLT	PS	GP	RP	MP	TH	WL	AOC
1	*Ae.* (*Stegomyia*) *aegypti* (*Linnaeus,1762*)	+	+	-	+	+	-	-	+	-	-	*
2	*Ae.*(*Stg.*) *albopictus* (*Skuse,1894*)	+	+	+	+	+	-	-	+	+	-	*
3	*Aedes* (*Aedimorphus*) *pipersalatus* (*Giles, 1901*)	-	-	-	-	-	-	-	-	-	-	+
4	*Aedes* (*Aedimorphus*) *vexans* (*Meigen,1830*)	-	-	-	-	-	-	-	-	-	-	+
5	*Ae.* (*Fredwardsius*) *vittatus* (*Bigot,1861*)	+	-	-	-	-	-	-	-	-	-	*
6	*Anopheles* (*Anopheles*) *barbirostris* (*Van der Wulp,1984*)	-	-	-	-	-	-	-	-	-	-	+
7	*An.* (*Ano.*) *gigas* (*Giles, 1901*)	-	-	-	-	-	-	-	-	-	-	+
8	*An.* (*An.*) *nigerrimus* (*Giles,1900*)	-	-	-	-	-	-	-	-	-	-	+
9	*An.* (*Ano.*) *sinensis* (*Wiedmann, 1828*)	-	-	-	-	-	-	-	-	-	-	+
10	*An.*(*Cellia*) *jamesii* (*Theobald, 1901*)	-	-	-	-	-	-	-	-	-	-	+
11	*An.* (*Cel.*) *karwari* (*James, 1902*)	-	-	-	-	-	-	+	-	-	-	*
12	*An.* (*Cel.*) *kochi* (*Doenitz, 1901*)	-	-	-	-	-	-	-	-	-	-	+
13	*An.* (*Cel.*) *stephensi* (*Liston,1901*)	+	-	+	+	+	-	-	-	-	-	*
14	*An.* (*Cel.*) *subpictus* (*Grassi,1899*)	-	-	-	-	-	-	-	-	-	-	+
15	*Anopheles* (*Cel.*) *tessellatus* (*Theobald, 1901*)	-	-	-	-	-	-	-	-	-	-	+
16	*An.* (*Cel.*) *vagus* (*Doenitz,1902*)	-	-	-	-	-	-	-	-	-	-	+
17	*Armigeres* (*Armigeres*) *subalbatus* (*Coquillett,1898*)	+	+	-	-	-	-	-	+	+	-	*
18	*Culex* (*Culex*) *bitaeniorhynchus* (*Giles,1901*)	-	-	-	-	-	-	-	-	-	-	*
19	*Cx.* (*Cx.*) *fuscocephala* (*Theobald,1907*)	+	-	-	+	-	+	-	-	-	-	*
20	*Cx.*(*Cx.*) *gelidus* (*Theobald,1901*)	-	-	-	-	-	+	-	-	-	-	*
21	*Cx.*(*Cx.*) *quinquefasciatus* (*Say,1823*)	+	-	-	-	-	+	-	+	-	+	*
22	*Cx.*(*Cx.*) *sitiens* (*Wiedemann,1828*)	-	-	-	-	-	+	-	-	-	-	*
23	*Cx.*(*Cx.*) *tritaeniorhynchus* (*Giles,1901*)	-	-	-	+	-	+	-	-	-	+	*
24	*Mansonia* (*Mansonioides*) *annulifera* (*Theobald,1901*)	-	-	-	-	-	-	-	-	-	-	+
25	*Ma.* (*Man.*) *uniformis* (*Theobald,1901*)	-	-	-	-	-	-	-	-	-	-	+
26	*Tx.* (*Toxorhynchites*) *splendens* (*Wiedemann,1819*)	+	+	-	-	-	-	-	-	-	-	*

+ = Present, - = Absent, * = Both Larvae and Adult

PC- Plastic Containers, TY- Tyre, OHT- Overhead Tank, GLT-Ground Level Tank, PS- Polythene sheet, GP- Ground Pools, RP-Rock Pools, MP- Mud Pot, TH-Tree Hole, WL- Well, and AOC- Adult Only Catch

4. Conclusions

The current study provides information about diversity of mosquito species in the district of Ernakulam of Kerala state. The biodiversity index was higher (0.86) during the month of

January 2018 and August 2018. 26 species belonging to 6 genera have been recorded in the present study. The mosquito faunal richness and presence of vectors of dengue, chikungunya, malaria Japanese encephalitis and filariasis in district suggests that the vector surveillance should be intensified to prevent vector borne disease outbreaks in the district. The current study was carried out only in selected areas of the district and recommend further studies to be carried out in order to explore the remaining areas of district for a detailed checklist of mosquito composition.

Table 2: Monthly variation in the diversity of adult mosquitoes recorded in study area (Ernakulam District) during the study period (October 2017- August 2018)

S. No.	Species Name	Species Diversity											Total
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
1	*Aedes aegypti*	0	0	0	0	0	2	0	0	0	0	0	2
2	*Aedes albopictus*	20	5	6	1	1	2	7	1	2	9	2	56
3	*Aedes pipersalatus*	0	0	0	0	0	6	0	0	0	0	0	6
4	*Aedes vexans*	0	0	0	7	0	1	4	0	0	0	0	12
5	*Aedes vittatus*	0	0	2	0	0	0	2	1	0	0	0	5
6	*Anopheles barbirostris*	4	0	50	114	27	9	5	0	0	0	23	232
7	*Anopheles gigas*	0	0	0	0	0	0	0	0	0	4	0	4
8	*Anopheles jamesii*	0	6	9	38	19	0	7	3	0	4	0	86
9	*Anopheles karwari*	0	0	0	8	8	0	0	0	0	0	0	16
10	*Anopheles kochi*	0	0	0	0	3	0	0	0	0	0	0	3
11	*Anopheles nigerrimus*	4	0	0	79	6	0	0	0	0	0	32	121
12	*Anopheles sinensis*	0	0	0	0	0	0	0	0	0	2	0	2
13	*Anopheles stephensi*	0	0	0	0	0	0	2	3	0	1	4	10
14	*Anopheles subpictus*	0	0	161	6	0	38	36	37	16	4	18	316
15	*Anopheles tessellatus*	0	0	0	22	159	0	0	8	0	0	0	189
16	*Anopheles vagus*	9	0	0	58	29	242	19	0	0	3	0	360
17	*Armigeres subalbatus*	18	27	38	70	17	98	92	24	9	24	29	446
18	*Culex bitaeniorhynchus*	0	0	0	0	0	5	13	39	0	15	13	85
19	*Culex fuscocephala*	0	0	0	0	0	0	8	0	0	0	0	8
20	*Culex gelidus*	170	34	79	86	202	55	126	124	26	87	52	1041
21	*Culex quinquefasciatus*	6	28	18	41	33	102	7	12	8	7	2	264
22	*Culex sitiens*	85	0	0	0	0	39	106	22	0	10	0	262
23	*Culex tritaeniorhynchus*	22	53	125	213	79	98	37	61	23	52	27	790
24	*Mansonia annulifera*	4	0	0	0	0	0	0	0	0	0	0	4
25	*Mansonia uniformis*	127	43	22	61	88	6	5	3	12	92	48	507
26	*Toxorhynchites splendens*	0	0	0	0	0	0	0	0	0	2	0	2
Total Number Of Individuals		469	196	510	804	671	703	476	338	96	316	250	4829
Species Richness		11	7	10	14	13	14	16	13	7	15	11	
Biodiversity Index		0.76	0.81	0.80	0.86	0.81	0.81	0.83	0.80	0.81	0.80	0.86	

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