



A survey on diversity and distribution of mosquitoes in Dharwad district, Karnataka, India

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Abstract

Mosquitoes are vectors of etiological agents of several illnesses that affect human beings as well as other vertebrates. Mosquito-borne diseases like Japanese encephalitis, Malaria, Lymphatic filariasis, and Dengue are prevalent in Karnataka, India. The present study is aimed at surveying the diversity and distribution of mosquito vectors in the Dharwad district of Karnataka state, India from Oct, 2017 to Oct, 2022. Random sampling was done so as to collect mosquito samples from temporary/permanent, natural/artificial water bodies in five different regions (Rural, Semi-urban, Urban, Agricultural Land and Forest) in the Dharwad district. A total number of 2658 mosquitoes belonging to 4 genera namely *Culex*, *Anopheles*, *Aedes* and *Mansonia* were collected during the study period. The genera *Culex*, *Aedes* and *Anopheles* mosquito species are predominant in Dharwad district, which suggests the presence and occurrence of much more illness. The diversity indices like Shannon diversity index, Simpson's diversity index, Simpson's reciprocal index and Shannon evenness index have been calculated and the results clearly indicate that the species richness and abundance of mosquito species in the study areas. The knowledge of the breeding environments of mosquitoes will be useful for developing a mosquito vector control plan and increased efforts should be undertaken to raise public awareness and also by taking precautions against illnesses spread by these mosquito vectors.

Keywords: Diversity, distribution, Dharwad district, mosquito vector and survey

Introduction

Mosquitoes are a group of insects belong to the family Culicidae, Order-Diptera with a global distribution that live in both temperate and tropical climates and even up to the Arctic Circle [1, 2]. Along with the Neotropics, the Oriental section, which includes India is recognized as one of the richest biogeographic areas in the globe for mosquitoes [3]. Mosquitoes reproduce in a variety of environments, including marshes, drains, ponds, water containers, pools, ditches, including the tree holes with comparable water accumulations. Different mosquito genera have their own unique breeding preferences [4, 5]. Changes in the seasonal temperature, climate and density dependent patterns have a significant impact on mosquito diversity and abundance [6-8]. The risk of contracting vector-borne diseases (VBDs) may be affected by climate change and human activities, with or without corresponding changes on mosquito abundance and their diversity [9-13].

Besides the widespread distribution of mosquitoes, they are also notable for their diverse habitat. Now there are 3,540 identified mosquito species worldwide, which are split across two subfamilies and 112 genera [14]. *Anopheles stephensi*, the main mosquito species that transmits Malaria in urban areas of India, belongs to the same subgenus as *Anopheles gambiae*, which is the dominant mosquito vector, transmits Malaria in that continent [15]. Both Filariasis and Japanese Encephalitis (JE) are transmitted by *Culex species*. The genus *Aedes* mosquitoes, which were once common in sub-tropical and tropical areas, are now found worldwide, with the exception of Antarctica. Dengue, Zika, and Haemorrhagic fever are all spread by the species of the subgenus *Stegomyia*, as well as by *Aedes albopictus* and *Aedes aegypti* [16].

Studies on the diversity and distribution of mosquitoes may be very helpful in understanding the intricate relationship among the environment and risks to human health. The variety of mosquito species in the Pushpagiri Wildlife Sanctuary was studied by Krishna (2021) from June, 2018 to May, 2019. Surveys on mosquito variation were conducted throughout the post-monsoon (Oct to Jan), monsoon (June to Sept), and summer (Feb to May) seasons. With the use of a dipper, mosquito adults and larvae were removed from a variety of water sources at more than twenty different locations across the wildlife refuge. A total of 25 mosquito spp. from six genera were identified, out of these, *Culex* were dominant with ten species followed by *Anopheles* seven species, *Aedes* four species, *Ochlerotatus* three species as well as *Uranotaenia* one species were recorded [17]. Chatterjee et al., (1988) reported that *Culex* and *Aedes* mosquitoes mostly favoured rainwater for reproduction during winter and post-winter [18]. A knowledge, attitude, and practice (KAP) study were conducted by Kumar and Gururaj (2006) in a rural and urban areas of Karnataka, India with the aim to investigate the level of knowledge of mosquitoes and the perceived risk of infectious diseases that are spread by mosquitoes among the community. The primary illness that mosquitoes spread was formerly known to be only Malaria. Now, more than 75% of people were taking personal precautions against mosquito bites [19].

In Karnataka, mosquito-borne illnesses are frequent and are dominant over other diseases. According to the "National Institute of Malaria Research", the three principal mosquito species present in the Dharwad district of Karnataka are *Culex quinquefasciatus*, *Anopheles stephensi* and *Aedes aegypti*. Many cases of Dengue, Lymphatic filariasis, Malaria, and Chikungunya are often recorded

from this region. Therefore, it is necessary to survey such mosquito vectors, which are detrimental to humans and their domestic animals. Hence, the present study is aimed to understand the variety and distribution of mosquito vector species in the Dharwad district of Karnataka state, India.

Materials and Methods

Study area and climatic conditions

The research was conducted in several geographic regions of Dharwad district. The district is located between “the latitudes of 15°02' and 15°51' North” and “the longitudes of 73°43' and 75°35' East” with 4263 km² in size. The district is located above 800 MSL with moderate climatic conditions. The Malnad, the Semi-Malnad, and the Maidan are the three natural zones of this district, typically contain lush vegetation, moderate to high rainfall, usually the taluka's such as Kalghatagi and Alnavar receives higher rainfall than that of other talukas in the district. The research was conducted in different regions of Dharwad district namely, Rural, Semi-urban, Urban, Agricultural land and Forest.

Collection of Mosquitoes

Mosquitoes were captured randomly by using mosquito traps, suction pumps, dippers, mouth and mechanical aspirators in various temporary/ permanent microhabitats, artificial/ natural water bodies, agricultural field's dump from Oct-2017 to Oct-2022. Over the period of six-years research, mosquito traps were positioned around 5 meters away from homes in the district for twenty-four hours (from 6:00 am to 6:00 am of the next day). This allowed for the collection of both daytime and nocturnal mosquito vectors. Early in the morning around 6:00 am, mosquito samples were taken from each trap and used for morphological identification. Similarly, mosquito larvae were also collected from the natural/artificial breeding grounds such as tree holes, coconut shells, tyres, overhead tanks and other stagnant water bodies. Adult mosquitoes were captured using mechanical and oral aspirators, then killed in lethal chambers by using “triethylamine” vapours.

Identification of mosquitoes

The collected larvae and pupae were raised to adult stages while being stored with the corresponding immature exuviae in cylindrical containers made up of plastic and filled with the same water as the native habitats of the larvae. The taxonomic ideas and keys of Clark-Gil and Darsie (1983) [20], Sirivanakarn (1982) [21], Burkett-Cadena (2013) [22], Darsie and Ward (2005) [23] and other taxonomic literature were used to identify the mosquito species.

Data analysis

Data analysis of the results was done with the help of the following diversity indices.

a. Shannon Wiener Diversity Index (H') = $-\sum [P_i \times \ln (P_i)]$

Where,

H' = Shannon Wiener Diversity Index.

\sum = Summation.

P_i = Proportion of ith species individuals in the entire community.

n_i = Number of individuals in a species.

N = Number of total individuals of all species in the community.

b. Shannon Evenness Index (E)

E = H' / H'_{max}

Where

H'_{max} = Highest value of Shannon Index of the different community/groups.

H = Shannon Diversity Index.

c. Simpson's Index (D): $D = \sum (n_i/N)^2$

Where,

D = Simpson's Index.

\sum = Summation.

n_i = Number of individuals of ith species.

N = Total number of individuals in the community.

d. Simpson's Reciprocal Index = 1-D.

Results

During the course of the study, a total of 2450 mosquitoes were collected and identified. 22 different species belonging to four genera (*Culex*, *Aedes*, *Anopheles*, and *Mansonia*). Out of which 10 species belonging to the genus *Culex*, 6 species belonging to the genus *Aedes*, 5 species belonging to the genus *Anopheles* and 1 species belonging to the genus *Mansonia* (Table-1).

Table-1 shows that, *Cx. quinquefasciatus* (0.1113%) was the leading species in the entire survey of the Dharwad district followed by *Ae. Aegypti* (0.0935%) and *An. Stephensi* (0.0875%). As per the record the overall mosquito population was more at urban region followed by semi-urban and rural areas in the Dharwad district.

Table 1: Names and numbers of mosquito species collected during field study and their percentage (Pi) during the study period (Oct-2017 to Oct-2022)

S. No.	Name of the genus	Name of the species	Number of mosquitoes collected (N)	Percentage (%) (Pi)
	<i>Culex</i>	1. <i>Culex quinquefasciatus</i>	293	0.1113
		2. <i>Culex tritaeniorhynchus</i>	143	0.0537
		3. <i>Culex vishnui</i>	98	0.0368
		4. <i>Culex mimulus</i>	149	0.0559
		5. <i>Culex lutzia</i>	72	0.027
		6. <i>Culex erraticus</i>	96	0.036
		7. <i>Culex territans</i>	129	0.0484
		8. <i>Culex pipiens</i>	113	0.0424
		9. <i>Culex nigripalpus</i>	128	0.0481
		10. <i>Culex restuans</i>	28	0.0105
	<i>Aedes</i>	1. <i>Aedes albopictus</i>	178	0.0668
		2. <i>Aedes aegypti</i>	249	0.0935

		3. <i>Aedes sollicitans</i>	118	0.0443
		4. <i>Aedes vexans</i>	23	0.0086
		5. <i>Aedes vittatus</i>	47	0.0176
		6. <i>Aedes stokesi</i>	43	0.0161
	<i>Anopheles</i>	1. <i>Anopheles subpictus</i>	169	0.0635
		2. <i>Anopheles culiciformis</i>	89	0.0334
		3. <i>Anopheles stephensi</i>	233	0.0875
		4. <i>Anopheles maculipennis</i>	132	0.0496
		5. <i>Anopheles minimus</i>	86	0.0323
	<i>Mansonia</i>	1. <i>Mansonia indiana</i>	42	0.0157

Both natural and manmade mosquito breeding sites like Plastic containers, Stagnant pools, abandoned tyres, Tree holes, Cattle shed, Coconut shell, Overhead tank, Mud pot, Unused well, Cess pit etc. at various regions of Dharwad district namely Urban, Semi-urban, Rural, Forest and Agricultural field were examined for their ability to serve as

efficient mosquitoes breeding sites. Out of which Stagnant pools, Plastic containers and abandoned tyres had the highest concentration of mosquitoes, followed by coconut shells and tree holes (Table-2), because naturally rain water gets accumulated in coconut shells, abandoned tyres, and plastic drums etc.

Table 2: Breeding Sites (B.S.) of mosquitoes' and their distribution in different study areas of Dharwad district.

S. No.	Breeding Sites (B.S.)	No. of B.S. searched for mosquitoes(N)	No. of B.S. in which mosquitoes presents (P)	Rural area		Semi-Urban region		Urban region		Forest area		Agricultural field	
				N	P	N	P	N	P	N	P	N	P
1.	Plastic containers	20	18	5	5	5	3	5	5	-	-	5	5
2.	Stagnant pools	51	44	11	8	13	9	23	21	2	2	2	2
3.	Discarded tyres	09	07	2	2	1	-	3	2	-	-	3	3
4.	Tree holes	28	18	6	3	7	5	5	3	5	3	5	4
5.	Cattle shed	18	11	5	2	2	-	03	01	-	-	10	8
6.	Coconut shell	38	23	8	6	5	3	11	6	9	4	5	4
7.	Overhead tank	08	04	2	-	-	-	6	4	-	-	-	-
8.	Mud pot	11	05	2	1	1	-	6	3	-	-	2	1
9.	Unused well	09	04	4	1	-	-	2	1	-	-	3	2
10.	Cess pit	17	04	3	2	2	1	8	1	-	-	4	-

The genera *Culex*, *Aedes*, *Anopheles* are most abundant mosquito species in Dharwad district of Karnataka. *Culex quinquefasciatus*, *Culex tritaeniorhynchus*, *Aedes aegypti* are the three mosquito species that are found distributed commonly in all the study areas i.e., urban, semi-urban,

rural, forest and agricultural fields, followed by *Anopheles subpictus* and *Aedes albopictus* respectively that are considered to be top 5 mosquito species available most commonly in Dharwad district (Table-3).

Table 3: Distribution of mosquitoes' species in various regions of Dharwad district during the study period.

Urban		Semi-Urban		Rural		Forest		Agricultural field	
Mosquito species	No.	Mosquito species	No.	Mosquito species	No.	Mosquito species	No.	Mosquito species	No.
<i>Culex quinquefasciatus</i>	89	<i>Culex quinquefasciatus</i>	36	<i>Culex quinquefasciatus</i>	57	<i>Culex quinquefasciatus</i>	33	<i>Culex quinquefasciatus</i>	78
<i>Culex tritaeniorhynchus</i>	39	<i>Culex tritaeniorhynchus</i>	20	<i>Culex tritaeniorhynchus</i>	19	<i>Culex tritaeniorhynchus</i>	26	<i>Culex tritaeniorhynchus</i>	39
<i>Culex mimulus</i>	56	<i>Culex lutzia</i>	30	<i>Culex nigripalpus</i>	24	<i>Culex vishnui</i>	53	<i>Culex mimulus</i>	42
<i>Culex nigripalpus</i>	39	<i>Culex mimulus</i>	51	<i>Culex lutzia</i>	42	<i>Culex territans</i>	63	<i>Culex territans</i>	37
<i>Culex erraticus</i>	33	<i>Culex erraticus</i>	63	<i>Culex territans</i>	29	<i>Culex restuans</i>	28	<i>Aedes aegypti</i>	23
<i>Culex pipiens</i>	35	<i>Culex pipiens</i>	78	<i>Culex vishnui</i>	45	<i>Aedes aegypti</i>	38	<i>Aedes sollicitans</i>	41
<i>Aedes aegypti</i>	72	<i>Aedes aegypti</i>	47	<i>Aedes aegypti</i>	69	<i>Aedes vittatus</i>	18	<i>Anopheles culiciformes</i>	29
<i>Aedes albopictus</i>	54	<i>Aedes albopictus</i>	56	<i>Aedes albopictus</i>	68	<i>Anopheles culiciformis</i>	22	<i>Anopheles stephensi</i>	28
<i>Aedes sollicitans</i>	49	<i>Aedes sollicitans</i>	28	<i>Aedes vittatus</i>	29	<i>Anopheles stephensi</i>	63	<i>Anopheles maculipennis</i>	45
<i>Aedes vexans</i>	6	<i>Aedes vexans</i>	17	<i>Aedes stokesi</i>	43	<i>Anopheles subpictus</i>	73	<i>Anopheles minimus</i>	7
<i>Anopheles subpictus</i>	23	<i>Anopheles subpictus</i>	44	<i>Anopheles subpictus</i>	29	<i>Anopheles minimus</i>	39		
<i>Anopheles culiciformis</i>	38	<i>Anopheles stephensi</i>	21	<i>Anopheles maculipennis</i>	18	<i>Mansonia indiana</i>	6		
<i>Anopheles maculipennis</i>	69	<i>Mansonia indiana</i>	20	<i>Anopheles minimus</i>	18				
<i>Mansonia indiana</i>	16								

The maximum Shannon Index value (2.5071) was found in the Urban area followed by Rural area (2.4622), Semi-Urban area (2.4584), Forest area (2.3456) and Agricultural field (2.1884) in Dharwad district. As per the results obtained above, it is clear that highest mosquito species diversity is seen in Urban areas followed by Rural area, Semi-Urban area, Forest area and Agricultural fields in the Dharwad district of Karnataka, India (Table - 4).

Simpson’s Diversity Indices of Urban, Semi-urban, Rural, Forest and Agricultural fields are 0.0888, 0.0936, 0.0932, 0.1051 and 0.1223 respectively, which indicates that highest mosquito species diversity is seen in Urban areas followed by Rural area, Semi-Urban area, Forest area and Agricultural fields. Similarly, the Simpson’s Reciprocal

Index values of Urban, Semi-urban, Rural, Forest and Agricultural areas are 0.9112, 0.9064, 0.9068, 0.8949 and 0.8777 respectively. This clearly indicates that mosquito diversity is highest in Urban areas followed by Rural, Semi-Urban, Forest and Agricultural field in the Dharwad district, Karnataka, India (Table-4).

One more diversity index i.e., Shannon Evenness Index (E) describes how evenly the mosquito species distribution is seen in a community. The values of E for Urban, Semi-urban, Rural, Forest and Agricultural fields are 1.0, 0.9805, 0.9820, 0.9355 and 0.8728 respectively, which indicates that the mosquito species distribution is even in Urban area followed by Rural, Semi-Urban, Forest and Agricultural fields in the Dharwad district (Table-4).

Table 4: Diversity indices of mosquitoes and their distribution in various study areas of Dharwad district. Diversity Index

Diversity Index	Urban	Semi-Urban	Rural	Forest	Agriculture field
Shannon Diversity Index H’.	2.5071	2.4584	2.4622	2.3456	2.1884
Simpson’s Diversity Index D.	0.0888	0.0936	0.0932	0.1051	0.1223
Simpson’s Reciprocal Index = (1-D).	0.9112	0.9064	0.9068	0.8949	0.8777
Shannon Evenness Index E= H’/ H’ _{max} .	1.0	0.9805	0.9820	0.9355	0.8728

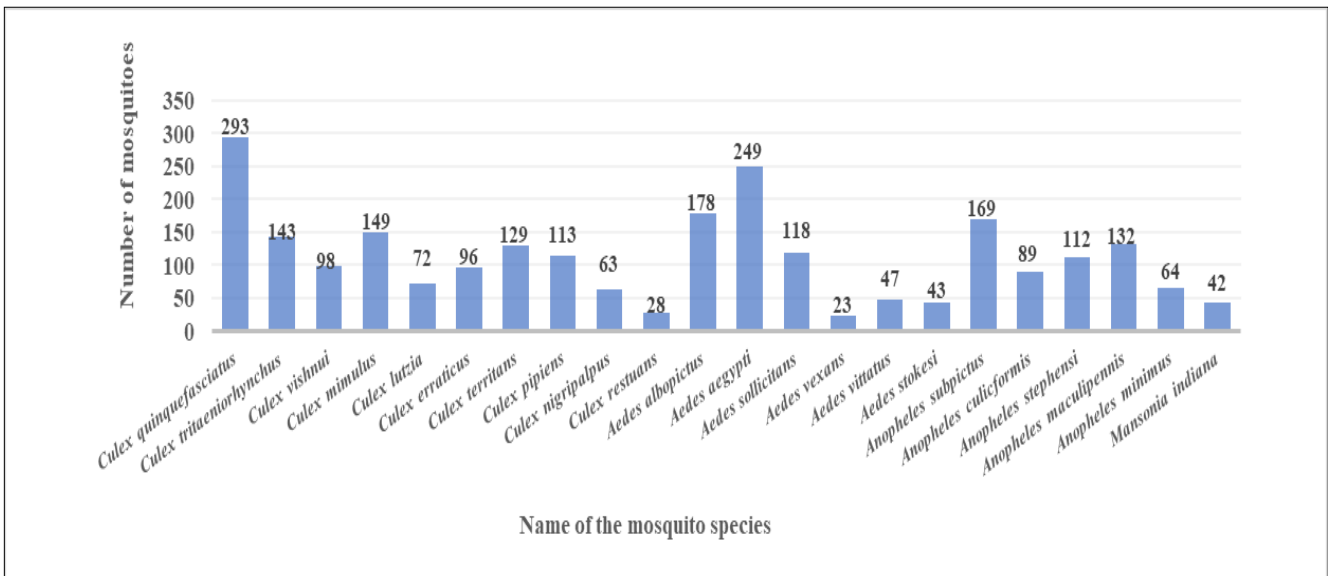


Fig 1: Graph indicating the names and numbers of mosquito species collected during the study period from Dharwad district.

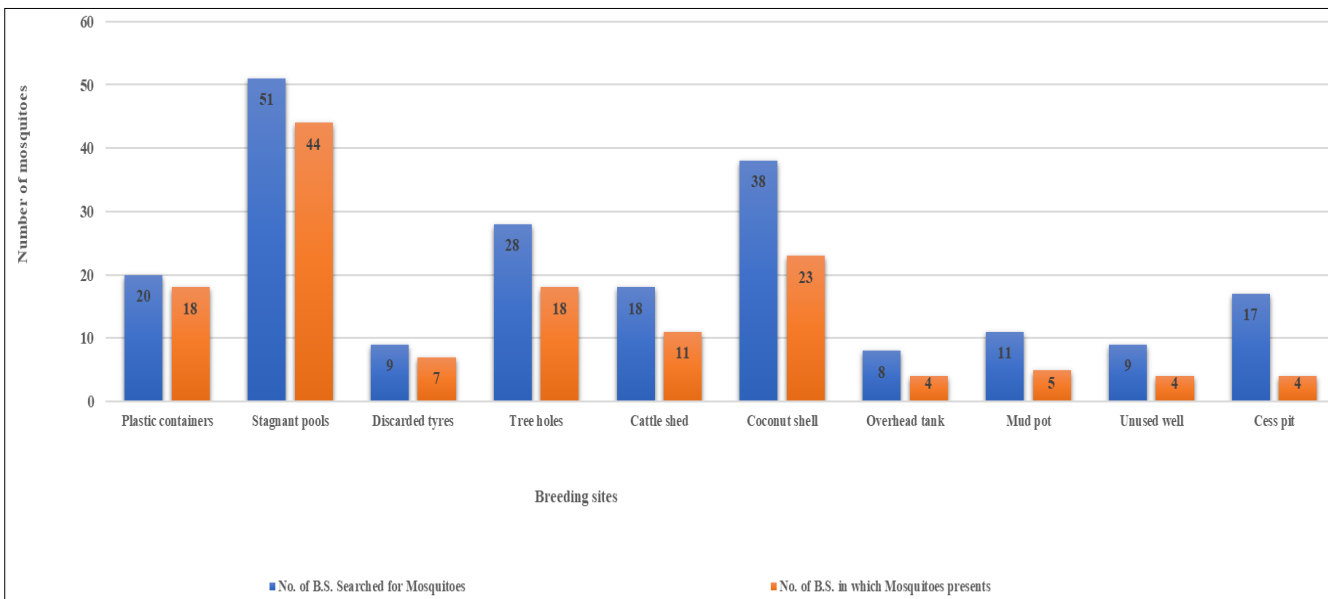


Fig 2: Graph indicating Breeding Sites (B.S.) of mosquitoes and their distribution.

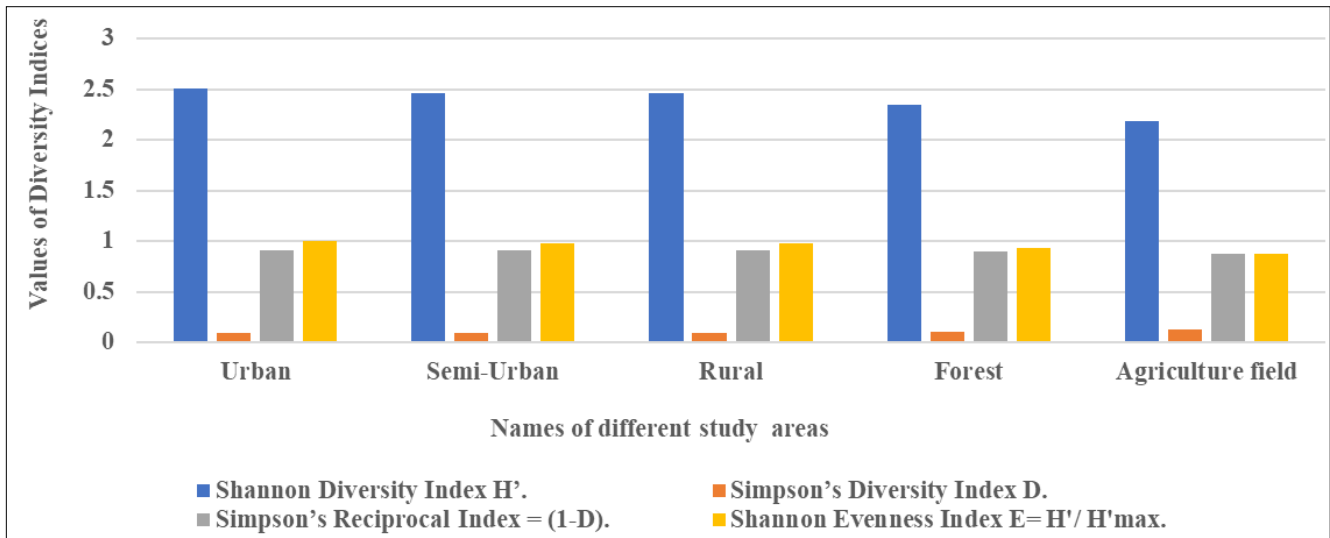


Fig 3: Graph indicating different study areas and their diversity indices

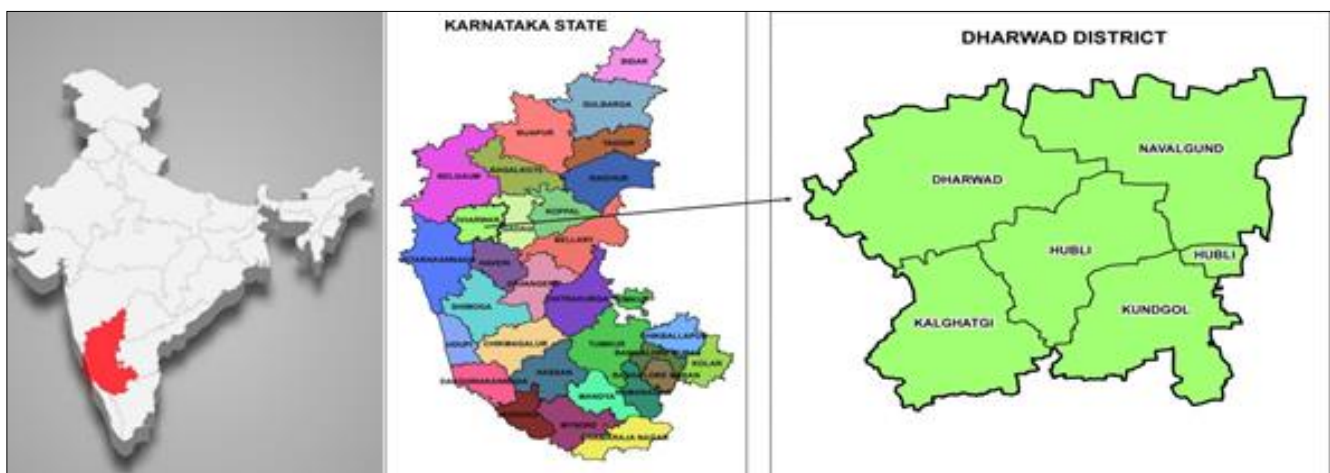


Fig 4: Map depicting the study area.

Discussion

Dengue and Chikungunya are the widespread diseases in the Dharwad district, but in recent years, filarial and other viral fevers have become common illness soon after the monsoon season, particularly in unplanned urban areas. The adult *An. subpictus* is a zoophilic species that has been identified as a *Japanese Encephalitis* (JE) vector in Karnataka, Tamil Nadu, as well as in Kerala [24, 25]. Dengue and Chikungunya are transmitted by the adult *Ae. albopictus* mosquito, sometimes referred to as the "Asian Tiger Mosquito" [26]. Naturally this species lay eggs in rock and tree crevices in forested places, however, because of deforestation, this mosquito has evolved to lay its eggs in abandoned tyres in various locations of India [27]. *Cx. vishnui*, a member of the genus *Culex*, is extensively dispersed in Rural areas is zoophilic, and is recognized in India, Taiwan, and Malaysia as a JE vector [28]. The findings of the present investigation revealed that abandoned tyres, stagnant pools, and different types of water bodies served as the primary habitat for various mosquito species belonging to different genera, such as *Cx. tritaeniorhynchus*, *Cx. quinquefasciatus*, *Ae. albopictus*, *Anopheles stephensi*, and *Aedes aegypti* etc. The most prevalent species observed in Dharwad district was *Cx. quinquefasciatus*. Similar to our studies, Hema et al., also determined mosquito larval breeding sites, located in Bengaluru's urban slums and were calculated entomological

indices. They surveyed a total of 2592 homes, as per the calculations, Container Index (CI), Breteau Index (BI), and House Index (HI) are equal to 4.75%, 0.73%, and 15.01% respectively. The most prevalent breeding locations were found in cisterns and cement tanks, both outdoor and indoor [29]. Additionally, numerous water bodies in the Dakshina Kannada area were also sampled by Prasad et al., 2021 to explore the prevalence of mosquito species from June-2014 to May-2017. Maximum records for mosquito species ranged from 12 to 37, with the leading genus being *Culex*. The majority of species have been identified in transient bodies of water, with receptacles housing the most species [30].

Summary and Conclusion

The present study shows that a total of 22 mosquito species exist in Dharwad district belonging to 4 genera. Of the existing mosquito species, the most abundant is *Cx. quinquefasciatus* followed by *Ae. Aegypti*, *An. stephensi*, and *Ae. albopictus*. The presence of these mosquitoes indicates that there is an increased chance of occurrence of mosquito vector borne diseases like Zika, West Nile virus, Dengue, Chikungunya, Malaria, filariasis etc. The distribution of mosquito species found to be higher in Urban and Rural areas followed by Semi-urban, Forest and Agricultural fields. Increased number of mosquitoes in urban and rural areas is due to improper management of water bodies such

as overhead tanks, pools, sumps, which need to be cleaned regularly or even kept closed with cap or lid. Even increased number of mosquitoes may also be due to accumulation of rain water in the ditches, coconut shells, abandoned tyres etc.

From the present study, it is concluded that Dharwad district has comparatively a higher mosquito species distribution in the Urban areas followed by Rural and Semi-urban areas and less distribution in the Forest and Agricultural fields. Further, studies should thoroughly investigate the diversity and population dynamics of mosquito fauna by taking into account of all conceivable environments, seasons of the year, climatic conditions like temperature, humidity, and rainfall. In addition, modern genetic and biotechnology techniques should be used so as to obtain a more accurate and complete picture of the diversity of mosquitoes in a particular area.

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