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Analysis of *Culex* Mosquitoes Surveillance in Udaipur District, Rajasthan, India 2021-2023

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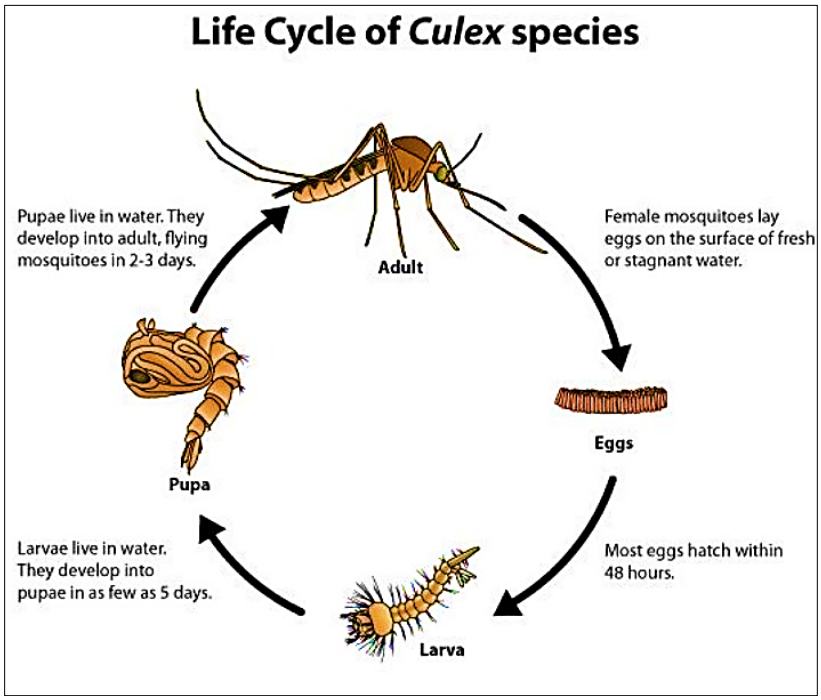
Abstract
Sampling was conducted over two consecutive years, April, 2021 to March, 2022 and April, 2022 to March, 2023, seasonally, *i.e.* rainy, winter and summer with three sampling in each season from both indoor (cattle sheds and human dwellings) and outdoor habitats. The adults were collected by hand catch method(aspirator). When indoor survey was conducted a total of 632 *Culex* mosquitoes were collected, out of which 343 *Culex* mosquitoes were collected from cattle sheds and 289 mosquitoes were collected from human dwellings. Similarly, when outdoor survey was conducted, a total of 125 mosquitoes were collected. A total of 757 adults were identified.

Keywords: Geographically weighted regression, dengue hemorrhagic fever, factor analysis

Introduction
Mosquito species vary in the type of aquatic habitats, they prefer based on location, physicochemical conditions of the water body and presence of potential predators (Shililu *et al*., 2003; Piyaratnea *et al*., 2005) [1, 2]. Physicochemical factors that influence organism status, survival and spatio-temporal distribution of important disease vector species include salt, dissolved organic and inorganic substances, degree of eutrophication, turbidity, presence of suspended soil, presence and absence of plants, temperature, light, shade and hydrogen ion concentration (Mogi, 1978; Amerasinghe *et al*., 1995; Gimning *et al*., 2001) [3, 4, 5]
Surveillance of mosquitoes is an important part of any mosquito control efforts. This allows for a better understanding of the biology and behavior of mosquitoes which can be useful for better decision making in disease and mosquito control programs. Carbon dioxide (CO_2) has been used successfully to trap mosquitoes. CO_2 released by animals is used by mosquitoes both for activation (take off and continued flight) as well as in host location (Gillies, 1980) [6]. Carbon dioxide to trap mosquitoes is primarily provided by live hosts (in the form of dry ice and tanked carbon dioxide) (Service, 1993) [7].
Various strategies including utilization of repellents are utilized to control mosquito borne diseases. Repellents assume a compelling part in reducing the human vector contact and furthermore help in reducing the disease transmission. More number of plant-based parts showhe
physiological and conduct exercises towards mosquitoes. Then again, chemicals are generally so effective in mosquito control tasks. It is fundamental for find out the effective repellents that could decrease the mosquitoes either by destroying them from biting human beings (Irrusappan and Nisha, 2018) [8].
An increase in mosquito abundance was observed on warmer degree days and an increase in MIR was associated with increased mosquito abundance. These models can be utilized in other mosquito monitoring and surveillance studies in different climate types and environments (Rehbein *et al.,* 2024) [10]. Temperature, salinity, nitrate and conductivity had positive correlation with mosquito larval density. The results proved that uncultivated wells and pools are a good and permanent source of mosquito breeding (Baz *et al.,* 2024) [9].



(**Source:** www.cdc.gov)

Figure 1: Life cycle of *Culex* mosquito

Materials and methods

Geography of Study Area

The Indian state of Rajasthan is home to Udaipur. The coordinates of Udaipur are 24'58°N; 73'68°E. Its overall size is 64 km², and its average elevation is 598 m (1961 ft). The districts of Rajsamand to the North and Chittorgarh and Pratapgarh to the East abut Udaipur. Gujrat to the South-East, Banswara district to the South-East, and Dungarpur to the South. Mavli, Gogunda, Kotra, Jhadol, Girwa, Vallabhnagar, Lasadia, Salumber, Sarada, Rishbhdev, Kherwara, and Semiri are among the twelve tehsils that make up Udaipur. The Sabarmati River, which rises in the Aravalli range in Udaipur district and empties into Gujarat, irrigates the Western part of the area, which is primarily hilly. The Ahar River, which passes through Udaipur city, is one of the tributaries of the Banas River that drain the district's Northern region. The tributaries of the Mahi River flow into the Som and Gomti in the district's central and southern regions. Two places in the Udaipur district were the focus of our investigation.

The socio-ecological features of this study region were taken into consideration when choosing it. The primary breeding ground for Culex mosquitoes is the area's rivers and flowing standing water. There are hilly places in this area. Peri-urban areas like Gogunda, Jhadol, Kotra, and Girwa make up most of the region. Hilly topography with seasonal rivers and waterfalls encircles the location. The communities are situated atop hilltops and are distinguished by the existence of springs and permanent streams, which serve as ideal mosquito breeding grounds.

Sample Collection

The survey was scheduled to take place between April 2021 and March 2022 and April 2022 and March 2023. Three sample collections were conducted at each of the chosen locations during each season. The Chief Medical Officer of Udaipur provided information on the prevalence of Culex, which was used to choose the survey location. For the full study, three seasons were chosen: summer (March to June), winter (November to February), and rainy (July to October).

Adult mosquitoes collection (Outdoor and Indoor)

Oral aspirators and light torches were used to gather mosquitoes during assessments of resting habitats, including human homes and cattle sheds. Mosquitoes were gathered from outdoor locations such as slum regions, villages, garden belts, and the vicinity of homes and ground cavities. Mosquitoes were captured from the living room, basement, main entrances, beneath the stairs, and other areas. Using the hand-catch method, mosquitoes were collected from human homes and cattle sheds from morning till night. After being gathered, the mosquitoes are placed in plastic containers that have been sliced on the side. The mosquitoes are transported to the lab for identification after the containers are wrapped in cloth and secured with rubber bands.

Identification of *Culex* mosquitoes

The body displays hunchback while it is at rest, meaning that the thorax and abdomen form an angle. Culex remains perpendicular to the surface. It breeds in large quantities in sewage- contaminated water. Even though it feeds all night long, there have been three recorded surges in biting activity: once between 2000 and 2200 hours, once in the middle of the night, and once right before the morning (0300 to 0400 hours). In the lab, a stereoscopic microscope was utilized to visualize these distinguishing characteristics. After being delivered to the lab, the captured mosquitoes were identified using standard keys (Reuben *et al*., 1994; Rattanarithikul *et al*., 2005) [12, 11]. Average values were computed after 30 nights of data collection.

Result

Survey of *Culex* Mosquito in Urban and Peri-Urban Areas

In a survey of *Culex* mosquito fauna, mosquitoes were collected in urban and peri-urban areas of Udaipur district. Sampling was conducted over two consecutive years, April, 2021 to March, 2022 and April, 2022 to March, 2023, seasonally, *i.e.* rainy, winter and summer, with three sampling in each season from both indoor and outdoor habitats. The adults were collected by hand aspirator method and larvae

were collected from various water bodies, mainly from breeding sites like puddles, sewage water, riverbed, tyres, cement tanks, tree holes and rock holes.

Survey of *Culex* mosquito fauna (Indoor survey) Hand catch method (cattle sheds and human dwellings)

Most of Udaipur is hilly. Kotra, Girwa, Jhadol and Gogunda have been included in survey of locality-I. Mosquitoes have been collected from important villages of each tehsil, based on the data of various disease caused by mosquitoes from RNT medical officer, Udaipur. Almost all the, important villages have been selected. When I compared the three seasons in percentage, I found that during the most rainy days, the percentage of *Culex* mosquitoes was found to be 44.34% and 34.83% in cattle sheds and human dwellings, whereas during winter and summer, almost equal number of mosquitoes were found. Data of Indoor survey of year April, 2021 to March, 2022 and April, 2022 to March, 2023 is given in following Table (1, 2, 3 and 4).

Table 1: Indoor collections of *Culex* mosquito fauna from cattle sheds by hand catch method, (April, 2021- March, 2022)

Species	Rainy (Qty / %)	Winter (Qty / %)	Summer (Qty / %)	Total (Qty / %)
Culex quinquefasciatus	27 (30.68%)	25 (40.32%)	21 (39.62%)	73 (35.96%)
Culex edwardsi	8 (9.09%)	9 (14.51%)	8 (15.09%)	25 (12.31%)
Culex whitei	7 (7.95%)	5 (8.06%)	4 (7.54%)	16 (7.88%)
Culex vagans	9 (10.22%)	10 (16.12%)	7 (13.20%)	26 (12.80%)
Culex pseudovishnui	19 (21.59%)	7 (11.29%)	6 (11.32%)	32 (15.76%)
Culex gelidus	5 (5.68%)	2 (3.22%)	1 (1.88%)	8 (3.94%)
Culex pipiens	9 (10.22%)	3 (4.83%)	4 (7.54%)	16 (7.88%)
Culex vishnui	4 (4.54%)	1 (1.61%)	2 (3.77%)	7 (3.44%)
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Total Collected	88	62	53	203
% of Total Collection	44.34%	30.54%	26.10%	100%

Table 2: Indoor collections of *Culex* mosquito fauna from human dwellings by hand catch method, (April, 2021- March, 2022)

Mosquito Species	Rainy (Coll.)	Rainy (%)	Winter (Coll.)	Winter (%)	Summer (Coll.)	Summer (%)	Total (Coll.)	Total (%)
Culex quinquefasciatus	17	31.48	13	26.53	15	28.84	45	29.03
Culex edwardsi	6	11.11	7	14.28	8	15.38	21	13.54
Culex whitei	2	3.70	2	4.08	0	0.00	4	2.58
Culex vagans	5	9.25	3	6.12	2	3.84	10	6.45
Culex pseudovishnui	12	22.22	11	22.44	10	19.23	33	21.29
Culex gelidus	4	7.40	4	8.16	5	9.61	13	8.38
Culex pipiens	5	9.25	6	12.24	7	13.46	18	11.61
Culex vishnui	3	5.55	3	6.12	5	9.61	11	7.09
Total	54	100	49	100	52	100	155	100
% Total	34.83		31.61		33.54		100	

Table 3: Indoor collections of *Culex* mosquito fauna from cattle sheds by hand catch method (April, 2022- March, 2023)

Mosquitoes collected	Rainy (Coll.)	Rainy (%)	Winter (Coll.)	Winter (%)	Summer (Coll.)	Summer (%)	Total (Coll.)	Total (%)
Culex quinquefasciatus	15	29.41	12	27.27	14	31.11	41	29.28
Culex edwardsi	5	9.80	4	9.09	5	11.11	14	10
Culex whitei	2	3.92	0	0.00	2	4.44	4	2.85
Culex vagans	2	3.92	1	2.27	2	4.44	5	3.57
Culex pseudovishnui	13	25.49	12	27.27	13	28.88	38	27.14
Culex gelidus	3	5.88	4	9.09	1	2.22	8	5.71
Culex pipiens	7	13.72	6	13.63	5	11.11	18	12.85
Culex vishnui	4	7.84	5	11.36	3	6.66	12	8.57
Total	51	100	44	100	45	100	140	100
% Total	36.42		31.42		32.14		100	

Table 4: Indoor collections of *Culex* mosquito fauna from human dwellings by hand catch method (April, 2022- March, 2023)

Mosquitoes collected	Rainy (Collected)	Rainy (% occurrence)	Winter (Collected)	Winter (% occurrence)	Summer (Collected)	Summer (% occurrence)	Total (Collected)	Total (% occurrence)
Culex quinquefasciatus	17	28.81	11	34.37	13	30.23	41	30.59
Culex edwardsi	6	10.16	2	6.25	5	11.62	13	9.70
Culex whitei	3	5.08	1	3.12	3	6.97	7	5.22
Culex vagans	2	3.38	3	9.37	4	9.30	9	6.71
Culex pseudovishnui	15	25.42	9	28.12	12	27.90	36	26.86
Culex gelidus	2	3.38	1	3.12	2	4.65	5	3.73
Culex pipiens	9	15.25	4	12.5	4	9.30	17	12.68
Culex vishnui	5	8.47	1	3.12	0	0.00	6	4.47
Total	59	100	32	100	43	100	134	100
% Total	44.02		23.88		32.08			

Almost equal number of species were found in cattle sheds and human dwellings and their names are *Culex quinquefasciatus, Culex edwardsi, Culex whitei, Culex vagans, Culex pseudovishnui, Culex gelidus, Culex pipiens* and *Culex vishnui*. The highest quantity was found in *Culex quinquefasciatus* cattle sheds and human dwellings with 35.96% and 29.03% respectively, whereas the lowest quantity was found in 2.85% *Culex whitei* in cattle sheds and 3.7% *Culex gelidus* in human dwellings. In the second year of the survey, the number of mosquitoes in cattle sheds was 51, 44 and 45 in rainy, winter and summer respectively, in cattle sheds 59, 32 and 43 in rainy, winter and summer respectively.

Outdoor survey
(April, 2021 to March, 2022 and April, 2022 to March, 2023)

Outdoor collection of resting mosquitoes was done from all the resting sites. For two consecutive years from April, 2021 to March, 2022 and April, 2022 to March, 2023, mosquitoes were collected from various habitats like tree hole, riverbeds, tyres, cement tanks, puddles, sewage water and rock holes. Out of all the species collected *Culex quinquefasciatus* was found in the first year, and *Culex pseudovishnui* in second year of the survey with a maximum percentage occurrence of 26.98% and 25.80% respectively. The lowest percentage incidence was observed for *Culex edwardsi* with 1.58% during the first year of survey and *Culex vishnui* 3.22% during the second year. If we compared the seasons with the current event no notable difference was observed. In the first year of the survey the incidence percentage during rainy, winter and summer season was found to be 34.92%, 31.74% and 33.33% respectively and during the second year the incidence during rainy, winter and summer season was 37.09%, 33.87% and 29.03% respectively. Overall, the number of mosquitoes was highest in the rainy season in both the year. The maximum number of mosquitoes of 37.09% was recorded outdoors in the rainy season from April, 2022 to March, 2023. Climatic conditions during this period ranged from minimum 4.6°C to maximum 40°C temperature and 13.4 to 87.6 % humidity with only 795.9 mm rainfall.

Data of Outdoor Survey April, 2021 to March, 2022 and April, 2022 to March, 2023 (Table 5 and 6).

Table 5: Outdoor resting collections of *Culex* mosquitoes, (April, 2021- March, 2022)

Mosquitoes collected	Rainy (Collected)	Rainy (% occurrence)	Winter (Collected)	Winter (% occurrence)	Summer (Collected)	Summer (% occurrence)	Total (Collected)	Total (% occurrence)
Culex quinquefasciatus	7	31.81	4	20.00	6	28.57	17	26.98
Culex edwardsi	0	0.00	1	5.00	0	0.00	1	1.58
Culex whitei	5	22.72	4	20.00	5	23.80	14	22.22
Culex vagans	3	13.63	7	35.00	5	23.80	15	23.80
Culex pseudovishnui	4	18.18	0	0.00	2	9.52	6	9.52
Culex gelidus	1	4.54	4	20.00	3	14.28	8	12.69
Culex pipiens	2	9.09	0	0.00	0	0.00	2	3.17
Culex vishnui	0	0.00	0	0.00	0	0.00	0	0.00
Total	22	100	20	100	21	100	63	100
% Total	34.92		31.74		33.33			

Table 6: Outdoor resting collections of *Culex* mosquitoes, (April, 2022- March, 2023)

Mosquitoes collected	Rainy (Coll.)	Rainy (%)	Winter (Coll.)	Winter (%)	Summer (Coll.)	Summer (%)	Total (Coll.)	Total (%)
Culex quinquefasciatus	6	26.08	4	19.04	2	11.11	12	19.35
Culex edwardsi	2	8.69	2	9.52	3	16.66	7	11.29
Culex whitei	4	17.39	3	14.28	1	5.55	8	12.90
Culex vagans	3	13.04	4	19.04	3	16.66	10	16.12
Culex pseudovishnui	5	21.73	6	28.57	5	27.77	16	25.80
Culex gelidus	0	0.00	1	4.76	2	11.11	3	4.83
Culex pipiens	2	8.69	3	14.28	1	5.55	6	9.67
Culex vishnui	1	4.34	0	0.00	1	5.55	2	3.22
Total	23	100	21	100	18	100	62	100
% Total	37.09		33.87		29.03		100	

Conclusion

Seasonally, that is, rainy, winter, and summer, three samplings were taken from both indoor (cattle sheds and human residences) and outdoor habitats over the course of two consecutive years, from April 2021 to March 2022 and April 2022 to March 2023. Using the hand catch approach (aspirator), the adults were gathered. Three hundred and forty-three Culex mosquitoes were collected from cow barns while two hundred and ninety-nine mosquitoes were captured from human residences during the interior survey. In a similar vein, 125 mosquitoes in total were gathered during the outside survey. 757 adults in all were recognized.

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