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SPATIAL AND SEASONAL DISTRIBUTION OF THREE MOSQUITO GENERA (DIPTERA: CULICIDAE) IN DHAKA SOUTH CITY AREA AND THEIR ASSOCIATION WITH METEOROLOGICAL FACTORS

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ABSTRACT

An assessment of prevalence of three mosquito species named *Culex* (*Cx.*), *Anopheles* (*An.*) and *Aedes* (*Ae.)* were conducted in eight places of Dhaka south city area (viz. Dholaikhal, Dhupkhola pond, Baldha garden, Ahsan Manzil, Dholaipar, Iskcon Temple, Bongshal pond and Shaheed Matiur Park) from December 2021 to November 2022. A total number of 8231 adult mosquitoes were examined constitutes 92.27% *Cx.* 5.32% *Ae.* and 2.41% *An.* The maximum percentage of *Cx.* (14.06%), mosquitoes were captured in the month of June but the maximum percentage of *An.*(19.70%) and *Ae.* (23.06%) mosquitoes were captured in the month of August. On the other hand, the lowest percentage of *Cx.* (2.69%) and *Ae.* (1.37%) were in the month of January, but the lowest percentage of *An.*(1.01%) mosquitoes were in the month of November. The mosquito prevalence in different study sites reflected almost similar percentage in abundance. The prevalence of mosquito have highly positive correlation with rainfall (r = 0.935) and temperature (*r* = 0.953) and moderate correlation with relative humidity (r = 0365).

Keywords: *Culex, Anopheles, Aedes, Dhaka South, Rainfall, Temperature, Humidity*

Introduction

Mosquitoes are the primary carriers of numerous viral and parasitic diseases that affect both humans and animals (Qasim *et al*., 2014). More than 700 million people are thought to contact infections from mosquitoes each year, and they are also thought to be responsible for 1 in 17 fatalities (Piovezan *et al*., 2022). The accurate identification of mosquito vector species and knowledge of their biology, ecology, and geographical distribution are considered important factors for surveillance and control of vectors and mosquito-borne diseases (Chan *et al*., 2014). From these genera, *An.*, *Ae.* and *Cx.* are medically important due to their ability to transmit mosquito-borne human diseases (Gubler, 2010). Of them only 117 species have been recorded in

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Bangladesh including 36 Anopheline, 79 Culicine, and two Toxorhynchitine species (Ahmed, 2009). *Cx.* mosquitoes can vary in color, typically appearing gray with white, silver, green or iridescent blue scales and were usually about 1/4 inch to 3/8 inch in length, although their body size can slightly differ depending on how recently they've fed.

These were involved in the transmission of human diseases like Filaria and Japanese Encephalitis. *Cx.* This type of mosquito is probably the most abundant house mosquito in towns and cities of the tropical countries which could develop in standing water such as polluted ponds, marshes, tanks, street gutters, tin cans, barrels, ornamental ponds, puddles, creeks, ditches, etc (Tennyson *et al*., 2007).

*Ae.*is a genus of mosquitoes originally found in tropical and subtropical region, but now found on all over the world except Antarctica (Ghosh *et al.*, 2022). The genus consists of 28 species (IT IS, 2022*)*. Unlike most other mosquitoes, they are active and bite only during the daytime. The peak biting periods are early in the morning and in the evening before dusk (WHO, 2021). *Ae. albopictus* is a single species that plays a key role in the transmission of dengue in Asia and is capable of transmitting at least 20 arboviruses and filarial worms (Gartz, 2004). *Ae. aegypti* and *Ae. albopictus* mosquitoes, both of which are found in Dhaka City, are the carriers of dengue fever. Bangladesh now experiences a high rate of dengue hemorrhagic fever (Mahmood *et al*., 2011).

An. mosquitoes are easily recognized in their resting position, in which the proboscis, head, and body are held on a straight line to each other but at an angle to the surface. The spotted coloring on the wings results from colored scales. Of the approximately 530 *An.* species, only 30-40 transmit malaria in nature (Service, 1992).Of the *Anopheles* species, only four namely *An. dirus, An. philippinensis, An. minimus,* and *An. Sundaicus* have been established as malaria vectors in Bangladesh (Bashar *et al*., 2014). Malaria threatens an estimated 3.4 billion people in 104 countries (WHO, 2022). Malaria is the most prevalent tropical and parasitic disease in the world among all the illnesses brought on by mosquito vectors, including filariasis, dengue, and yellow fever (WHO, 2012).

The abundance and distribution of mosquito fauna are influenced by many factors including, but not limited to, host availability, climatic conditions, especially rain and temperature, human mobility and activities, and land cover (Amini *et al.*, 2020).Temperature affects mosquito breeding grounds and feeding habits and some mosquitoes are drawn to hosts based on their preferences, such as body odor, temperature, moisture, or visual signals (Steib *et al*., 2001). Rainfall has been discovered to have an impact on the number of mosquitoes in homes (Koenraadt *et al*., 2003). Mosquitoes are significantly impacted by humidity as well (Cohen *et al*., 2008). According to Haque *et al.* (2007), rainfall is regarded as a significant element impacting the spread of malaria in Bangladesh.

Because mosquitoes are important for public health, mosquito survey is a useful way to learn about the prevalence, distribution, and species variety of different mosquitoes (Prakash *et al*., 1998). This can help researchers working in sectors including medical and veterinary entomology, ecology, and other related biological sciences. This purpose of this study was to determine the

prevalence and distribution of three mosquito genera in eight specifically chosen locations within the Dhaka south city area, as well as their relationships with some environmental factors.

Materials and Methods

Study area

The study were carried out in eight selected places of Dhaka south city area (Fig. 1). The places include Dholaikhal (at 23°70' N and 90°42'E ; DSCC Ward No. 44), Dhupkhola pond (at 23°70' N and 90°42' E; DSCC Ward No. 45), Baldha garden (at 23°72' N and 90°42' E;DSCC Ward No. 41), Ahsan Manzil (at 23°71' N and 90° 41'E; DSCC Ward No. 33), Dholaipar (at 23°70' N and 90°43' E;DSCC Ward No. 51), Iskcon Temple (at 23°71'N and 90°42' E;DSCC Ward No. 40), Bongshal pond (at 23° 1' N and 90° 0' EDCC Ward No. 34) and Shaheed Matiur Park (at 23° 2' N and 90°41' E;DSCC Ward No. 20).

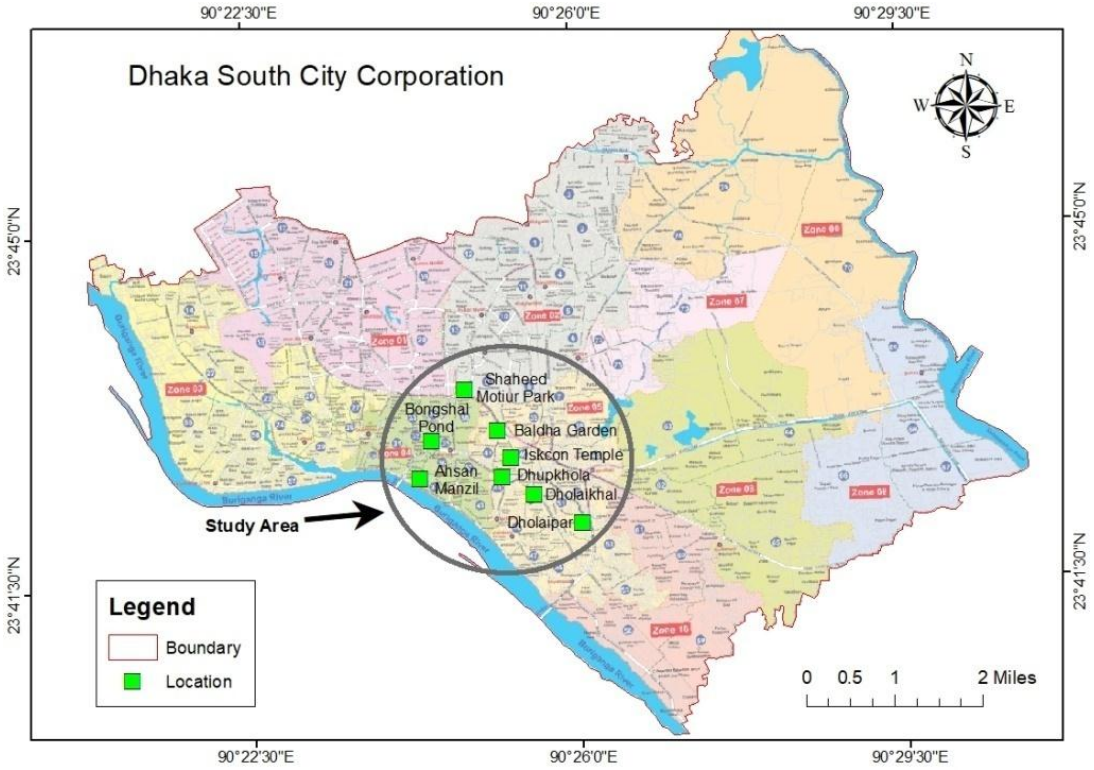

Fig. 1. Eight selected locations of mosquitoes sampling in Dhaka south city area.

Sampling of Mosquitoes

Mosquito sampling was conducted round the year from December 2021 to November 2022. With the aid of a sweep net, the adult mosquitoes were captured. When mosquitoes were breeding, relaxing, or feeding inside their habitat, the sweep net was employed to gather them. The survey was carried out twice a month in each location, right after sundown to preserve the coolest

temperature. Cotton swabs coated in ethyl acetate were used to kill mosquitoes captured alive in nets and stored in a jar. Then, with labels indicating the date, time, and location, maintained in separate boxes.

Morphological Identification and labeling of mosquitoes

Collected genera of mosquito were taken to the Entomological laboratory of the department of Zoology, Jagannath University. To prepare sample slides, mosquitoes were first recognized by naked eye and then under a microscope using morphological descriptions and diagnostic traits. Following the taxonomic keys of Gillies and Coetzee (1987), the morphological identification of three genera was carried out by examining the scales and color of the palps at the head region, the patterns of spots on the wings, thorax, terminal abdominal segments, and scales of the legs under a stereoscopic microscope. For the next study's purposes, the adult mosquitoes were preserved in vials of 70% alcohol with correct labeling, information about the location, specimen number, name, habitat, and date of collection.

Data analyses

Collected mosquito specimens were sorted into genera based on the reported literature on the taxonomic keys. The data was subjected to descriptive statistics and percentages were generated and shown in tables through Microsoft Excel Worksheet. For these times, monthly information on rainfall, relative humidity, minimum and maximum temperatures was gathered from a weather website on Google.

Results and Discussion

Month wise total sampled mosquitoes of different genera during the study period is shown in the Table 1. A total number of 8231 adult mosquitoes were collected by sweeping net constitutes 92.27% *Cx.* 5.32% *Ae.* and 2.41% *An.*(Fig. 2). Results of month and area wise sampled mosquitoes of three genera during the study period is shown in the Table 2.

Month wise prevalence of *Cx.*, *An*., and *Ae*. Mosquitoes have been shown in the figure no. 2. The highest (14.06%) and the lowest (2.69%) percentage of *Cx.* mosquitoes were captured in the month of June-2022 and January-2022, respectively. The highest number followed by gradually 13.43%, 12.52%, 11.26%, 10.48%, 9.10%, 8.81%, 6.65%, 4.42%, 3.37% and 3.21%at the month of May’22, August’22, July’22, September’22, April’22, October’22, November’22, March’22, February’22 and December’21, respectively.

The highest (19.70%) and the lowest (1.01%) percentage of *An.* mosquitoes were captured in the month of August-2022 and November-2022, respectively. The highest number followed by gradually 17.17%, 13.13%, 11.11%, 10.61%, 8.59%, 6.57%, 4.04%, 3.03%, 2.53% and 2.53% , at the month of July’22, June’22, May’22, September’22, April’22, March’22, October’22 , February’22, January’22 and December’21, respectively.

The highest (23.06%) and the lowest (1.37%) percentage of *Ae.* mosquitoes were captured in the month of August-2022 and January-2022, respectively. The highest number followed by gradually 17.35%, 13.93%, 13.47%, 9.59%, 6.62%, 4.11%, 3.88%, 2.28%, 2.28% and 2.05% , at the month of July’22, September’22, June’22, May’22, April’22, March’22, October’22, November’22, December’21 and February’22, respectively.

Table 1. Month wise sampled total mosquitoes of different genera during the study period

	Dec'21	Jan'22	Feb'22	Mar'22	Apr'22	May'22	Jun'22	Jul'22	Aug'22	Sep'22	Oct'22	Nov'22	Total	%
Culex	244	204	256	336	691	1020	1068	855	951	796	669	505	7595	92.27 %
Anopheles	5	5	6	13	17	22	26	34	39	21	8	2	198	2.41%
Aedes	10	6	9	18	29	42	59	76	101	61	17	10	438	5.32%
Total	259	215	271	367	737	1084	1153	965	1091	878	694	517	8231	100%

Table 2. Month and area wise sampled mosquitoes of three genera during the study period

Study Area	Dec'21	Jan'22	Feb'22	Mar'22	Apr'22	May'22	Jun'22	Jul'22	Aug'22	Sep'22	Oct'22	Nov'22	Total
Culex													
Dholaikhal	36	35	42	52	90	142	156	115	124	104	92	76	1064
Dhupkhhola pond	27	29	35	41	87	117	142	100	121	94	88	74	955
Baldha garden	43	35	39	44	78	103	113	87	109	96	73	58	878
Ahsan Manzil	39	27	33	42	75	123	130	103	126	114	98	67	977
Dholaipar	33	26	37	60	117	169	150	139	147	106	96	73	1153
Iskcon Temple	18	16	20	26	63	86	80	73	75	62	52	38	609
Bongshal pond	29	25	34	49	92	145	155	121	129	106	86	57	1028
Shaheed Matiur Park	19	11	16	22	89	135	142	117	120	114	84	62	931
Anopheles													
Dholaikhal	0	0	0	2	3	3	4	5	5	2	1	1	26
Dhupkhhola pond	1	1	1	3	3	3	4	4	5	3	1	0	29
Baldha garden	1	1	1	2	3	4	4	5	6	4	1	1	33
Ahsan Manzil	1	1	1	2	2	3	3	4	4	3	1	0	25
Dholaipar	1	0	1	1	2	2	3	4	5	3	1	0	23
Iskcon Temple	0	1	1	1	2	2	2	3	3	1	1	0	17
Bongshal pond	1	0	0	1	1	2	3	4	5	3	1	0	21
Shaheed Matiur Park	0	1	1	1	1	3	3	5	6	2	1	0	24

						Aedes							
Dholaikhal	2	0	1	1	4	7	10	15	16	10	3	1	70
Dhupkhhola pond	2	0	1	2	4	5	8	9	13	6	3	2	55
Baldha garden	2	1	2	4	5	6	8	10	13	8	2	2	63
Ahsan Manzil	1	1	2	3	4	5	6	7	11	8	2	1	51
Dholaipar	1	1	0	1	2	4	7	9	11	7	2	1	46
Iskcon Temple	1	1	1	1	3	4	6	8	11	7	2	1	46
Bongshal pond	0	1	1	3	4	6	7	9	12	8	2	1	54
Shaheed Matiur Park	1	1	1	3	3	5	7	9	14	7	1	1	53

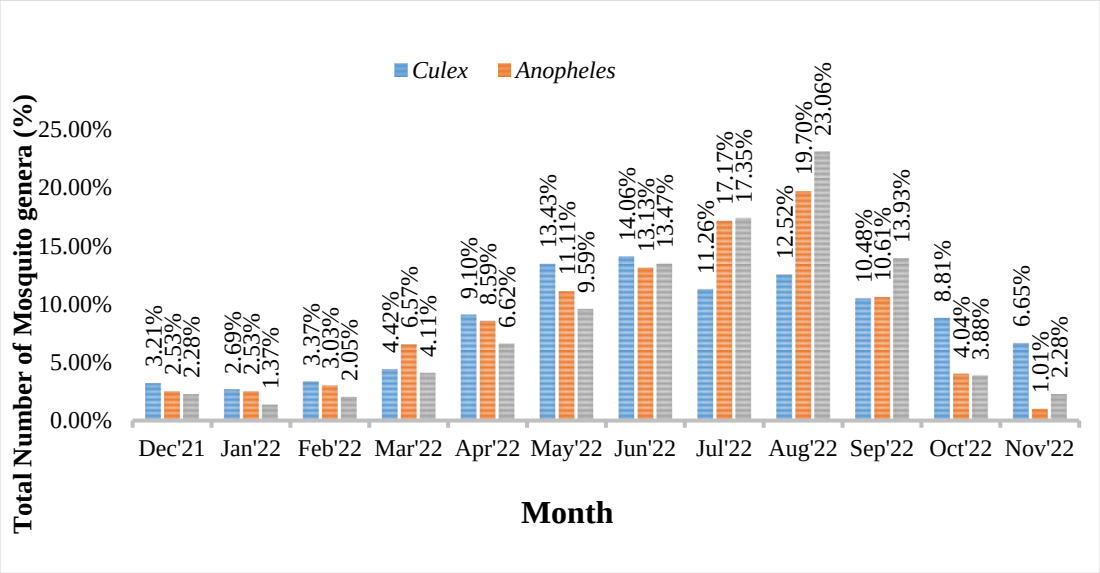

Fig. 2. Month wise prevalence of mosquito genera in percentage.

Site wise prevalence of *Cx.*, *An.*, and *Ae.* mosquitoes have been shown in the figure no. 3. The highest (15.18%) and the lowest (8.02%) percentage of *Cx.* mosquitoes were captured at Dholaipar and Iskcon Temple, respectively. The highest number followed by gradually 14.01%, 13.54%, 12.86%, 12.57%, 12.26% and 11.56% at Dholaikhal, Bongshal pond, Ahsan Manzil, Dhupkola pond, Shaheed Matiur Park and Baldha garden, respectively.

The highest (16.67%) and the lowest (8.59%) percentage of *An.* mosquitoes were captured at Baldha garden and Iskcon Temple, respectively. The highest number followed by gradually 14.65%, 13.13%, 12.63%, 12.12%, 11.62%and 10.61% at Dhupkola pond, Dholaikhal, Ahsan Manzil, Shaheed Matiur Park, DholaiparandBongshal pond, respectively.

The highest (15.98%) and the lowest (10.50%) percentage of*Ae.* mosquitoes were captured at Dholaikhal and Dholaipar, Iskcon Temple respectively. The highest number followed by

gradually14.38%,12.56%, 12.33%, 12.10%and 11.64% at Baldha garden, Dhupkhhola pond, Bongshal pond, Shaheed Matiur Park and Ahsan Manzil, respectively.

The prevalence of *Cx.* mosquito found in this study was similar to the outcomes of Akter (2014), Farjana (2015) and Alam (2015). The similar findings were reported by Wolf and Aslam (1971) in Dhaka city and Ameen and Moizuddin (1973) in Dinajpur district. The occurrence of *Cx.*species recorded in this study conforms to the findings of Anosike *et al*. (2007) and Hopkins (1952). *Cx.* species usually breed profusely in polluted gutters, blocked drains and other water retention habitats with organic matter but *Ae.* and *An.*mosquitoes which prefer clean ground pools and man-made containers, respectively (Khan and Ahmed, 1986). The study area had many polluted drains and runoffs providing conducive environment for the prolific breeding of *Cx.* species. *Cx.* species has been noted to be very common in polluted waters and sites which have foul smell (Anosike *et al*., 2007), and the mosquitoes collected in this study were done mostly from dirty places of houses, polluted drains, ditches, cowsheds, poultry farm having foul smell, and waste products. *Cx. quinquefasciatus*is widely distributed in urban and rural areas of Bangladesh due to the presence of many irrigation ditches and rice fields provides suitable breeding site for this mosquito (Hossain *et al*., 1996). Characterizations of dominant mosquito vectors include well adaptation to a wide range of climatic conditions and habitats, high anthropophilic propensity, and variable adult resting behavior (Gaffigan *et al*., 2019).

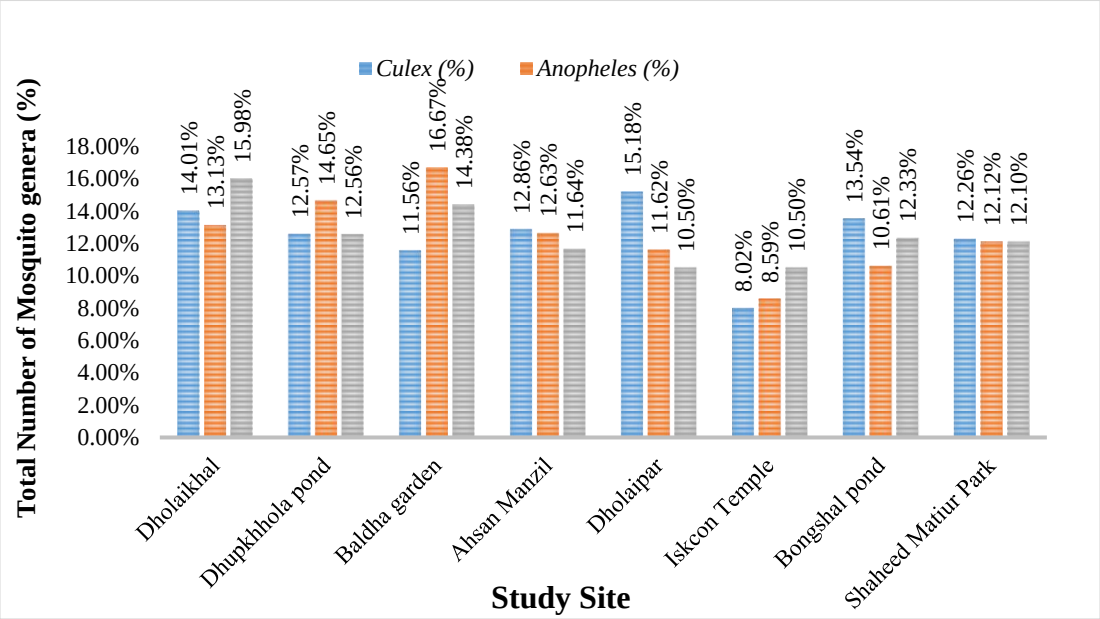

Fig. 3. Site wise prevalence of mosquito genera in percentage.

Climate factors such as temperature, humidity and rainfall have been considered while studying mosquito population dynamics. The correlation in between mosquito population and climatic factors are shown in the Fig. 4, 5 and 6. The results show that the prevalence of mosquito have highly positive correlation with rainfall (r = 0.935) and temperature (*r* = 0.953) and moderate

correlation with relative humidity (r=0365). For mosquito investigations, temporally comprehensive sampling of mosquitoes is preferable since the population of *An.* species closely coincides with the seasonal patterns of rainfall, grows up quickly and peaks immediately after the start of the rainy season (Mbogo *et al*., 2003). The rainy season is the best period to gather information on adult mosquitoes, and highland areas frequently have malaria outbreaks after the rainy season (Shanks *et al*., 2002). Insects are exceedingly sensitive to temperature and rainfall; tropical and temperate species frequently show great variations in abundance in different seasons (Samways, 1995). The reproduction of *Ae. aegypti*and *Ae. albopictus*from tropical to subtropical zones occurs all the year round and their abundance is associated with rainfall (Moore *et al*., 1978, Chadee, 1992; Kalra *et al*., 1997; Micieli and Campos, 2003). The adult mosquito is directly affected by temperature, relative humidity and rainfall, but larval life is mainly affected by rainfall and water temperature (Micieli and Campos, 2003).

By providing breeding areas for the mosquitoes to lay eggs, high temperatures, regular rains, and an appropriate relative humidity of at least 50 to 60% increased the duration of the mosquitoes' ability to survive. The lifespan of mosquito vectors is shortened by relative humidity levels below 60%. (Rogers and Randolph, 2006). The life cycle of the *Cx. quinquefasciatus* has been revealed to be closely related to temperature in numerous studies (Ciota *et al*., 2014) showed that this species reproductive activity increases with temperature, and Almirón and Brewer (1996) demonstrated that this species can only survive in environments with a temperature above 10°C. The relationship between temperature and mosquito development and survival has been discovered (Loetti *et al*., 2011). The breeding ecology of mosquitoes, including the types and preferences for larval habitats, the spatial and temporal distribution of breeding sites, as well as the physical, biological, and chemical characteristics of the habitats, must be well-understood for vector control measures to be effective (Olayemi *et al*., 2010). To ascertain their impact on mosquito distribution, abundance, and diversity, a research of mosquito biology and physicochemical aspects of breeding sites would be crucial (Afolabi *et al*., 2013). Understanding the variety and number of mosquito species is essential to the success of any mosquito control measure.

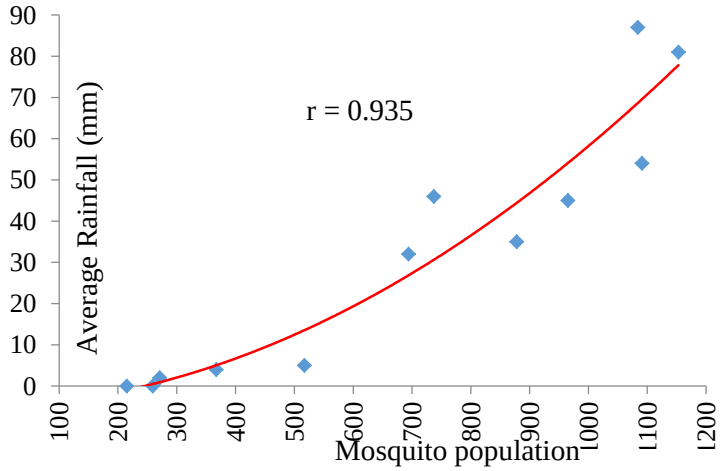

Fig. 4. Correlation of mosquito population with monthly average rainfall (mm).

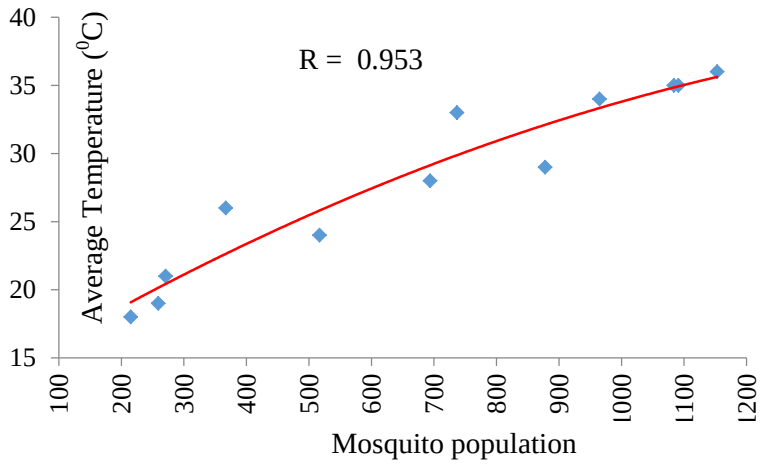

Fig. 5. Correlation of mosquito population with monthly average temperature (^{0}C).

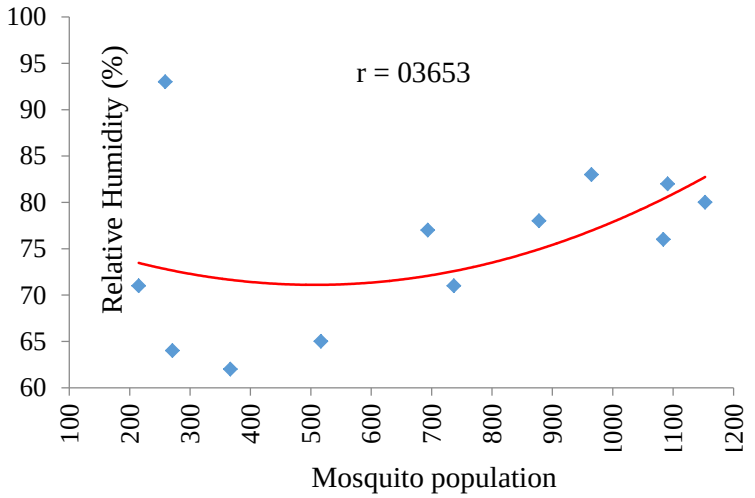

Fig. 6. Correlation of mosquito population withrelative humidity (%).

Conclusion

In this study, *Cx.* was the predominant genus in Dhaka south city area, followed by *An.*and *Ae.* The prevalence of the *Cx.* species in all areas could be attributed also to their wide suitability to different breeding sites and variable extreme climatic factors prevailing there. Although the study was small, the basic information was nevertheless helpful for other areas of Dhaka city and Bangladesh. *Cx.* outnumbered *An.* and *Ae.* in every research site.

References

Afolabi, O. J., Simon-Oke, I. A. and Osomo, B. O. (2013). Distribution, abundance and diversity of mosquitoes in Akure, Ondo State, Nigeria. *Journal of Parasitology and Vector Biology*, 5(10): 132–136.

Ahmed, S. M., Haque, R., Haque, U. and Hossain, A. (2009). Knowledge on the transmission, prevention and treatment of malaria among two endemic populations of Bangladesh and their health-seeking behaviour. *Malaria Journal*, 8: 173.

Akter, F., Farjana, T., Islam, T., Khanom, T. F., Islam, K. R., and Alim, A. (2014). Seasonal distribution of mosquitoes (Diptera: Culicidae) in Bangladesh Agricultural University (BAU) campus, Mymensingh, Bangladesh. *Bangladesh Veterinary Journal*, 48 (1-4): 11–24.

Alam, N., Farjana, T., Khanom, T. F., Labony, S. S., Islam, K. R., Ahmmed, S. and Mondal, M. M. H. (2015). Prevalence of mosquito species (Diptera: Culicidae) in and around Bangladesh Agricultural University campus, Mymensingh, Bangladesh. *Progressive Agriculture Journal*, 16(1): 37–46.

Almirón, W. R., and Brewer, M. E. (1996). Winter biology of *Culexpipiensquinquefasciatus say*, (diptera: Culicidae) from Córdoba, Argentina. *Memorias Do Instituto Oswaldo Cruz*, 91: 649-654.

Ameen, M., Moizuddin, M. (1973). Bionomics of the common mosquitoes of Dacca. *Journal of Natural History*, 7: 1-21.

Amini, M., and Hanafi-Bojd, A. A., Aghapour, A. A. and Chavshin, A. R. (2020). Larval habitats and species diversity of mosquitoes (Diptera: Culicidae) in West Azerbaijan Province, Northwestern Iran, *BMC Ecology*, 20(1): 60.

Anosike, J. C. B. E., Nwoke, A. N., Okere, E. E., Oku, J. E., Asor, I. O., Emmy-Egb, and Adimike, D. A. (2007). Epidemiology of tree-hole breeding mosquitoes in the tropical rainforest of Imo state, South East Nigeria. *Annals of Agricultural Environment and Medicine*, 14: 31–38.

Bashar, K., and Tuno, N. (2014). Seasonal abundance of *Anopheles* mosquitoes and their association with meteorological factors and malaria incidence in Bangladesh. *Parasites & vectors*, *7*(1): 1–10.

Chadee, D. D. (1992). Seasonal incidence and horizontal distribution patterns of oviposition by *Aedes aegypti* in an urban environment in Trinidad, West Indies. *Journal of the American Mosquito Control Association*, 8: 281-284.

Chan, A., Chiang, L. P., Hapuarachchi, H. C., Tan, C. H., Pang, S. C., Lee, R., Lee, K. S., Ng, L. C. and Lam-Phua, S. G. (2014). DNA barcoding: complementing morphological identification of mosquito species in Singapore. *Parasites & Vectors*, 7(1): 1–12.

Ciota, A. T., Matacchiero, A. C., Kilpatrick, A. M., and Kramer, L. D. (2014). The effect of temperature on life history traits of *Culex* mosquitoes. *Journal of Medical Entomology*, 51: 55–62.

Cohen, J., Ernst, K., Lindblade, K., Vulule, J., John, C., and Wilson, M. (2008). Topography-derived wetness indices are associated with household-level malaria risk in two communities in the western Kenyan highlands. *Malaria Journal*, 7:40.

Farjana, T., Ahmmed, S., Khanom, T. F., Alam, N., and Begum, N. (2015). Surveillance of mosquitoes larva at selected areas of Mymensingh district in Bangladesh. *Bangladesh Journal of Veterinary Medicine,* 13(1): 79–88.

Gaffigan, T. V., Wilkerson, R. C., Pecor, J. E., Stoffer, J. A. and Anderson, T. (2019). *Systematic Catalog of Culicidae Suitland, Walter Reed Biosystematics Unit, Museum Support Center, Smithsonian Institution.* Suitland, MD, USA.

Gartz, N. G. (2004). Critical review of vectors status of *Aedesalbopictus. Medical and Veterinary Entomology,* 18: 215–227.

Ghosh, S. K., and Ghosh, C. (2022). COVID-19's impacts on dengue transmission: Focus on neighbourhood surveillance of *Aedes* mosquitoes. *Asian Pacific Journal of Tropical Medicine,* 15(8): 339.

Gillies, M. T., and Coetzee, M. (1987). A Supplement to the Anophelinae of Africa south of the Sahara (Afrotropical Region). South African Institute for Medical Research, Johannesburg, South Africa.

Gubler, D. J. (2010). The global threat of emergent/re-emergent vector-borne diseases. Springer, New York, NY, USA. *Vector Biology, Ecologyand Control,* 39–62.

Haque, U., Hashizume, M., Glass, G., Ashraf, M., Dewan, A., and Overjaard, H. (2007). The role of climate variability in the spread of malaria in Bangladesh highlands. *PLoS One,* 5(12): c14341.

Hopkins, G. H. E. (1952). *Mosquitoes of Ethiopian region, I. Larval Bionomics of Mosquitoes and Taxonomy of Culicine Larvae*. 1st Edition, British Museum (Natural History), London, 335.

Hossain, M. I., Ameen, M., and Chowdhury, M. A., (1996). Mosquito breeding grounds in the city of Dhaka. *Journal of Life Science,* 8: 41–47.

ITIS. (2022). Report: Aedes. www.itis.gov. *Retrieved 2022-10-07*.

Kalra, N. L., Kaul, S. M., and Rastogi, R. M. (1997). Prevalence of *Aedes aegypti* and *Aedes albopictus*- Vectors of Dengue and Dengue haemorrhagic fever in North, North-East and Central India. *Dengue Bulletin,* 21: 84-92.

Khan, M., and Ahmed, T. U. (1986). Dengue status in Bangladesh. *Dengue News Letter,* 12:11.

Koenraadt, C., Paaijmans, K., Githeko, A., Knols, B., and Takken, W. (2003). Egg hatching, larval movement and larval survival of the malaria vector *Anopheles gambiae* in desiccating habitats. *Malaria Journal,* 2: 20.

Loetti, V., Schweigmann, N., and Burroni, N. (2011). Development rates, larval survivorship and wing length of *Culexpipiens* (Diptera: Culicidae) at constant temperatures. *Journal of Natural History,* 45: 2207–2217.

Mahmood, B., and Mahmud, S. (2011). Emergence of Dengue in Bangladesh a major international public health concern in recent years. *Journal of Environmental Research and Management,*2(3): 35–41.

Mbogo, C., Mwangangi, J., Nzovu, J., Gu, W., Yan, G., Gunter, J., Swalm, C., Keating, J., Regens, J., and Shililu, J. (2003). Spatial and temporal heterogeneity of *Anopheles* mosquitoes and

Plasmodium falciparum transmissionalong the Kenyan Coast. *American Journal of Tropical Medicine and Hygiene*, 68(6): 734–742.

Micieli, M. V., and Campos, R. E. (2003). Oviposition activity and seasonal pattern of a population of *Aedes (Stegomyia) aegypti* (L.) (Diptera: Culicidae) in Subtropical Argentina. *Memorias Do Instituto Oswaldo Cruz*, 98: 659–663.

Moore, C. G., Cline, B. L., Ruiz-Tiben, E., Lee, D., Romney-Joseph. H., and Rivera-Correa, E. (1978). *Aedes aegypti* in Puerto Rico: environmental determinants of larval abundance and relation to dengue virus transmission. *American Journal of Tropical Medicine and Hygiene*, 27: 1225–1231.

Olayemi, I. K., Omalu, I. C. J., Famotele, O. I., Shegna, S. P., and Idris, B. (2010). Distribution of mosquito larvae in relation to physico-chemical characteristics of breeding habitats in Minna, North Central, Nigeria. *Reviews in Infection*, 1(1): 49–53.

Piovezan-Borges, A. C., Valente-Neto, F., Urbieta, G. L., Laurence, S. G., and de Oliveira Roque, F. (2022). Global trends in research on the effects of climate change on *Aedesaegypti*: international collaboration has increased, but some critical countries lag behind. *Parasites & Vectors*, 15(1): 1–12.

Prakash, A., Bhattacharrya, D. R., Mohapatra, P. K., and Majarta, J. (1998). Mosquito fauna in a broken forest ecosystem of district Dibrugarh with updated list of mosquito record in Assam, India. *Entomon-Trivandrum*, 23(4): 291–298.

Qasim, M., Naeem, M., and Bodlah, I. (2014). Mosquito (Diptera: Culicidae) of Murree Hills, Punjab, Pakistan. *Pakistan Journal of Zoology*, 46(2): 523–529.

Rogers, D. J., and Randolph, S. E. (2006). Climate change and vector-borne diseases. *Advances in Parasitology*, 62: 345–381.

Samways, M. J. (1995). *Insect Conservation Biology*, Chapman & Hall, London, 358.

Service, M. W. (1992). Vector control. Where are we now? *Bulletin of the Society of Vector Ecology*, 17: 94–108.

Shanks, G., Hay, S., Stern, D., Biomndo, K., and Snow, R. (2002). Meteorologic influences on Plasmodium falciparum malaria in the highland tea estates of Kericho, western Kenya. *Emerging Infectious Diseases*, 8(12): 1404–1408.

Steib, B. M., Geier, M., and Boeckh, J. (2001). The effect of lactic acid on odour-related host preference of yellow fever mosquitoes. *Chemical Senses*, 26(5): 523–528.

Tennyson, S., Jayakumar, M. and William, S.J. (2007). *Culex* mosquito: An overview. *Defeating the public enemy, the mosquito: a real challenge. Chennai, India: Loyola Publication*, 95-116.

WHO. (2012). The global malaria situation: current tools for prevention and control. Global fund to fight AIDS, tuberculosis and malaria. 55 world assembly, WHO, document no. A551. INF. Doc. 16.

WHO. (2021). *"Dengue and severe dengue"*.

WHO. (2022). *World malaria report 2022*. World Health Organization.

Wolfe, M.S., and Aslamkhan, M. (1971). Filariasis in East Pakistan. *Transaction of Royal Society Tropical Medicine and Hygiene*, 65: 63–69.