Rahman *et al. Beni-Suef University Journal of Basic and Applied Sciences* (2021) 10:32
https://doi.org/10.1186/s43088-021-00122-x

Beni-Suef University Journal of Basic and Applied Sciences

RESEARCH

Open Access

Entomological survey for identification of *Aedes* larval breeding sites and their distribution in Chattogram, Bangladesh

Md. Sahidur Rahman[1,2*], Md. Omar Faruk[3], Sumiya Tanjila[1], Nur Mohammad Sabbir[1], Najmul Haider[4] and Sharmin Chowdhury[2]

Abstract

Background: Studying the characteristics of *Aedes* mosquito habitats is essential to control the mosquito population. The objective of this study was to identify the breeding sites of *Aedes* larvae and their distribution in Chattogram, Bangladesh. We conducted an entomological survey in 12 different sub-districts (Thana) under Chattogram City, during the late monsoon (August to November) 2019. The presence of different wet containers along with their characteristics and immature mosquitoes was recorded in field survey data form. Larvae and/or pupae were collected and brought to the laboratory for identification.

Results: Different indices like house index, container index, and the Breteau index were estimated. The multiple logistic regression analysis was applied to identify habitats that were more likely to be positive for *Aedes* larvae/pupae. A total of 704 wet containers of 37 different types from 216 properties were examined, where 52 (7.39%) were positive for *Aedes* larvae or pupae. Tire, plastic buckets, plastic drums, and coconut shells were the most prevalent container types. The plastic group possessed the highest container productivity (50%) whereas the vehicle and machinery group was found as most efficient (1.83) in terms of immature *Aedes* production. Among the total positive properties, 8% were infested with *Aedes aegypti*, 2% with *Aedes albopictus*, and 1% contained both species *Ae. aegypti and A. albopictus*. The overall house index was 17.35%, the container index was 7%, and the Breteau index was 24.49. Containers in multistoried houses had significantly lower positivity compared to independent houses. Binary logistic regression represented that containers having shade were 6.7 times more likely to be positive than the containers without shade ($p< 0.01$).

Conclusions: These findings might assist the authorities to identify the properties, containers, and geographical areas with different degrees of risk for mosquito control interventions to prevent dengue and other *Aedes*-borne disease transmissions.

Keywords: Entomological survey, *Aedes* mosquito, Dengue transmission, Breeding sites, Wet container, Vector-borne disease, *Stegomyia* indices, Vector control

* Correspondence: sahid.dvm@gmail.com
[1]One Health Center for Research and Action, Akbarshah, Chattogram 4207, Bangladesh
[2]One Health Institute, Chattogram Veterinary and Animal Sciences University, Khulshi, Chattogram 4225, Bangladesh
Full list of author information is available at the end of the article

1 Background

Aedes mosquitoes (Diptera: Culicidae) are a highly efficient vector of various arboviruses, including dengue, chikungunya, and Zika around the globe. Dengue fever is an important mosquito-borne disease (MBD) that poses a risk for more than 128 countries globally [1]. *Aedes aegypti* is the primary vector of the dengue virus (DENV) found in urban areas due to its anthropophilic blood-feeding behavior. *Aedes albopictus* belongs to the same subgenus (*Stegomyia*) considered as a secondary vector of DENV. They are primarily found in rural areas and peridomestic sites of urban areas like parks and green corridors interspersing housing estates. Both of these species were first recorded in Bangladesh in 1952 [2]. Since 2000, dengue fever (DF) cases have been reported every year in all major cities in Bangladesh [3]. The outbreak of chikungunya fever took place in 2008, and the Zika virus was also introduced in the country in 2016 [4, 5]. During 2019, Bangladesh recorded its largest dengue virus outbreak with 101,354 cases, more than double the cases in the last 20 years [6]. The *Aedes* spp. mostly breed in artificial water-holding containers but have been reported in natural containers as well [7]. Vector control remains the center of dengue prevention options, which can be done by limiting the transmission potential by reducing the emergence of adult mosquitoes. This could be achieved by targeting the aquatic habitats of the immature stages of *Ae. aegypti* through source reduction or biological and/or biocidal treatment [8, 9]. The productivity of a container type depends on a range of factors, such as size and shape, the purpose of use, their locations, method of filling (passively/actively), the material of the container (plastic, metal, cement/clay, etc.), temperature, availability of food, and competition among co-species [10, 11].

Various entomological indices are used to measure dengue vector infestation in and around infrastructures, such as homes and buildings [12]. Examples of such indices are the different *Stegomyia* indices—house index (HI, the proportion of *Aedes* positive houses) and container index (CI, the proportion of *Aedes* positive containers), and the Breteau index (BI, the number of *Aedes* positive containers per 100 houses) [13, 14]. There is a lack of a sensitive vector surveillance tool to estimate the vector density in the outbreak areas. Therefore, the vector abundances for both *Ae. aegypti* and *Ae. albopictus* are still expressed as house index, Breteau index, and container index.

A few studies on *Aedes* mosquito abundance and breeding preference were conducted in the capital city Dhaka, Bangladesh. However, data on other big cities like Chattogram, the 2nd popular city in the country, are still absent. Therefore, during the late monsoon (August to November) of 2019, we conducted a comprehensive entomological survey in Chattogram. The expansion of residential areas to natural ecosystems, continuous changes in biodiversity, and increasing industrial areas in Chattogram promote the human-vector contact and the transmission of arboviruses to humans [15]. The objective was to identify the breeding sites of *Aedes* larvae and their distribution in Chattogram metropolitan area.

2 Methods

This entomological survey was conducted in late monsoon in 2019 between August and November, when dengue incidence was high in the study area and throughout Bangladesh [6]. The study location was Chattogram City of Bangladesh. Chattogram is the second largest city of Bangladesh and an area poorly studied in terms of mosquito surveys. A total of 12 sub-districts (Thana) under the Chattogram City Corporation (CCC) area were chosen for this survey (Fig. 1). A Thana is defined as the small administrative boundaries within the metropolitan area.

2.1 Entomological survey

An entomological study for DENV was designed to detect immature stages of the *Aedes aegypti* (L.) (Diptera: Culicidae). Our survey targeted all groups of juveniles (1st–4th instar larvae and pupae) by inspecting all accessible water-holding containers in public and private areas to identify the most productive and efficient container types of these species. The wet container is defined as any container with stagnant water at the time of the survey. Samples were taken by pipetting, dipping, or netting [16] in small plastic jars with water. Each sample jar was labeled with the unique identification number, date, location, and number of collected larvae/pupae. Breeding habitats of the collected mosquito species were recorded in a pre-defined survey data sheet during the sample collection (Appendix 1). Different indices were calculated to document the primary breeding source and density of the *Aedes* mosquito. A container was recorded as positive for *Aedes* if one or more juvenile *Ae. aegypti* or *Ae. albopictus* was found in the given type of container and was distinguished from those with no juveniles (negative). During the survey period, the ambient temperature of the area ranged from 21 to 32 °C. The rainfall was 435.6 mm in August, and then gradually decreased to 18.9 mm in November 2019 [17].

2.2 Selection of properties

A total of 18 different locations were surveyed, including government-owned properties. The properties were purposely selected from each Thana and were categorized into nine classes, depending on the possession of living properties, working stations, and other public gathering places, as shown in Table 1. Moreover, all properties were broadly divided into two classes—residential and

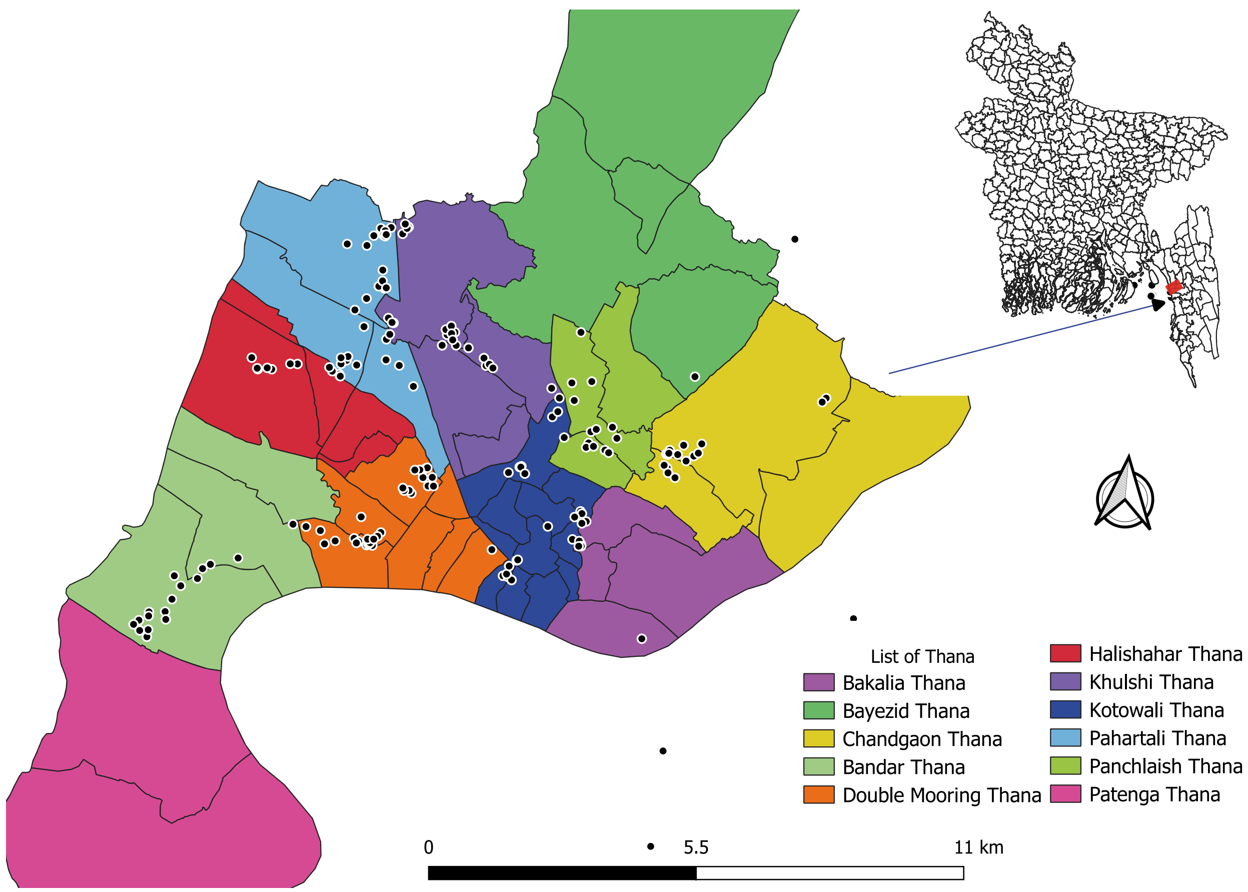

Fig. 1 Map of the study area with survey points

Table 1 Number and type of properties surveyed in each Thana

Types of properties	Number of properties from each Thana	Definition of different properties
Independent house	4	These were brick-built single-family homes, either single floor or duplex with the surrounding garden.
Multistoried house	4	These were brick-built apartment houses having two or more floors. More than one family lives in these houses.
Slum	4	Slum houses are usually made of bamboo and tin, or even mud walls. These are inadequate infrastructure with congested tenements.
Construction site	1	Independent or multi-storied buildings in the construction phase
Police station	1	The local police station area in each Thana. This is usually an area of a single building with an open place and garden.
Educational institution	1	Any properties like schools, colleges, universities, or others used for educational purposes. It comprises either small or big areas.
Hospital	1	Government or private hospitals, clinics, diagnostic centers
Open place/park	1	Any open spaces like parks, roadside places, or playgrounds without any establishment
Bus stand/garage	1	Small and large bus stands, garages, or fuel station

non-residential. All types of households were included under residential areas whereas other properties considered as non-residential areas.

2.3 Classification of containers found as larval development sites

The containers were divided into two broad groups based on their purposes: controllable and disposable ones. Controllable containers were household containers that could be manipulated by man to avoid mosquito larval breeding. It included concrete tanks, metal drums, flower pots, aluminum tanks, small buckets, and other plastic containers used to carry or store water. Disposable containers were those that are not used in households, are abandoned or stored in backyards having the potential as breeding sites in the rainy season. Examples of disposable containers include tires, cans, and tubs.

2.4 Identification of mosquitoes

After collection, the larvae and/or pupae were brought to the pathology and parasitology laboratory of Chattogram Veterinary and Animal Sciences University, located within the city of Chattogram. Larvae were identified under microscopes in the laboratory. Pupae and the rest of the larvae were reared in rearing trays for the identification of adult mosquitos. Species identification was completed using standard identification keys as described in a literature [18]. The laboratory findings were recorded in the corresponding survey sheet.

2.5 Determine the key containers

All wet containers were divided into six categories based on the materials they were composed of or the purposes they served. The categories were plastic receptacles, tin and metal receptacles, cement and clay receptacles, natural receptacles, vehicle and machinery parts, and other receptacles. The role of these container categories regarding the production of *Aedes* mosquito was estimated by the value of container productivity and container efficiency [19]

$$\text{PC} = \text{positive containers}$$
$$\text{CP} = \text{container productivity (no.of immaturex} \times 100/\text{all immature)}$$
$$\text{CE} = \text{Container efficiency (productivity/prevalence of container)}$$
$$\text{Prevalence of container} = \text{no.of wet containers} \times 100/\text{all containers}$$

2.6 Estimate different indices

The number of different wet containers, the percentage of positive containers, and the percentage of *Aedes* larvae in each container category were calculated to determine the various *Stegomyia* indices as follows [16]:

Container index: the percentage of water-holding containers infested with larvae and/or pupae

House index: the percentage of house infested with larvae and/or pupae

Breteau index: the number of positive containers per 100 houses inspected.

2.7 Statistical analysis

Zero-inflated negative binomial regression analysis was performed to find the factors associated with the number of immature *Aedes* positive mosquito per container. The binary logistic regression was used to find the odds of the background characteristics causing the containers to be *Aedes* positive. The exponential of the logistic regression parameter was the odds of the category of the background characteristics being *Aedes* positive of water-holding containers. The exponential of zero-inflated negative binomial regression was the ratio of the average number of immature *Aedes* positive mosquitoes among the groups of background characteristics. Data analysis was conducted in R version 3.5.2, and the binary logistic regression model was performed in SPSS version 25.

3 Results

A total of 704 wet containers of 37 varieties were identified around 216 surveyed properties, with a mean of 3.3 containers per property. Of these, 204 (29%) were controllable, and 500 (71%) were disposable containers. More containers were identified on privately owned properties (N = 531, 75%) than government (N = 173, 25%) owned properties. We collected 573 *Aedes* juveniles, including 101 pupae. The number of *Ae. aegypti* (n=371) was higher than the number of *Ae. albopictus* (202). We calculated the house index as 17.35%, container index 7%, and the Breteau index 24.49. The distribution of wet containers found in the entomological survey is summarized in Table 2.

3.1 Distribution of positive containers and juvenile *Aedes spp.*

Among the total of 704 wet containers, 49 (6.9%) were positive for immature *Aedes* mosquitoes. Among positive containers, 31% (n=15) were controllable (plastic bucket, plastic drums, plastic bag, and earthen jar), and 69% (n=34) were disposable (containers like tires, coconut shell, cock sheet, mineral water jar, and bamboo hole). A total of 32.65% (n=16) positive containers were found in government-owned properties, and the rest 67.35% (n=33) were in private properties. Among positives, 96% (n=47) of containers was under shades, and 39% (n=19) had vegetation in and around the container. Independent houses possessed maximum numbers of positive containers amounting 33% (n=16). Other than living places, different open places or parks contained 13% (n=6), and educational institutions had 10% (n=5) of the positive containers.

Table 2 General distribution of the background characteristics of wet containers in Chattogram, Bangladesh

Variables	Category	Frequency	Percentage	*Aedes*-positive container (%)
Container function	Controllable	204	29	15 (31)
	Deposable	500	71	34 (69)
Ownership	Government	173	25	16 (32.65)
	Private	531	75	33 (67.35)
Vegetation	No	401	58	30 (61)
	Yes	297	42	19 (39)
Shade	No	129	18	2 (4)
	Yes	572	82	47 (96)
Residence type	Residential area	432	61	30 (61)
	Non-residential area	272	39	19 (39)
Property category	Independent house	157	22	16 (33)
	Multistoried house	141	20	4 (8)
	Slum	134	19	10 (20)
	Police station	67	10	3 (6)
	Hospital	48	7	0 (0)
	Bus stand/garage	51	7	4 (8)
	Educational institutions	37	5	5 (10)
	Open place/park	49	7	6 (13)
	Construction site	20	3	1 (2)
Container category	Plastic reservoir	215	31	16 (33)
	Metal/tin/aluminum reservoir	47	7	2 (4)
	Cement/clay/ceramic reservoir	86	12	4 (8)
	Natural and plant material	181	26	13 (27)
	Vehicles and machinery items	116	16	12 (24)
	Others	59	8	2 (4)
Geographic location	Khulshi	109	15	8 (16)
	Pahartali	70	10	13 (27)
	Bakalia	41	6	2 (4)
	Kotowali	62	9	1 (2)
	Panchlaish	52	7	11 (23)
	Double Mooring	55	8	5 (10)
	Halishahar	22	3	3 (6)
	Bandar	43	6	1 (2)
	Chandgawn	91	13	1 (2)
	EPZ	51	7	1 (2)
	Akbarshah	69	10	3 (6)
	Bayezid	39	6	0 (0)

The highest positive containers were recorded in Panchlaish followed by Pahartali and Halishahar Thana. No positive containers were found in Bayezid Thana. Figure 2 shows the distribution of positive containers in different Thanas.

A total of 216 properties from 12 Thanas under the Chattogram City Corporation (CCC) area were visited, where 16.2% (n=35) properties were found positive for immature *Aedes* mosquito. Among the total positive properties, 7.2% (n=28) were infested with *Aedes aegypti* and 2.3% (n=9) were *Aedes albopictus*. Moreover, *Ae. aegypti* co-existed with *A. albopictus* in 1.3% (n= 5) properties.

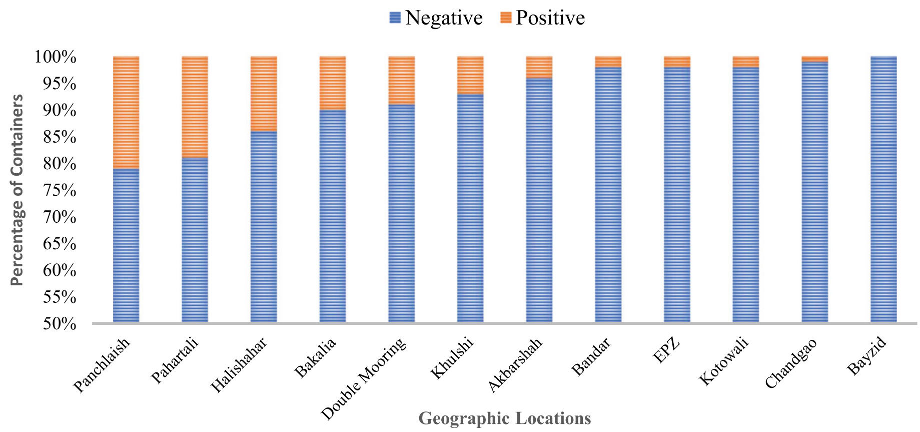

Fig. 2 Percentage of *Aedes* positive and negative containers in different geographical locations in Chattogram

Among individual containers, tires 16.33% (*n*=8) were revealed as the most productive container for the *Aedes* larval breeding, followed by plastic buckets 14.29% (*n*=7), coconut shells 12.24% (*n*=6), plastic drums 12.24% (*n*=6), and flower tub and tray 8.16% (*n*=4) (see Fig. 3).

3.2 Determining the key containers

According to immature *Aedes* production in different container categories, the plastic container had the most abundantly (33%) found positive and possessed the highest container productivity (50). Vehicle and machinery group was the most efficient (1.83) and 2nd most productive (30) group. The natural group contained 27% positive containers with container productivity of 11. So, these three container categories could be considered as necessary for *Aedes* spp. mosquito breeding. The role of all container categories is shown in Table 3.

Zero-inflated negative binomial regression (Table 4) revealed that the number of immature *Aedes* mosquito produced per container had a significant association with the property category and shade ($p < 0.01$). Binary logistic regression (Table 5) elucidated that containers having shade had 6.7 times more likely to be positive than the containers without shade ($p < 0.05$). Containers in multi-storied houses had significantly lower positivity in comparison to independent houses. Besides, Kotowali and Bandar Thana produced significantly lower number of positive containers ($p < 0.05$) as their odds found below one.

4 Discussion

We inspected a broad spectrum of wet containers from different properties in the second most populated city of Bangladesh and identified *Aedes* larvae and/or pupae. The total number of *Ae. aegypti* larvae and/or pupae was higher than the number of *Ae. Albopictus*, and the record was consistent with previous studies [20, 21]. Opposite results were found in Malaysia that 77% of breeding containers were positive for *Aedes albopictus* and 23% for *Aedes aegypti* [22]. As the survey was conducted in city areas only, the breeding sites of *Ae. albopictus* were reached partially which might be a reason

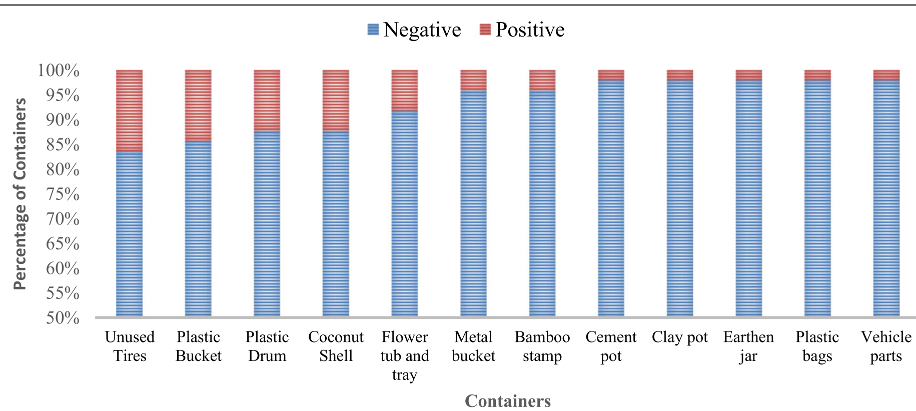

Fig. 3 Positive and negative percentages of different container types for *Aedes* breeding

Table 3 The efficiency of different container categories for the production of *Aedes* larvae

Container category	Containers	Frequency (%)	Positive containers (%)	Immature *Aedes*	CP	CE
Plastic receptacles	Plastic bucket, plastic drum, mineral water jar, Dahi pot, plastic bag, water tank, plastic bottle, plastic mug	215 (31)	16 (33)	4818	50	1.62
Tin and metal receptacles	Metal/tin can, metal bucket, metal drum, metal pan, aluminum pot	47 (7)	2 (4)	345	3.5	0.53
Cement and clay receptacles	Cement pot, clay pot, animal bowl, glass bottle, ceramic pot, melamine bowl, earthen jar	86 (12)	4 (8)	295	3	0.25
Natural receptacles	Coconut shell, mud hole, bamboo stamp, plant axil, tree hole, flooded floor, money plan tub, flower tub, and tray.	181 (25)	13 (27)	1086	11	0.43
Vehicle and machinery parts	Vehicle parts, tires, battery, water motor, cock sheet, air cooler, musical instrument, cement mixture	116 (17)	12 (24)	2934	30	1.83
Others receptacles	Unused sheet, plastic sheet, discarded food wrapper, broken toilet parts	59 (8)	2 (4)	275	3	0.34

CP = container productivity (no. of immature × 100/all immature)
CE = container efficiency (productivity/prevalence of container)
Prevalence of container = no. of wet containers × 100/all containers

for the lower count of *Ae. albopictus*. The mean number of wet containers per property was 3.3 in our study, which is comparatively lower than the mean numbers of two previous studies 4.20 found in Dhaka [7] and 7.9 found in Southern Mexico [23]. A possibility could be because people were more aware due to the devastating dengue epidemic in 2019.

The overall house index (HI), container index (CI), and Breteau index (BI) were calculated high which is supported by a similar study conducted in Dhaka earlier stating the overall HI 14.2%, BI 24.65, and CI 5.9% [7]. All of the indexes showed a high level of risk for dengue transmission. A survey in Nepal found higher CI in the post-monsoon period than monsoon [24]. A recent study in Malaysia showed maximum HI= 13.33%, BI=13, and CI=19.05% [22]. In a literature [13], it has been criticized that these indices are of operational value and are of limited use in assessing the transmission risk. However, these indexes are indicative of the global transmission risk at the community level.

The biggest portion of *Aedes* larvae containing water-holding containers was under the group of disposable containers. The estimated larval productions in disposable containers in other settings were 70% and 55.4% [23]. This indicates that the proper and regular disposal of unused containers will make a great contribution to vector control programs. The common containers for *Aedes* breeding were plastic containers (30%) in Kuala Lumpur, Malaysia [22]. As individual container types, we found the contribution of unused tires as the highest for *Aedes* larval breeding along with other key containers—plastic buckets, plastic drums, coconut shells, and flower tubes and trays. Our results are consistent with the findings of two previous studies in Dhaka, Bangladesh, conducted during 2011–2013 [25, 26]. A study in Nepal stated discarded tires as the preferable wet containers [24]. Another study revealed flower pots as the principal types of containers with *Ae. aegypti* larvae [27].

Figure 2 shows that Panchlaish, Pahartali, and Halishahar Thana contained maximum positive containers. These Thanas possess many residential areas residing a huge population of the city. And many parts under these areas become flooded after a rain due to poor sewerage system, whereas Bayezid Thana had no positive containers as this area is an intensive industrial hub with limited access and having minimum residential properties. Within a community, not all houses have the same potential for larval breeding. The identification of those houses that are likely

Table 4 Zero-inflated negative binomial regression of *Aedes* positive with the background characteristics of water-holding containers

Predictors	Estimate (coefficient)	Standard error	Odds ratio	Confidence interval at 95% level	
Vegetation (yes)	0.2212	0.2506	1.247573	0.7633177	2.0389762
Function (disposable)	−0.06422	0.39760	0.937799	0.4302001	2.0443182
Container category	0.13840	0.10919	1.148435	0.9271832	1.4224860
Property category (Mult. house)	1.49129	0.64479	4.442823	1.255475	15.721946 **
Location (Kotowali)	2.02446	1.15621	7.572021	0.7853205	73.0097627*
Property type (private)	−0.02158	0.57382	0.978651	0.3178280	3.0134419
Shade (yes)	−1.87277	0.77507	0.153697	0.0336452	0.7021209**

Significance codes: **0.01, *0.05

Table 5 Binary logistic regression to identify factors associated with the presence of *Aedes sp.* larvae and/or pupae

Predictors	Estimated	Standard error	Odds ratio	Confidence interval at 95%	
Function (controllable)			1		
Function (disposable)	0.091	0.431	1.095	0.471	2.547
Vegetation (no)			1		
Vegetation (yes)	0.685	0.42	1.983	0.87	4.521
Property type (Gov.)			1		
Property type (private)	0.15	0.695	1.162	0.297	4.539
Shade (no)			1		
Shade (yes)	1.902	0.808	6.701	1.374	32.675*
Property category (independent house)			1		
Property category (multistoried house)	−1.246	0.605	0.288	0.088	0.942*
Property category (slum)	−0.381	0.526	0.683	0.244	1.915
Property category (police stations)	0.358	1.104	1.431	0.164	12.461
Property category (hospitals)	−19.407	7369.331	0	0	.
Property category (bus stations)	0.03	0.905	1.031	0.175	6.07
Property category (educational institutions)	0.313	1.033	1.368	0.181	10.357
Property category (open place)	0.114	0.819	1.12	0.225	5.575
Property category (construction site)	−0.07	1.26	0.933	0.079	11.018
Thana (Khulshi)			1		*
Thana (Pahartali)	0.421	0.787	1.524	0.326	7.127
Thana (Bakalia)	−1.27	0.931	0.281	0.045	1.74
Thana (Kotowali)	−2.538	1.176	0.079	0.008	0.793*
Thana (Panchlaish)	0.285	0.657	1.33	0.367	4.823
Thana (Double Mooring)	−0.925	0.745	0.397	0.092	1.708
Thana (Halishahar)	−0.098	0.875	0.907	0.163	5.041
Thana (Bandar)	−2.45	1.182	0.086	0.008	0.876*
Thana (Chandgaon)	−1.74	1.185	0.175	0.017	1.791
Thana (EPZ)	−2.281	1.207	0.102	0.01	1.089
Thana (AkbarShah)	−1.406	0.826	0.245	0.049	1.237
Thana (Patenga)	−20.22	6992.331	0	0	.
Container category (plastic)			1		
Container category (metal)	−0.547	0.939	0.579	0.092	3.649
Container category (cement)	−0.439	0.682	0.644	0.169	2.452
Container category (natural)	−0.941	0.587	0.39	0.123	1.234
Container category (vehicles)	0.334	0.533	1.397	0.491	3.973
Container category (others)	−1.724	0.851	0.178	0.034	0.945*

Significance codes: *0.05

to have high larval production is important to better direct control activities. Independent households having disposable wet containers in shaded outdoor premises were significantly associated with the infestation of *Aedes* larvae [7]. Notably, the survey found more juveniles in containers of private properties compared to those on government properties, similar to the findings of a previous study which showed more containers on privately owned properties than in government properties [28]; private properties also have 1.7 times greater odds (95% CI = 1.1–2.5) of being infested compared with containers on government properties [29]. We observed that *Ae. aegypti* and *A. albopictus* co-existed in different properties supported by an earlier study in Jinghong City, China [30]. It suggested that both species should be managed during the dengue epidemic season.

This study revealed that independent houses were the most infested with containers possessing *Aedes* larvae, followed by slums and open places/parks. The findings are concordant with the earlier studies conducted in other cities of the country which stated that the household positivity rate was the highest in independent houses (18.6%), followed by slum houses (14.3%), semi-permanent houses (12.9%), and multi-storied houses (12.8%) [7]. A study in Japan during a dengue epidemic showed that more than 80% of dengue patients visited a city park where *Ae. albopictus* was present [31]. It reveals that positive containers in open places/parks might impose risk of the dengue fever for city dwellers.

The observations or experimental units were the water-holding containers spread over the different locations in Chittagong city. We analyzed the count data of the number of immature *Aedes*-positive larvae and/or pupae per container, with access zero accounts for non-*Aedes*, by a statistical model. A multiple regression model was applied using the predictors of background characteristics (container function, ownership, vegetation, shade, property category, container category, and geographic location) of water-holding containers [28]. To deal with access zero, we considered the zero-inflated Poisson regression model [32] and zero-inflated negative binomial regression model [33] to find the association between the number of immature *Aedes*-positive mosquitoes per container and the background characteristics of the water-holding containers. Both of the considered models are modifications of the count data regression model. The Akaike Information Criteria (AIC) value was calculated to find the improved model between the two [34, 35]. The zero-inflated negative binomial regression model (543.82) has less AIC value than the zero-inflated Poisson regression model (693.16). Hence, the zero-inflated negative binomial regression model better fit our data.

Containers located under any shelter that did not allow rain water to get into are considered as containers with shade. We observed that wet containers under shade were more likely to have *Ae. aegypti*, unlike previous findings where more larvae and pupae were detected in containers without shade than the containers located in areas with full shades [26]. The opposite findings may have been due to the classification of containers as partially shaded and fully shaded by the researchers. However, a recent study in Dhaka found that containers with partial shades produced 4.6 times more pupae than without shade [25]. Containers located outdoors and proximal to vegetation were significant for producing larvae [29]. We also found odds greater than one for containers possessing vegetation. Vegetation in and around containers might enhance mosquito breeding by facilitating resting sites for gravid females to lay eggs and important sugar-feeding resources for larvae [36]. The larval production of any species of mosquitoes is significantly affected by vegetation near the containers [26].

Probability sampling was not performed in this study which could lead to a selection bias in the result. We examined the surroundings outside of the properties, excluding the inside. The survey covered different residential and non-residential properties like open places/parks, educational institutes, hospitals but devoid of shopping/open market areas, other office buildings, and religious buildings. The total number of containers was also limited to some extent. A few recent studies used different container parameters like size or volume of the container, exposure to sunlight, cover status, and filling methods for evaluating container productivity. We considered exposure to sunlight/shade and vegetation status, function of composing materials of containers. Previous studies suggested that the extensive vector control program by reducing breeding sites could maintain a low *Aedes* house index [27]. Therefore, the weekly cleaning of the water-holding containers could effectively control larval production [21].

5 Conclusions

The study detected *Ae aegypti* in 8%, *Ae albopictus* in 2% of the properties, and the co-existence of both *Ae. aegypti* and *A. albopictus* in 1% of properties, which posed high risks of dengue transmission. The presence of shades on the breeding sites could significantly increase the risk of having *Aedes spp.* mosquito larvae. Plastic containers were the most abundant and productive containers while the vehicle and machinery category was found as the most efficient container group for *Aedes* mosquito breeding. We recommend vector control through regular inspection and destruction of potential container types to prevent the dengue outbreak.

Abbreviations

Ae: *Aedes*; /: Divide; etc.: Etcetera; <: Less than; ×: Multiply; *n*: Number; R: Analytic software; 2nd: Second; spp.: Species; SPSS: Statistical packages for social sciences

6 Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43088-021-00122-x.

Additional file 1: Appendix 1. Survey sheet

Acknowledgements

We would like to thank the residents and the police department of Chattogram City for allowing us in their premises. We acknowledge the sincere guidance from Mrs. Entazar Ferdous, district entomologist, Chattogram. We are also thankful to all the research ambassadors who worked under the "One Health Center for Research and Action" especially Imran Khan, Tishita Sen Ape, Md. Mynul Islam, and Md. Ibnul Bakhtier for their assistance during the field work.

Authors' contributions

Conceptualization: MSR, NH. Methodology: MSR, NH. Field-work and data curation: MSR, ST, NMS. Laboratory work: MSR. Data analysis: MSR, OMF, SC. Writing—original draft: MSR, MOF, ST, NMS. Writing—review and editing: SC, MSR, NH. The authors read and approved the final manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Availability of data and materials

Data and supporting materials will be available from the authors upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was carried out in accordance with the recommendations of the Chattogram Veterinary and Animal Sciences University's Ethics Committee. However, this study was waived for written approval and consent as it did not involve human participants, human data or human tissues.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Author details

[1]One Health Center for Research and Action, Akbarshah, Chattogram 4207, Bangladesh. [2]One Health Institute, Chattogram Veterinary and Animal Sciences University, Khulshi, Chattogram 4225, Bangladesh. [3]Department of Statistics, Noakhali Science and Technology University, Noakhali, Bangladesh. [4]The Royal Veterinary College, University of London, London, UK.

Received: 4 February 2021 Accepted: 3 May 2021
Published online: 13 May 2021

References

1. WHO (2017) Dengue and severe dengue. Updated Apr 2017. Im Internet www.who.int/mediacentre/factsheets/fs117/en
2. Asir-Ud-Din M (1952) Mosquitoes breeding in tree-holes and bamboo stumps in Dacca (East Pakistan). Pak J Health 2:110–112
3. Mahmood B, Mahmood S (2011) Emergence of dengue in Bangladesh a major international public health concern in recent years. J Environ Res Manag 2:35–41
4. Khatun S, Chakraborty A, Rahman M, Nasreen Banu N, Rahman MM, Hasan SMM, Luby SP, Gurley ES (2015) An outbreak of chikungunya in rural Bangladesh, 2011. PLoS Negl Trop Dis 9(7):e0003907. https://doi.org/10.1371/journal.pntd.0003907
5. Salje H, Lessler J, Paul KK, Azman AS, Rahman MW, Rahman M, Cummings D, Gurley ES, Cauchemez S (2016) How social structures, space, and behaviors shape the spread of infectious diseases using chikungunya as a case study. Proc Natl Acad Sci 113(47):13420–13425. https://doi.org/10.1073/pnas.1611391113
6. Ahsan A, Haider N, Kock R, Benfield C (2020) Possible drivers of the 2019 dengue outbreak in Bangladesh: the need for a robust community-level surveillance system. J Med Entomol. https://doi.org/10.1093/jme/tjaa150
7. Ferdousi F, Yoshimatsu S, Ma E et al (2015) Identification of essential containers for *Aedes* larvae breeding to control dengue in Dhaka, Bangladesh. Trop Med Health 43(4):253–264. https://doi.org/10.2149/tmh.2015-16
8. Lin C-H, Schiøler KL, Ekstrøm CT, Konradsen F (2018) Location, seasonal, and functional characteristics of water holding containers with juvenile and pupal *Aedes aegypti* in Southern Taiwan: a cross-sectional study using hurdle model analyses. PLoS Negl Trop Dis 12(10):e0006882. https://doi.org/10.1371/journal.pntd.0006882
9. WHO (2014) Global strategy for dengue prevention and control 2012-2020. WHO, Geneva 2012. Assoc dengue symptoms with Haematol parameters a Retrosp study 10 Hosp India
10. Strickman D, Kittayapong P (2003) Dengue and its vectors in Thailand: calculated transmission risk from total pupal counts of *Aedes aegypti* and association of wing-length measurements with aspects of the larval habitat. Am J Trop Med Hyg 68(2):209–217. https://doi.org/10.4269/ajtmh.2003.68.209
11. Morrison AC, Gray K, Getis A, Astete H, Sihuincha M, Focks D, Watts D, Stancil JD, Olson JG, Blair P, Scott TW (2004) Temporal and geographic patterns of *Aedes aegypti* (Diptera: Culicidae) production in Iquitos, Peru. J Med Entomol 41(6):1123–1142. https://doi.org/10.1603/0022-2585-41.6.1123
12. Bowman LR, Runge-Ranzinger S, McCall PJ (2014) Assessing the relationship between vector indices and dengue transmission: a systematic review of the evidence. PLoS Negl Trop Dis 8(5):e2848. https://doi.org/10.1371/journal.pntd.0002848
13. Focks DA (2003) A review of entomological sampling methods and indicators for dengue vectors. World Health Organization, Geneva
14. Guo YH, Lai SJ, Liu XB et al (2016) Governmental supervision and rapid detection on dengue vectors: an important role for dengue control in China. Acta Trop 156:17–21. https://doi.org/10.1016/j.actatropica.2015.12.011
15. Ferro C, Las Salas J, González M et al (2015) Do some conditions contribute to the reemergence of the Venezuelan equine encephalitis virus in the Colombian Alta Guajira? Biomédica 35(1):62–72. https://doi.org/10.1590/S0120-41572015000100009
16. WHO (2009) Dengue guidelines for diagnosis, treatment, prevention and control
17. Weather2visit (2020) Chittagong weather averages & monthly temperatures | Bangladesh | Weather-2-Visit. https://www.weather2visit.com/asia/bangladesh/chittagong.htm. Accessed 26 Mar 2021
18. Rueda L (2004) Pictorial keys for the identification of mosquitoes (Diptera: Culicidae) associated with dengue virus transmission
19. Hammond SN, Gordon AL, Del Lugo EC, et al. (2007) Characterization of *Aedes aegypti* (Diptera: Culcidae) production sites in Urban Nicaragua
20. Dhar-Chowdhury P, Haque CE, Lindsay R, Hossain S (2016) Socioeconomic and ecological factors influencing *Aedes aegypti* prevalence, abundance, and distribution in Dhaka, Bangladesh. Am J Trop Med Hyg 94(6):1223–1233. https://doi.org/10.4269/ajtmh.15-0639
21. Arunachalam N, Tana S, Espino F, Kittayapong P, Abeyewickreme W, Wai KT, Tyagi BK, Kroeger A, Sommerfeld J, Petzold M (2010) Eco-bio-social determinants of dengue vector breeding: a multicountry study in urban and periurban Asia. Bull World Health Organ 88(3):173–184. https://doi.org/10.2471/BLT.09.067892
22. Amierul Fikri Mahmud M, Hatta Mutalip M, Aliza Lodz N et al (2018) Study on key *Aedes spp* breeding containers in dengue outbreak localities in Cheras district, Kuala Lumpur. Int J Mosq Res 5:23–30
23. Danis-Lozano R, Rodriguez MH, Hernández-Avila M (2002) Gender-related family head schooling and *Aedes aegypti* larval breeding risk in Southern Mexico. Salud Publica Mex 44(3):237–242. https://doi.org/10.1590/s0036-36342002000300007
24. WHO (2014) Dengue Bulletin. https://apps.who.int/iris/bitstream/handle/10665/204945/B5158.pdf;jsessionid=67D7917D78E52202605FA76C6368F083?sequence=1. Accessed 26 Dec 2020
25. Islam S, Haque CE, Hossain S, Rochon K (2019) Role of container type, behavioural, and ecological factors in *Aedes* pupal production in Dhaka, Bangladesh: an application of zero-inflated negative binomial model. Acta Trop 193:50–59. https://doi.org/10.1016/j.actatropica.2019.02.019
26. Paul KK, Dhar-Chowdhury P, Haque CE, al-Amin HM, Goswami DR, Kafi MAH, Drebot MA, Lindsay LR, Ahsan GU, Brooks WA (2018) Risk factors for the presence of dengue vector mosquitoes, and determinants of their prevalence and larval site selection in Dhaka, Bangladesh. PLoS One 13(6):e0199457. https://doi.org/10.1371/journal.pone.0199457
27. Egger J, Ooi E et al (2008) Reconstructing historical changes in the force of infection of dengue fever in Singapore: implications for surveillance and control. SciELO Public Heal:187–196
28. Lin CH, Schiøler KL, Ekstrøm CT, Konradsen F (2018) Location, seasonal, and functional characteristics of water holding containers with juvenile and pupal *Aedes aegypti* in Southern Taiwan: a cross-sectional study using hurdle model analyses. PLoS Negl Trop Dis 12(10):e0006882. https://doi.org/10.1371/journal.pntd.0006882
29. Walker KR, Williamson D, Carrière Y, Reyes-Castro PA, Haenchen S, Hayden MH, Jeffrey Gutierrez E, Ernst KC (2018) Socioeconomic and human behavioral factors associated with *Aedes aegypti* (Diptera: Culicidae) immature habitat in Tucson, AZ. J Med Entomol 55(4):955–963. https://doi.org/10.1093/jme/tjy011

30. Liu Q, Guo Y, Lai S et al (2016) Coexistence of *Aedes aegypti* and *Aedes albopictus* in Jinghong City, Yunnan Province: a survey of *Aedes aegypti* invasion. J Trop Dis 4:1–6
31. Tsuda Y, Maekawa Y, Ogawa K, Itokawa K, Komagata O, Sasaki T, Isawa H, Tomita T, Sawabe K (2016) Biting density and distribution of *Aedes albopictus* during the September 2014 outbreak of dengue fever in Yoyogi park and the vicinity of Tokyo metropolis, Japan. Jpn J Infect Dis 69(1):1–5. https://doi.org/10.7883/yoken.JJID.2014.576
32. UCLA (2020) Zero-inflated Poisson regression | R data analysis examples. https://stats.idre.ucla.edu/r/dae/zip/. Accessed 28 Sep 2020
33. UCLA (2020) Zero-inflated negative binomial regression | R data analysis examples. https://stats.idre.ucla.edu/r/dae/zinb/. Accessed 28 Sep 2020
34. Zeileis A, Kleiber C, Jackman S (2008) Regression models for count data in R. J Stat Softw 27(8):1–25. https://doi.org/10.18637/jss.v027.i08
35. CRAN (2020) CRAN - Package AICcmodavg. https://cran.r-project.org/web/packages/AICcmodavg/index.html. Accessed 28 Sep 2020
36. Chaves LF, Keogh CL, Nguyen AM, Decker GM, Vazquez-Prokopec GM, Kitron UD (2011) Combined sewage overflow accelerates immature development and increases body size in the urban mosquito *Culex quinquefasciatus*. J Appl Entomol 135(8):611–620. https://doi.org/10.1111/j.1439-0418.2010.01580.x

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.