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BREEDING HABITAT PREFERENCES OF *Aedes aegypti* AS A DENGUE VECTOR IN URBAN AREAS OF BANJARMASIN, INDONESIA

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ABSTRACT

Dengue fever continues to be a public health challenge in Indonesia, especially in urban areas such as Banjarmasin City, where mosquito breeding is closely linked to household water storage practices. Despite ongoing control efforts, limited entomological data on larval habitats hinders the implementation of targeted and effective vector control programs. This study aims to identify and describe the breeding habitat preferences of *Aedes aegypti* in urban areas, both endemic and non-endemic areas in Banjarmasin. A cross-sectional larval survey was conducted in 235 households across eight neighbourhoods, during which 948 water-holding containers were examined for mosquito larvae. Entomological indices, including the House Index (HI), Container Index (CI), and Breteau Index (BI), along with the Breeding Preference Ratio (BPR), were calculated. Associations between container characteristics and larval presence were assessed using chi-square tests and binary logistic regression analysis. Of all inspected containers, 21.7% were found positive for larvae. Although buckets were the most common, they were not the preferred breeding sites. Flower vases exhibited the highest BPR (5.20), indicating a greater likelihood of larval occurrence. Containers located outdoors were significantly associated with larval infestation (OR = 3.366; 95% CI: 1.522–7.444), while other factors such as container material, colour, presence of fish, and cleaning frequency showed no significant relationship. The results of this study highlight the influence of container type and placement on the breeding behaviour of *Ae. aegypti*. These findings support the implementation of behaviour-focused measures, namely prioritizing high-risk container types and encouraging routine cleaning and biological control to reduce the risk of dengue transmission.

Keywords: *Aedes aegypti*; breeding habitat preference; dengue vector; container index; Banjarmasin

ABSTRAK

Demam denggi terus menjadi cabaran kesihatan awam di Indonesia, terutamanya di kawasan bandar seperti Kota Banjarmasin, di mana pembiakan nyamuk berkait rapat dengan amalan penyimpanan air isi rumah. Walaupun usaha pengawalan sedang dijalankan, data entomologi terhadap habitat pembiakan larva yang terhad menghalang pelaksanaan program kawalan vektor yang bersasar dan berkesan. Kajian ini bertujuan untuk mengenal pasti dan menghuraikan keutamaan habitat pembiakan *Aedes aegypti* di kawasan bandar, iaitu di kawasan endemik dan bukan endemik di Banjarmasin. Satu tinjauan larva keratan lintang telah dijalankan di 235 isi rumah merentasi lapan kejiranan, di mana sebanyak 948 bekas takungan air telah diperiksa untuk kehadiran larva nyamuk. Indeks entomologi termasuk Indeks Rumah (HI), Indeks Bekas (CI), dan Indeks Breteau (BI) bersama dengan Nisbah Keutamaan Pembiakan (BPR) telah dikira. Perkaitan antara ciri-ciri bekas dan kehadiran larva dinilai menggunakan ujian khi kuasa dua dan analisis regresi logistik binari. Daripada kesemua bekas yang diperiksa, 21.7% didapati positif larva. Walaupun baldi adalah bekas yang paling biasa dijumpai, ia bukanlah tempat pembiakan pilihan. Jambangan bunga menunjukkan BPR tertinggi (5.20), menandakan kecenderungan yang lebih tinggi untuk kehadiran larva. Bekas yang terletak di luar rumah didapati mempunyai perkaitan signifikan dengan infestasi larva (OR = 3.366; 95% CI: 1.522–7.444), manakala faktor lain seperti jenis bahan bekas, warna, kehadiran ikan dan kekerapan pembersihan tidak menunjukkan hubungan yang signifikan. Dapatan kajian ini mengetengahkan pengaruh jenis dan penempatan bekas terhadap tingkah laku pembiakan *Ae. aegypti.* Penemuan ini menyokong pelaksanaan langkah-langkah yang berfokuskan tingkah laku, iaitu mengutamakan jenis bekas berisiko tinggi serta menggalakkan pembersihan rutin dan kawalan biologi untuk mengurangkan risiko penularan denggi.

Kata kunci: *Aedes aegypti;* keutamaan habitat pembiakan; vektor denggi; indeks bekas; Banjarmasin

INTRODUCTION

Dengue fever is a viral disease transmitted by *Aedes aegypti* and *Ae. albopictus* mosquitoes that have become a serious global health threat, especially in tropical and subtropical regions. The World Health Organization (WHO) reports that between 2022 and 2023, more than 6.5 million cases of dengue fever and more than 6,800 deaths were recorded worldwide (Paz-Bailey et al. 2024). The disease is mainly transmitted by *Ae. aegypti*, a mosquito species that thrives in close association with human habitats and commonly breeds in water-filled containers found in and around residential areas (Fansiri et al. 2021; Indriyani et al. 2025; Sauer et al. 2021).

Despite widespread vector control efforts, dengue incidence rates continue to show an upward trend in many endemic countries, including Indonesia. Indonesia is one of the countries with reported outbreaks of dengue almost every year, particularly in densely populated urban areas (Gibb et al. 2023; Mamenun et al. 2024; Yin et al. 2022). One such endemic area is the city of Banjarmasin in South Kalimantan Province, which has consistently reported high case numbers over the past decade. Banjarmasin City is experiencing a worsening Dengue Hemorrhagic Fever (DHF) outbreak, with incidence rates climbing from 5.79 per 100,000 population in 2019 to 12.10 per 100,000 in 2023, and a concurrent increase in Case Fatality Rate (CFR) from 2.4% to 6.8%. This detrimental trend is in direct opposition to the World Health Organization's 2030 targets (25% reduction in incidence, 50% reduction in CFR) and the Indonesian Ministry of Health's goal of maintaining an incidence rate below 10 per 100,000 population. These alarming statistics underscore the critical imperative for immediate and effective interventions in Banjarmasin to align with these national and global health agendas. The combination of a tropical climate, rapid urban growth, and high population density creates conditions that are highly conducive to the development of *Ae. aegypti* populations in the region (Norjanah & Ridha 2024; Ridha et al. 2026).

A deep understanding of vector ecology, particularly the breeding habitat preferences of mosquitoes, is crucial in designing effective and sustainable control strategies. Identifying the most productive breeding sites is fundamental because larval control, or source reduction (PSN), remains the primary strategy for dengue prevention. Control efforts that target all containers uniformly are less efficient and effective than those focused on the specific habitat types preferred by *Ae. aegypti* for oviposition. By understanding these preferences, programs can prioritize resources toward the containers that contribute most to the mosquito population, thereby maximizing the public health impact of PSN activities. However, to date, entomological surveillance data specific to the most productive containers supporting the development of *Ae. aegypti* in Banjarmasin City remains limited. Yet, data-driven control strategies have proven more efficient, especially in areas with similar characteristics (Gouveia et al. 2025; Nagaraj et al. 2025). This data limitation poses a challenge in designing efficient control programs at the local level.

The habitat preferences for *Ae. aegypti* breeding are influenced by a combination of various factors, including physical environmental characteristics, climatic conditions, and human behavior (Chandrasegaran et al. 2020; Nurdin et al. 2022). Several studies have shown that these mosquitoes typically choose containers such as water storage tanks, flower pots, or used plastic containers as breeding sites (Agus Nurjana et al. 2023; Prasad et al. 2023). However, the type and productivity of larval and pupae habitats vary greatly depending on local geographical and socio-cultural conditions (Combs et al. 2022; Macêdo et al. 2021, Hashim and Ahmad. 2025). Therefore, identifying the most productive breeding habitats in a given area is crucial to support larval-focused control interventions, which remain the primary strategy for dengue prevention, especially given the limited availability of vaccines and effective antiviral treatments.

Banjarmasin City is an economic and educational center, so the rapid pace of urbanization has led to many new residential areas, which are expected to affect the ecological dynamics of mosquito vectors. However, research specifically examining these changes is still limited. Therefore, this study aims to identify and describe the breeding habitat preferences of *Ae. aegypti* in dengue-endemic areas in Banjarmasin Regency, Indonesia. The results of this study are expected to provide evidence-based understanding that supports the formulation of vector control strategies tailored to local conditions and strengthens community-driven sustainable interventions for dengue prevention.

MATERIALS AND METHODS

Study Sites

Banjarmasin City is geographically positioned between 3°16'46"–3°22'54" South Latitude and 114°31'40"–114°39'55" East Longitude, covering an administrative area of 98.46 km². The city is divided into five administrative districts, South, East, West, Central, and North Banjarmasin (Figure 1). Known as the "City of a Thousand Rivers," Banjarmasin is traversed by the Barito and Martapura rivers, spanning approximately 25.07 kilometers. It is also the most populous city in South Kalimantan, with a total population of 657,663 residents recorded in 2022. In terms of healthcare infrastructure, the city is equipped with 9 general hospitals, 3 specialty hospitals, 28 community health centers (*puskesmas*), 77 clinics, and 232 pharmacies, all contributing to the surveillance and management of vector-borne diseases. This study was conducted in eight selected urban villages (*kelurahan*) across Banjarmasin City, representing both endemic and non-endemic areas. The endemic sites included Sungai Andai, Karang Mekar, Pemurus Baru, and Kuripan, while the non-endemic sites comprised Alalak Selatan, Belitung Utara, Kelayan Dalam, and Sungai Bilu. An area is classified as dengue hemorrhagic fever (DHF) endemic when cases are reported every year for at least three consecutive years, indicating sustained local transmission, with evidence of indigenous transmission rather than imported cases, the presence and establishment of the vectors *Ae. aegypti*, and a recurring or seasonal pattern of cases that typically increases during the rainy season.

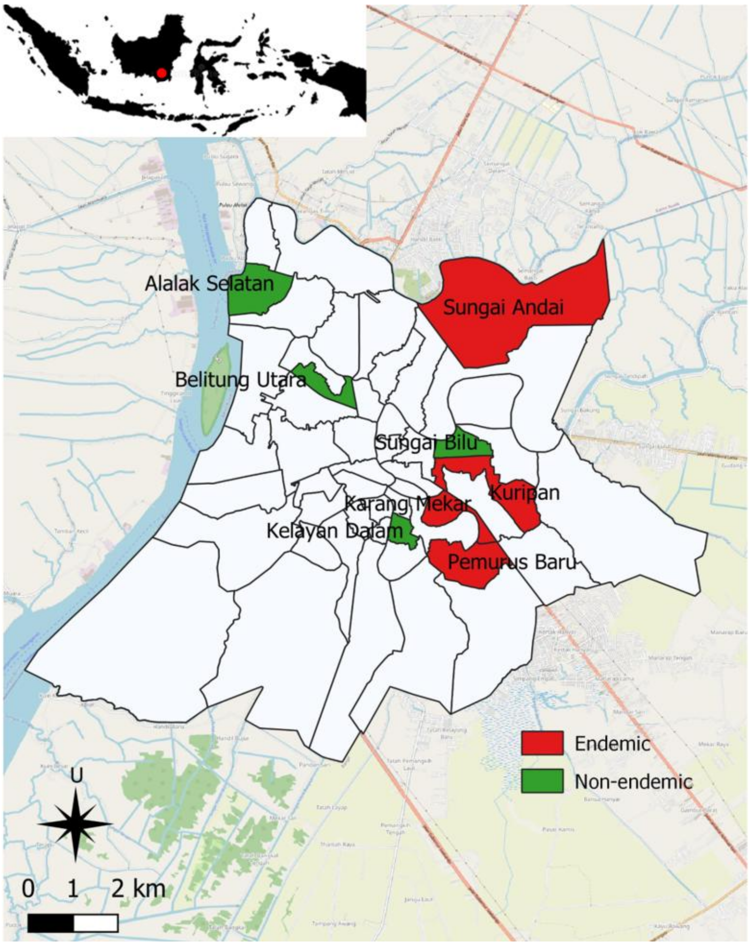

Figure 1. Study Sites in Banjarmasin, Indonesia

Study Design

This study used a community-based cross-sectional design to assess the breeding habitat preferences of *Aedes aegypti* and related container characteristics in endemic and non-endemic urban areas in Banjarmasin City, Indonesia. Data were collected using the single-larva method in water containers in selected households. The sample size was calculated using the single population proportion formula for cross-sectional studies (Lakens 2022):

$$n = \frac{Z^2 \times p(1-p)}{d^2}$$

where n = minimum sample size, Z = 1.96 (95% confidence level), p = expected proportion of positive larvae, and d = margin of error (precision). Based on previous larval surveys in urban areas of Indonesia that reported approximately 19% positive containers (Wanti et al. 2017), p was set at 0.20 and d at 0.05. The minimum sample size calculated was 235 households. Households were randomly selected from eight urban villages representing endemic and non-endemic areas for dengue fever.

Larval Survey

The survey applied the single-larva method for each water-holding container found to contain larvae (WHO 2016). A total of 235 households were included in the study, with samples randomly selected from various locations. Both natural and artificial containers, located inside and around the houses, were inspected for the presence of mosquito larvae. Observations were carried out using flashlights and larval collection bottles to detect and collect larvae. Data recorded during the inspection included mosquito species, larval presence, container lid condition, color, and placement location.

To ensure systematic inspection, larval surveys were conducted both indoors and outdoors in each selected household. Indoor areas inspected included the kitchen, bathroom/toilet, bedroom, living room, and any other rooms containing water-holding containers. Outdoor areas covered the yard, garden, veranda, drainage surroundings, animal shelters, and other peri-domestic spaces within the household compound. All accessible water-holding containers whether permanent or temporary, covered or uncovered were carefully examined using a flashlight for the presence of larvae. When larvae were detected, a single specimen was collected using a larval dipper or pipette for identification.

Container types were categorized into 11 categories: bathtub/toilet, drum, jar/barrel, bucket, holy water/ablution container, animal container (drinking or feeding container), refrigerator reservoir, plant part (tree hole/leaf stalk), vase/flower pot, and others if outside these categories (Ridha & Sulasmi 2022). Color, condition, location, presence of fish, and history of temefos use were also observed in this study.

All collected larvae were placed in labeled plastic vials containing water from the original container and transported to the Entomology Laboratory on the same day of collection. In the laboratory, larvae were first sorted and rinsed with clean distilled water to remove debris. Specimens were then preserved in 70% ethanol for morphological examination. Prior to identification, larvae were examined under a stereomicroscope (40–100× magnification) and, when necessary, mounted temporarily on glass slides using lactophenol solution to allow detailed observation of diagnostic structures.

Data collection was conducted by 12 trained enumerators. Prior to field implementation, all enumerators participated in a structured training session covering study objectives, operational definitions, larval inspection procedures, container classification, and data recording protocols. A field pilot test was conducted in a non-study area to standardize inspection techniques and ensure consistency in identifying and recording container characteristics. To ensure alignment of operational understanding, a calibration session was carried out in which each questionnaire item and observational variable was discussed in detail. This process included clarification of operational definitions (e.g., container type classification, criteria for indoor and outdoor categorization, definition of weekly drainage, and presence of larvivorous fish) to minimize inter-observer variability. Discrepancies identified during the pilot phase were reviewed collectively, and consensus was established before formal data collection commenced. During field data collection, enumerators were accompanied by sanitation officers or dengue program managers from the local health authority. Data collection was conducted after obtaining official permission from the head of the local authority in each village to ensure administrative compliance and community acceptance.

Larva Identification

Larvae collected from positive containers were morphologically identified to species level in the laboratory using standard taxonomic keys. Identification of *Ae. aegypti* was performed under a stereomicroscope at 40–100× magnification based on morphological characteristics described in the pictorial identification keys by Rueda (2004), published by Walter Reed Biosystematics Unit (Rueda 2004). Species determination was based on diagnostic larval characters including: (1) a short and stout siphon with a siphon index typically ranging from 2.0–3.0; (2) a single row of evenly spaced pecten teeth along the basal portion of the siphon; (3) comb scales on abdominal segment VIII arranged in a single patch, each scale bearing a long median spine with lateral fringes; (4) the presence of seta 1–X (anal segment) with multiple branches; and (5) thoracic and abdominal chaetotaxy patterns consistent with *Ae. aegypti*.

Data Analysis

Data analysis was conducted in two phases: descriptive and inferential. In the descriptive phase, standard entomological indices were calculated following the guidelines of the World Health Organization (WHO 2016). The formulas used were as follows:

House Index (HI)

$$HI = \frac{\text{Number of houses positive for larvae}}{\text{Total number of houses inspected}} \times 100$$

Container Index (CI)

$$CI = \frac{\text{Number of containers positive for larvae}}{\text{Total number of containers inspected}} \times 100$$

Breteau Index (BI)

$$BI = \frac{\text{Number of containers positive for larvae}}{\text{Total number of houses inspected}} \times 100$$

These indices are widely used indicators for assessing dengue vector infestation levels and transmission risk. In addition, three habitat-specific indices were calculated to assess breeding preference patterns (Flaibani et al. 2020; Herath et al. 2024):

Index of Available Containers (IAC)

$$IAC_i = \frac{\text{Number of containers of type } i}{\text{Total number of containers inspected}} \times 100$$

Index of Contribution to Breeding Sites (ICBS)

$$ICBS_i = \frac{\text{Number of positive containers of type } i}{\text{Total number of positive containers}} \times 100$$

Breeding Preference Ratio (BPR)

$$BPR_i = \frac{ICBS_i}{IAC_i}$$

where i_i represents each container category. A BPR value >1 indicates that a container type contributes disproportionately more to larval production relative to its availability, suggesting preferential breeding.

In the inferential phase, associations between container characteristics (location, material, color, presence of fish, and cleaning frequency) and larval occurrence (binary outcome: presence/absence) were analyzed using chi-square tests for bivariate comparisons. Variables with *P<0.25* in bivariate analysis were entered into a binary logistic regression model to estimate adjusted Odds Ratios (OR) with 95% Confidence Intervals (CI). Model fit was assessed using the Hosmer–Lemeshow goodness-of-fit test, with *P>0.05* indicating adequate model calibration.

RESULTS

A total of 948 water storage containers were inspected during the survey in endemic and non-endemic areas, with 206 containers (21.7%) found to be positive for *Ae. aegypti* larvae. Figure 2 shows some of the storage containers found to contain larvae, such as bathtubs (indoor and outdoor), buckets, plant pots, used tires, and water dispenser containers. The most dominant type of container was the bucket, accounting for nearly half of all containers inspected (44.6%), and also contributing the largest proportion of containers positive for larvae (23.8%). In endemic areas, the most commonly found containers were buckets (35.5%), followed by bathtubs (20.5%) and drums (10.6%). In non-endemic areas, buckets were found in greater numbers, accounting for 53% of the total containers, followed by jars and bathtubs. Interestingly, all flower vases or pots found (14 units) showed the presence of larvae, making them the container type with the highest positive rate (100%) (Table 1). Conversely, some container types, such as coconut shells and natural plant parts (such as tree holes and leaf sheaths), showed no larvae at all during the observation period.

Table 1. Number of containers positive for larvae based on endemicity

Containers	**Endemic**		**Non-Endemic**		**Total**	
	Frequency (%)	**Frequency Positive Larvae (%)**	**Frequency (%)**	**Frequency Positive Larvae (%)**	**Frequency (%)**	**Frequency Positive Larvae (%)**
<u>*Artificial (human-made)*</u>						
bathub/toilet	93.0 (20.5)	17.0 (15.3)	69.0 (14.0)	20.0 (21.2)	162.0 (17.1)	37.0 (18.0)
Drum	48.0 (10.6)	19.0 (17.1)	23.0 (4.7)	8.0 (8.4)	71.0 (7.5)	27.0 (13.1)
Jar/barrel	48.0 (10.6)	6.0 (5.4)	73.0 (14.8)	17.0 (17.9)	121.0 (12.8)	23.0 (11.2)
Bucket	161.0 (35.5)	26.0 (23.4)	262.0 (53.0)	23.0 (24.2)	423.0 (44.6)	49.0 (23.8)
Holy water/ablution basin	7.0 (1.5)	0.0 (0.0)	18.0 (3.6)	1.0 (1.1)	25.0 (2.6)	1.0 (0.5)
Animal trough	7.0 (1.5)	3.0 (2.7)	7.0 (1.4)	6.0 (6.3)	14.0 (1.5)	9.0 (4.4)
Refrigerator storage container	7.0 (1.5)	1.0 (0.9)	4.0 (0.8)	0.0 (0.0)	11.0 (1.2)	1.0 (0.5)

Containers	**Endemic**		**Non-Endemic**		**Total**	
	Frequency (%)	**Frequency Positive Larvae (%)**	**Frequency (%)**	**Frequency Positive Larvae (%)**	**Frequency (%)**	**Frequency Positive Larvae (%)**
Dispenser storage container	8.0 (1.8)	2.0 (1.8)	1.0 (0.2)	1.0 (1.1)	9.0 (0.9)	3.0 (1.5)
Vase/flower pot/coaster	13.0 (2.9)	13.0 (11.7)	1.0 (0.2)	1.0 (1.1)	14.0 (1.5)	14.0 (6.8)
Others (water storage containers)	53.0 (11.7)	24.0 (21.6)	36.0 (7.3)	18.0 (18.9)	89.0 (9.4)	42.0 (20.4)
<u>*Natural*</u>						
Coconut shell/husks	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Plant parts (tree holes/leaf stalks)	9.0 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	9.0 (0.9)	0.0 (0.0)
TOTAL	454.0 (100.0)	111.0 (100.0)	494.0 (100.0)	95.0 (100.0)	948.0 (100.0)	206.0 (100)

Figure 2. *Aedes* mosquito breeding habitats identified during entomologival surveillance. 1. Tub (outdoor), 2. Bucket (indoor), 3. Tub (indoor), 4. Plant pot (plastic mineral water bottle), 5. Bucket (outdoor), 6. Plant pot (water tray), 7. Used tire, 8. Water dispenser container

Analysis of the three main entomological indices shows that endemic and non-endemic areas have relatively similar levels of larval infestation, although there are differences in the intensity of infestation. The House Index (HI) in endemic areas was recorded at 43.70%, while it was slightly higher at 43.97% in non-endemic areas, indicating that nearly half of the houses inspected in both areas had *Aedes* larvae. The prevalence of houses infested with larvae did not differ between endemic and non-endemic areas (PR=0.99; 95% CI:0.73–1.34; P=0.964). The

Container Index (CI), which describes the proportion of water containers infested, shows slightly different results; endemic areas have a CI of 24.45% and non-endemic areas at 19.23%. However, the prevalence of positive containers was significantly higher in endemic areas (PR=1.27; 95% CI: 1.01–1.60; P=0.046). The most striking difference was observed in the Breteau Index (BI), where the endemic area recorded a value of 93.28 compared to 81.90 in the non-endemic area. The Breteau Index showed no statistically significant difference between the two areas (RR=1.14; 95% CI:0.91–1.44; P=0.118) (Table 2). This indicates that in the endemic area, there are more positive containers per 100 households, suggesting a higher potential risk of transmission.

Table 2. Larval Index based on Endemicity

Variable	**Endemic**	**Non-Endemic**	**PR/RR (95% Confidence Intervals)**	***P*-Value**
Number of houses infested	52	51		
Total number of houses inspected	119	116		
Number of positive containers	111	95		
Total number of containers inspected	454	494		
House Index (HI) (%)	43.70*	43.97*	0.99 (0.73-1.34)	0.964[a]
Container Index (CI) (%)	24.45*	19.23*	1.27 (1.01-1.60)	0.046[a]
Breteau Index (BI)	93.28*	81.90*	1.14 (0.91-1.44)	0.118[b]

PR: Prevalence Rate (for HI and CI); RR: Rate Ratio (for BI)
*above standard (WHO Standard Description : HI standard: < 5%, CI standard: < 3–5% and BI standard: < 20 (WHO 2016)).
[a]Chi-square test
[b]Rate proportion test

Analysis based on breeding site location showed distinct patterns between endemic and non-endemic areas. In endemic areas, 61 out of 340 indoor containers (17.9%) were positive for larvae, compared to 60 out of 377 indoor containers (15.9%) in non-endemic areas. This difference was not statistically significant (PR = 1.13; 95% CI: 0.81–1.58; P=0.467). In contrast, outdoor containers showed a significantly higher larval positivity rate in endemic areas (43.9%) than in non-endemic areas (29.9%). Outdoor containers in endemic areas were 1.47 times more likely to contain larvae (PR = 1.47; 95% CI: 1.05–2.06; P=0.024). These findings suggest that while *Ae. aegypti* is commonly associated with indoor breeding, outdoor containers play a more prominent role in sustaining transmission in endemic areas (Table 3).

Table 3. Comparison of Indoor and Outdoor Breeding Sites between Endemic and Non-Endemic Areas

Location	**Endemic Positive Larvae (%)**	**Non-Endemic Positive Larvae (%)**	**PR (95% CI)**	***P*-Value**
Indoor	17.9	15.9	1.13 (0.81-1.58)	0.467
Outdoor	43.9	29.9	1.47 (1.05-2.06)	0.024*

PR: Prevalence Rate; CI: Confidence Intervals
*Chi-square test *P<0.05*

The results of the analysis of the breeding preference ratio (BPR) indicate that certain types of containers are more likely to be preferred habitats for *Ae. aegypti*. In endemic areas, containers with the highest BPR values were flower vases (4.09), animal containers (1.75), and drums (1.62), indicating a strong preference for these types of containers despite their relatively low numbers. In non-endemic areas, a similar pattern is observed, with flower pots (5.20), animal containers (4.46), and dispenser containers (5.20) having the highest BPR values. However, when statistically compared between endemic and non-endemic areas using prevalence ratios (PR) with 95% confidence intervals, most container types did not show significant differences in larval positivity. For example, bathtubs showed a lower likelihood of infestation in endemic areas (PR = 0.63; 95% CI: 0.35–1.12; P=0.118), and jars/barrels also demonstrated a non-significant lower risk (PR = 0.54; 95% CI: 0.23–1.25; P=0.146). Drums did not differ significantly between areas (PR = 1.14; 95% CI: 0.58–2.24; P=0.701).

Conversely, buckets although the most commonly found containers have low BPR values in both regions (0.66 in endemic and 0.46 in non-endemic), indicating that buckets are less preferred compared to other container types when considering the proportion of larvae presence relative to their availability. Buckets in endemic areas were 1.84 times more likely to be positive for larvae compared to those in non-endemic areas (PR = 1.84; 95% CI: 1.10–3.07; P=0.019) (Table 4).

Table 4. BPR Index by container type in endemic and non-endemic study sites

No.	Containers	Endemic			Non-Endemic			PR (95% CI)	*P*-Value
		IACs (X%)	ICBSs (Y%)	BPR (Y%/X%)	IACs (X%)	ICBSs (Y%)	BPR (Y%/X%)		
1	Bathtub	20.48	15.32	0.75	13.97	21.05	1.51	0.63 (0.35-1.12)	0.118
2	Drum	10.57	17.12	1.62	4.66	8.42	1.81	1.14 (0.58-2.24)	0.701
3	Jar/barrel	10.57	5.41	0.51	14.78	17.89	1.21	0.54 (0.23-1.25)	0.146
4	Bucket	35.46	23.42	0.66	53.04	24.21	0.46	**1.84 (1.10-3.07)**	**0.019***
5	Holy water/ablution basin	1.54	0.00	0.00	3.64	1.05	0.29	-	0.548[f]
6	Animal trough	1.54	2.70	1.75	1.42	6.32	4.46	0.50 (0.19-1.33)	0.091
7	Refrigerator storage container	1.54	0.90	0.58	0.81	0.00	0.00	-	0.694[f]
8	Dispenser storage container	1.76	1.80	1.02	0.20	1.05	5.20	-	0.398[f]
9	Plant parts (tree holes/leaf stalks)	1.98	0.00	0.00	0.00	0.00	0.00	-	-
10	Vase/flower pot/coaster	2.86	11.71	4.09	0.20	1.05	5.20	-	0.312[f]
11	Coconut shell/husks	0.00	0.00	0.00	0.00	0.00	0.00	-	-
12	Others (water storage containers)	11.67	21.62	1.85	7.29	18.95	2.60	0.91 (0.55-1.50)	0.713

IACs: Inspected Available Containers; ICBSs: Infested Containers Based on Survey; BPR: Breeding Preference Ratio; PR: Prevalence Ratio; CI: Confidence Interval
* Chi-square test: *P<0.05*
[f] Fisher's exact test

Figure 3 illustrates the physical characteristics of containers based on type, material, and color in endemic and non-endemic areas. In general, buckets are the most commonly found type of container in both areas, indicating their great potential as breeding sites for *Ae. aegypti* mosquitoes. In terms of material, plastic dominates as the main material for containers, reflecting the common use of containers in household environments. Meanwhile, the most commonly found container colors are dark colors, particularly black and dark blue, which are ecologically preferred by *Aedes* mosquitoes as oviposition sites.

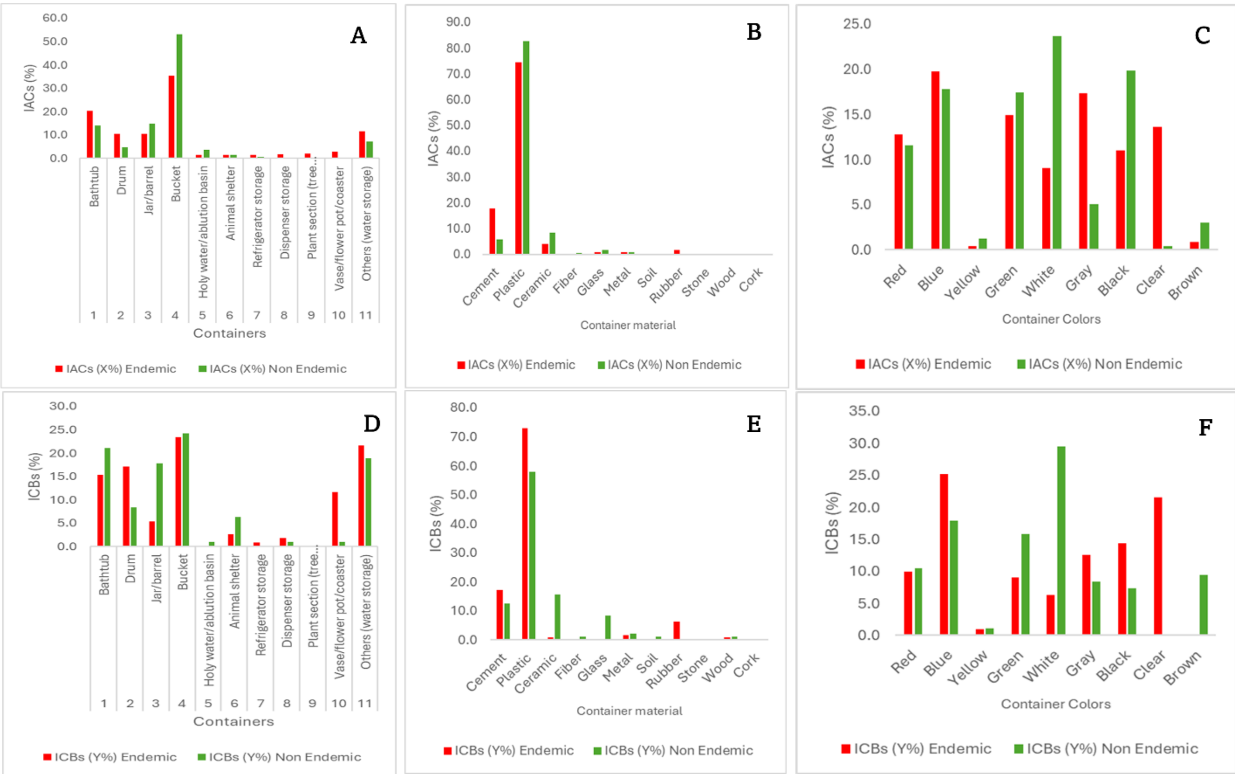

Figure 3. Characteristics of containers in endemic and non-endemic areas. A. IACs Type, B. IACs Material, C. IACs Color, D. ICBs Type, E. ICBs Material, F. ICBs Color

Figure 4 shows the distribution of container characteristics based on location, presence of fish that eat mosquito larvae, and frequency of water drainage per week in endemic and non-endemic areas. In both regions, most containers were found outside homes, but the proportion was higher in non-endemic areas. The presence of fish as biological agents for mosquito larvae control was very low in all containers examined, both in endemic and non-endemic areas. Meanwhile, the practice of draining containers at least once a week appeared to be more common in non-endemic areas than in endemic areas. This pattern suggests that differences in community behavior regarding container management, particularly concerning container placement and preventive measures such as emptying and maintaining fish, may contribute to variations in mosquito larvae infestation levels between regions.

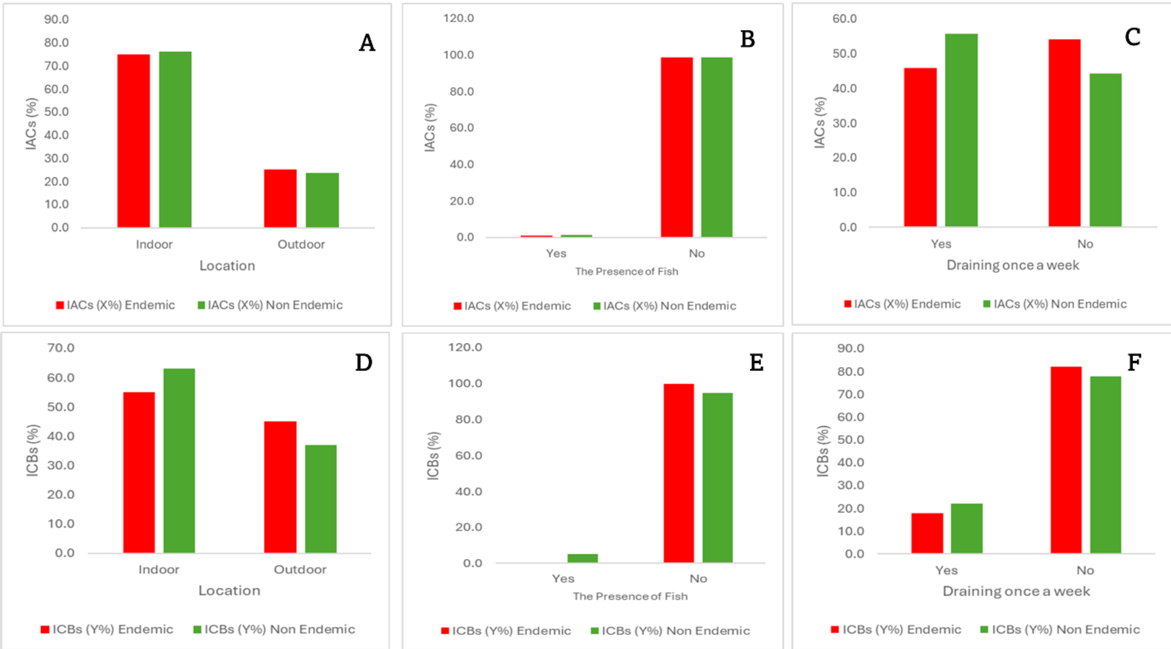

Figure 4. Characteristics of containers in endemic and non-endemic areas. A. IACs Location, B. IACs Presence of Fish, C. IACs Draining once a week, D. ICBs Location, E. ICBs Presence of Fish, F. ICBs Draining once a week

Table 5 shows the results of bivariate and multivariate analyses of five container characteristics: location, material, color, presence of fish, and frequency of emptying. The results of the chi-square test indicate that only the container location variable shows a significant association with the presence of larvae (P=0.002), where containers located outside the house are more likely to test positive for larvae. This finding is reinforced in the binary logistic regression analysis, which shows that container location is the only significant predictor (P=0.003) with an odds ratio (OR) of 3.366 (95% CI: 1.522–7.444), meaning that containers located outside the house had more than three times the risk of being found with larvae compared to containers inside the house. Meanwhile, the variables of material, color, presence of fish, and frequency of emptying did not show a significant relationship in either analysis. The goodness-of-fit test using the Hosmer–Lemeshow test yielded a p-value of 0.459, indicating that the regression model used has good fit.

Table 5. Analysis of the Relationship between Location, Material, Color, Presence of Fish, and Drainage on the Presence of Larvae

Variable	Sig. (p)[1]	OR (95% CI)	Sig. (p)[2]	OR Multivariate (Exp(B))	CI 95% OR Multivariate	Hosmer–Lemeshow (p)
Container Location	0.002*	0.297 (0.134–0.657)	0.00*	3.366	1.522–7.444	0.459 (Step 1)
Container Material	0.691	0.615 (0.055–6.882)	0.825	0.76	0.067–8.591	-
Container Color	0.836	1.088 (0.490–2.414)	0.518	1.323	0.567–3.089	-
Fish Presence	0.272	2.535 (0.455–14.117)	0.533	1.766	0.296–10.541	-
Drainage Frequency/week	0.373	0.773 (0.438–1.364)	0.44	0.795	0.445–1.422	-

[2]Binary Logistic Regression, *Significant

DISCUSSION

One of the main findings in this study was the dominance of buckets as the most commonly found water container, but they did not have the highest breeding preference ratio (BPR). This indicates that although they are numerous, buckets are not proportionally the most preferred place for *Aedes aegypti* to lay eggs. In contrast, flower vases had the highest BPR in both areas, reaching 5.20 in the non-endemic area. Although flower vases exhibited the highest BPR, the limited number of such containers (only 14 containers found across all study sites) suggests caution in interpreting this as a true habitat preference. The small sample size may inflate the proportional impact of flower vases, and a larger sample would be needed to confirm whether this container type consistently functions as a major breeding site across different settings**.**

This finding confirms the results of previous studies in Guatemala and Brazil, which showed that *Ae. aegypti* tends to prefer relatively small, sheltered containers with dark colors for oviposition (Oliva et al. 2014; Soto-López et al. 2024). In Delhi, the most productive habitats were relatively small domestic containers such as clay pots, metallic vessels, and solid waste; clay containers were overwhelmingly preferred in lab choice tests (82% of eggs) over plastic, paper, metal, and glass (Prasad et al. 2023). The identification of small, confined containers, such as plastic buckets, grinding stones, and flower vases, as key breeding sites in larval surveys from India and temperate North America is consistent with experimental evidence of "claustrophilic" oviposition behavior in *Ae. aegypti* (Dharmamuthuraja et al. 2023; Soto-López et al. 2024; Wilson et al. 2020). In forced-oviposition assays, significantly more females deposited eggs in the smallest tubes (1.5–5 mL), reinforcing the species' attraction to spatially restricted aquatic habitats (Dagg et al. 2025).

The high BPR differences in flower vase-type containers, animal shelters, and dispensers highlight the importance of understanding the domestic behavioral context of local communities. In a previous study by Parker et al. (2020), it was found that mosquitoes tend to choose containers that are rarely cleaned and located in shaded areas, particularly those not detected in routine management programs (Parker et al. 2020). In the present study, observational data showed that the frequency of container emptying was low and the presence of larvivorous fish was rarely observed. However, these factors were not statistically analyzed in relation to larval presence, so their contribution to breeding risk cannot be conclusively determined. Further analysis would be needed to test whether these behavioral factors significantly influence container productivity**.** The location of the containers was statistically significant in influencing the presence of larvae, indicating a higher risk for containers outside the house.

Mosquito preference for outdoor containers can also be linked to microclimatic factors such as temperature, humidity, and light, which affect larval survival and pupal development. Evans et al. (2022) and Sukiato et al. (2019) explain that shaded microhabitats protected from direct sunlight support higher larval survival rates, explaining why outdoor containers, especially those under shade, are at higher risk (Evans et al. 2022; Sukiato et al. 2019). From a public health entomology perspective, the higher Breteau Index (BI) values in endemic areas (93.28) compared to non-endemic areas (81.90) indicate greater infestation intensity. The BI is a key indicator in determining the risk of dengue transmission, as it reflects the number of larval-positive containers per 100 households. The WHO recommends that a BI value above 50 is an indicator of high risk for a dengue outbreak (Morales-Pérez et al. 2020; WHO 2009).

Therefore, endemic areas in Banjarmasin require more aggressive interventions to reduce larval breeding sites, particularly those that are permanent or semi-permanent, such as bathtubs, drums, and water jars. Although a BI value above 50 according to the WHO indicates a high risk of dengue transmission, the application of this threshold in the urban context in Indonesia, including Banjarmasin, needs to be critically reviewed. Previous studies have shown that the larval index has limitations as a predictor of outbreaks because it is static and only describes the vector population at a single point in time, without considering dynamic factors such as adult mosquito population density, human population immunity, circulating dengue virus serotypes, and seasonal climate variations (Bowman et al. 2014; Cromwell et al. 2017). In endemic areas such as Banjarmasin, a high BI value does not always correlate directly with the occurrence of outbreaks because dengue transmission is also influenced by population mobility, housing density, and the effectiveness of existing vector control programs. Therefore, the interpretation of the WHO threshold needs to be adjusted to the local context and ideally supplemented with other indicators such as entomological surveys of adult stages, laboratory-confirmed case data, and spatial-temporal analysis to provide a more comprehensive picture of the risk.

This finding is reinforced by the observation that dark-colored plastic containers, particularly black and dark blue were the most commonly found in the field. The preference of *Ae. aegypti* for dark-colored oviposition sites has long been established, as such colors resemble natural habitats like tree holes and provide protection from direct sunlight (Jung et al. 2021; Menda et al. 2013). However, this preference is not exclusive to *Ae. aegypti*. A study by Nurjanah et al. (2023) demonstrated that *Ae. albopictus* also exhibits high oviposition attraction to black containers, indicating shared visual preferences between the two dengue vector species (Nurjanah et al. 2023). Differences in preference become more apparent when considering container type and material. Herath et al. (2024) reported that *Ae. aegypti* prefers rubber and cement materials, while *Ae. albopictus* tends to select natural habitats such as coconut shells and earthen pots (Herath et al. 2024). In the multivariate statistical analysis of the present study, container color and material were not found to be significant predictors of larval presence, likely due to the predominance of dark-colored plastic containers across all categories, which reduced variability in the analysis. These findings underscore that while both species share similar visual preferences, container material and type remain important distinguishing factors that should be considered in targeted vector control strategies.

Although the presence of fish that eat larvae is known to be effective as a biological control agent, data show that only a small proportion of containers have them. This indicates low adoption of biological control methods at the household level. A study in Brazil shows that integrating socio-ecological approaches and active community participation in vector control practices are crucial in reducing larval density (Little et al. 2017; Ryan et al. 2019). Limitations in drainage practices are also evident in this study, where only a small proportion of the community routinely drains water containers weekly. This practice is an important component of the 3M Plus strategy (drain, cover, and recycle), a behavior-based dengue control strategy that has been implemented in Indonesia for a long time. The lack of community compliance in maintaining water container cleanliness directly contributes to high infestation rates. Several studies indicate that community behavior significantly influences larval infestation rates (Gowelo et al. 2022; Ha et al. 2021; Ridha & Sulasmi 2022), and consistent health education is necessary to increase community participation (Hossain et al. 2024; Marston et al. 2020).

Overall, this study emphasizes the importance of locally-based entomological surveillance for understanding vector habitat dynamics and designing more focused control strategies. The use of indices such as BPR provides a quantitative approach to identifying containers with the highest contribution to larval populations, which is particularly important in the context of risk-based control. A similar study also showed that a quantitative approach to habitat preferences can significantly improve the efficiency of larval control interventions (Aik et al. 2019; Gowelo et al. 2022; Peterson & Rolston 2022).

Based on these findings, several practical vector control strategies can be implemented in Banjarmasin. First, control programs should prioritize containers with high breeding preference ratios (BPR), such as flower vases, rather than focusing only on the most abundant containers. This risk-based approach allows more efficient use of limited resources. Community-based interventions have proven effective in similar settings. For example, a study in Samarinda, Indonesia demonstrated that partnership-driven programs improved community participation and sustained vector control behaviors compared to conventional approaches (Ridha et al. 2023; Ridha et al. 2024). Similarly, an eco-bio-social approach in Latin America and the Caribbean successfully reduced mosquito breeding through community engagement and multi-stakeholder collaboration (Barkhad et al. 2025; Barkhad et al. 2026). For Banjarmasin, targeted health education should emphasize the specific risks of flower vases, animal shelters, and outdoor containers, combined with practical guidance on regular cleaning or larvicide use. Second, biological control methods deserve greater attention. The low adoption of larvivorous fish represents an untapped opportunity, but this can be done in combination. The combination of guppy fish (*Poecilia reticulata*) and a novel larvicide (Pyriproxyfen) product (Sumilarv 2MR) has shown significant results in reducing dengue cases (Shafique et al. 2019). Promoting native larvivorous fish in permanent outdoor containers (e.g., water jars, drums) could provide continuous larval control. Third, the strong association between larval presence and outdoor containers indicates that peri-domestic environments require specific intervention strategies. Future directions should also embrace technological innovations. Integrating entomological data, weather information, and digital mapping into early warning systems could shift dengue control from reactive to proactive (Saadatian-Elahi et al. 2025).

However, this study has several limitations that need to be considered. First, observations were made during a single survey period, so they do not reflect seasonal variations that may affect larval density. Second, data collection was conducted in urban areas without considering semi-urban or rural contexts, which may exhibit different habitat preference patterns. Third, limitations in recording other environmental parameters such as water temperature, pH, and organic matter content, which are known to influence larval development, limit deeper ecological interpretations. Fourth, Fourth, while the analysis identified container location as a notable predictor of larval presence, the overall explanatory power of the model was limited. This suggests that other unmeasured factors such as microclimate conditions, container material, water quality parameters, or human behavioral factors likely play important roles in determining container productivity. Therefore, the findings should be interpreted as identifying associations rather than establishing definitive causal relationships. As a direction for future research, longitudinal studies covering various seasons and regions with different demographic characteristics will provide a more comprehensive understanding. As a direction for future research, longitudinal studies covering various seasons and regions with different demographic characteristics will provide a more comprehensive understanding. Further research is also recommended to evaluate the effectiveness of educational approaches and community participation in larval-based control, as well as to explore the potential use of digital technology (e.g., GIS or AI) for location-based vector risk mapping.

CONCLUSION

This study found that although buckets were the most abundant containers, flower vases had the highest breeding preference, and outdoor containers were 3.4 times more likely to harbor *Ae. Aegypti* larvae. These findings underscore the need for vector control programs to shift from generalized interventions toward targeted strategies prioritizing high-risk containers (flower vases, animal troughs, dispensers) and outdoor locations. With Breteau Index values (93.28 endemic; 81.90 non-endemic) far exceeding the WHO threshold of 50, intensified larval source management is urgently needed. Recommendations include risk-based surveillance using BPR, community-based behavioral interventions promoting regular cleaning of outdoor containers, and integration of biological control methods. Future research should include longitudinal seasonal studies and digital technologies (GIS/AI) for real-time vector risk mapping to support evidence-based, locally adapted dengue control strategies.

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AUTHORS DECLARATION

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Conflict of Interest

The authors declare that they have no conflict of interest.

Ethics Declarations

Health Research Ethics Committee of the National Research and Innovation Agency, with approval number No: 076/KE.03/SK/04/2024.

Data Availability Statement

The original data is available on request from the author

Authors' Contribution

Muhammad Rasyid Ridha contributed to conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, and writing of the original draft, as well as review and editing. Misna Tazkiah and Ririh Yudhatuti contributed to conceptualization, data curation, formal analysis, investigation, methodology, resources, writing of the original draft, and review and editing. Yudi Yahya, Nurul Hidayah, and Liestiana Indriyati contributed to formal analysis, investigation, methodology, resources, writing of the original draft, review and editing, and project administration. Khairatun Nisa and Ahmad Budidarma contributed to conceptualization, data curation, formal analysis, investigation, writing of the original draft, review and editing, project administration, resources, supervision, validation, and visualization. Muhammad Pahruddin and Isnawati contributed to methodology, resources, writing of the original draft, review and editing, project administration, supervision, and validation.

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