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Abundance of adult *Aedes aegypti* and *Ae. albopictus* (Diptera: Culicidae) across six settlements in South Sulawesi, Indonesia

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Abstract. *Saputra FR, Wahid I, Supriyono, Hadi UK. 2025. Abundance of adult* Aedes aegypti *and* Aedes albopictus *(Diptera: Culicidae) across six settlements in South Sulawesi, Indonesia. Biodiversitas 26: 509-519. Aedes aegypti* and *Ae. albopictus* are major vectors of dengue, chikungunya, and Zika. These diseases impose a significant global health burden, particularly in tropical and subtropical regions where environmental conditions favor mosquito population growth and disease transmission. This study aimed to analyze the abundance of adult *Ae. aegypti* and *Ae. albopictus* across six settlements in South Sulawesi Province, Indonesia. Mosquito collections were conducted from January to October 2023. The selected settlements were Manuju, Pangembang, Tamala'lang, Adatongeng, Lae-Lae, and Panaikang. The findings indicated that *Ae. aegypti* was predominantly found indoors in Lae-Lae, with a total of 696 individuals (58.7%) from 100 surveyed houses, while *Ae. albopictus* was mostly found indoors in Pangembang, with 31 individuals (55.4%). Outdoors, *Ae. aegypti* was most abundant in Lae-Lae, where 32 individuals (80.0%) were captured in vegetated areas around 100 surveyed houses, such as near bamboo trees and other vegetation surrounding the settlements Similarly, *Ae. albopictus* was more frequently found outdoors in the same area, with 177 individuals (33.1%) captured under similar conditions. In total, *Ae. aegypti* was primarily found indoors, with 1186 individuals ($p<0.01$), while *Ae. albopictus* was mainly found outdoors, with 535 individuals ($p<0.001$). These findings reveal significant differences in the abundance of these mosquito species between indoors and outdoors, highlighting the influence of local environmental factors on their distribution in South Sulawesi Province, Indonesia.

Keywords: *Aedes* surveillance, distribution, habitat, propopack, vector-borne diseases

INTRODUCTION

The mosquitoes *Aedes aegypti* (Linnaeus, 1762) and *Ae. albopictus* (Skuse, 1894) (Diptera: Culicidae) are essential vectors of infectious diseases such as dengue, chikungunya, and Zika (Delrieu et al. 2023). *Aedes aegypti* is widely regarded as the primary vector for all three diseases (Souza-Neto et al. 2019), while *Ae. albopictus*, although capable of transmitting these viruses, is generally considered a secondary vector in many countries (Ferreira-De-Lima and Lima-Camara 2018). The spread of *Ae. aegypti* is marked by long-distance importation, whereas *Ae. albopictus* has expanded predominantly along the fringes of its distribution (Kraemer et al. 2019). In 2023, a total of 2,216,405 arboviral infection cases were reported across several American countries (Pan American Health Organization 2023). Of these, 1,994,088 (90%) were dengue cases, 213,561 (9.6%) were chikungunya cases, and 8,756 (0.4%) were Zika cases. Indonesian Ministry of Health (2024) reported that, as of the 17th week of 2024, 88,593 cases of dengue fever and 621 related deaths were recorded in Indonesia. Understanding the bioecology of vectors, including their population dynamics, abundance, and habitats, is crucial for epidemiology and the development of effective vector-borne disease control strategies (Hadi 2016).

Settlements with diverse environmental conditions and configurations play a significant role in shaping mosquito population dynamics and disease transmission patterns. Phenotypic analyses have deepened our understanding of local adaptation and seasonal pressures that may affect vector diseases (Chaiphongpachara et al. 2024). Urbanization, land-use changes, and variations in settlement structures create distinct ecological niches that influence the proliferation and survival of *Ae. aegypti* and *Ae. albopictus*. Agricultural land use/cover changes affect the abundance, distribution, and host-seeking behavior of anthropophagic and non-anthropophagic *Aedes* vectors (Zahouli et al. 2017). Research focusing on mosquito abundance and habitat distribution provides invaluable insights into the complex interactions between vector populations and their environments. Such studies are fundamental to understanding how these interactions contribute to the epidemiology of arboviral diseases.

Research focusing on the abundance and habitat of *Ae. aegypti* and *Ae. albopictus* has garnered much attention due to its implications for mosquito-borne disease epidemiology. Several studies on the abundance of *Aedes* spp. have been conducted in various regions of Indonesia. However, in Makassar City, Maros District, and Gowa

District, South Sulawesi, Indonesia, comprehensive studies on arboviruses and their vectors, *Ae. aegypti* and *Ae. albopictus*, are minimal despite relatively high dengue case reports in South Sulawesi Province, averaging 2,781 cases from 2017 to 2021 (Saputra et al. 2023).

The ecological diversity of settlements in South Sulawesi offers a unique opportunity to study the abundance and habitat preferences of *Ae. aegypti* and *Ae. albopictus*. These settlements include urban areas, rural regions, and coastal zones, each with distinct environmental conditions that can influence mosquito breeding and population dynamics. Understanding how these ecological factors shape mosquito populations is critical for designing localized and effective vector control strategies. For instance, urban settlements with dense human populations often provide abundant breeding sites for *Ae. aegypti*, while more rural or semi-urban areas may offer diverse ecological niches for *Ae. albopictus*. Padonou et al. (2023) reported *Ae. aegypti* exhibits a broader geographic distribution, while *Ae. albopictus* tends to have a more localized range.

The integration of ecological, entomological, and epidemiological factors is essential for developing targeted and sustainable public health interventions against arboviral diseases. The interplay of these factors influences the distribution and abundance of mosquito populations, thereby impacting disease transmission. Kolimenakis et al. (2021) emphasize the need for localized vector control strategies informed by ecological and epidemiological data to combat the spread of mosquito-borne diseases effectively.

This study aims to address the knowledge gap by analyzing the abundance of adult *Ae. aegypti* and *Ae. albopictus* across six settlements in South Sulawesi Province. Additionally, it evaluates the Breteau Index of larvae in the same area. By examining the bioecology of mosquitoes across different settlement configurations, this research provides insights into mosquito population dynamics and habitat preferences. These findings are crucial for developing context-specific vector control strategies tailored to the unique ecological conditions of each settlement.

MATERIALS AND METHODS

Study area

This study employed a cross-sectional observational approach conducted in three regions: Makassar City, Gowa District, and Maros District, South Sulawesi Province, Indonesia, from January to October 2023 (Figure 1, Table 1). Settlements were purposively selected to represent subdistricts with varying dengue endemicity and environmental conditions. Subdistricts with high dengue endemicity (Panaikang in Makassar City, Adatongeng in Maros District, and Tamala'lang in Gowa District) were selected based on recent dengue case data from local health centers (*Puskesmas*). Subdistricts with low dengue endemicity (Lae-Lae in Makassar City, Pangembang in Maros District, and Manuju in Gowa District) were included to explore mosquito populations under different conditions, such as coastal, lowland, and highland areas.

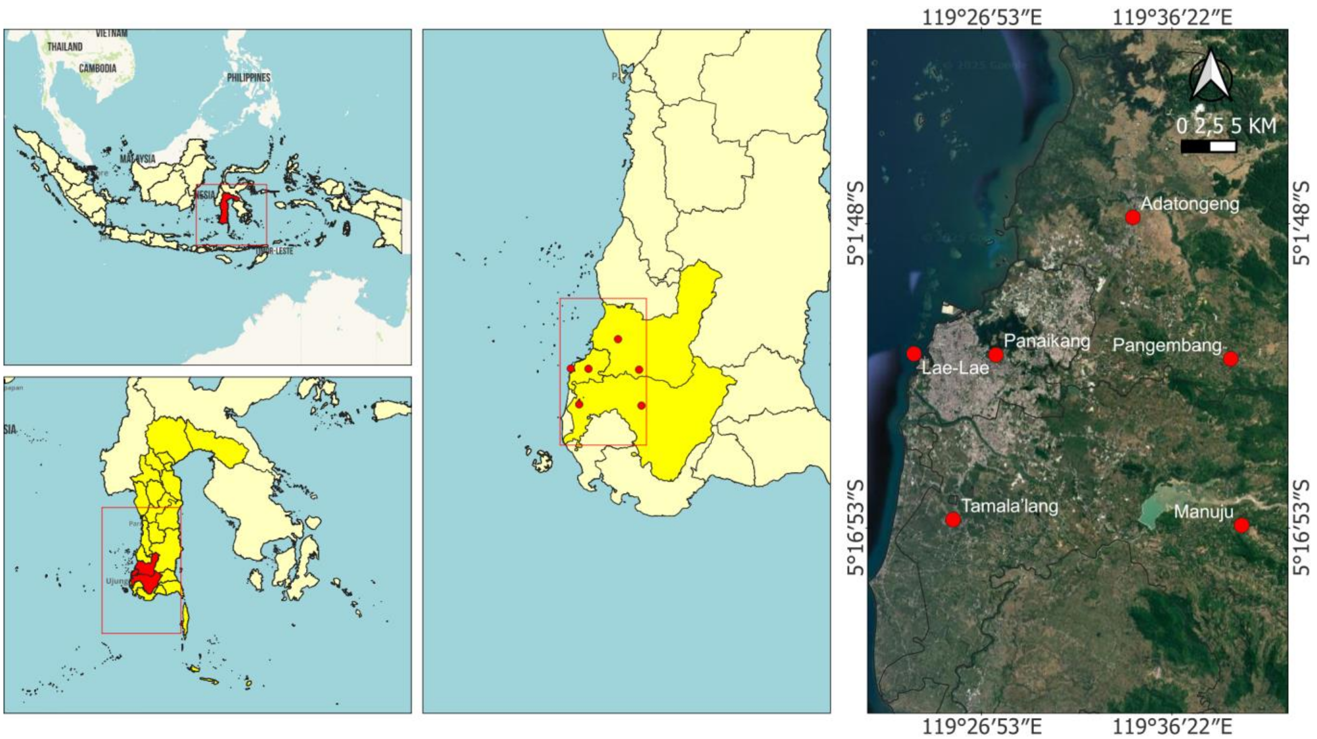

Figure 1. Research map of mosquito collection sites in six settlements in Makassar City, Maros, and Gowa Districts, South Sulawesi, Indonesia

Table 1. Characteristics of research locations and adult mosquito collection periods in South Sulawesi Province, Indonesia in 2023

Research location	Dengue endemicity	Subdistrict	Class.	Collection sites	Coordinate point	Month of mosquito adult collection
Gowa District	Low	Manuju	Rural	Manuju	5°16'45"S, 119°39'50"E	February (Indoors) and May (Outdoors)
Maros District	Low	Tompobulu	Urban	Pangembang	5°08'30"S, 119°39'17"E	March (Indoors) and June (Outdoors)
Gowa District	High	Bajeng	Urban	Tamala'lang	5°16'28"S, 119°25'28"E	August (Indoors; Outdoors)
Maros District	High	Turikale	Urban	Adatongeng	5°01'29"S, 119°34'25"E	July (Indoors; Outdoors)
Makassar City	Low	Ujung Pandang	Urban	Lae-Lae	5°08'15"S, 119°23'31"E	January (Indoors) and May (Outdoors)
Makassar City	High	Panakkukang	Urban	Panaikang	5°08'18"S, 119°27'36"E	September and October (Indoors; Outdoors)

The subdistricts with high dengue endemicity referred to in this study are those with an average of more than 52 dengue cases per 100,000 population between 2017 and 2021. Conversely, subdistricts with low endemicity are those with an average of fewer than 10 dengue cases per 100,000 population during the same period. This classification of endemicity refers to the 2022 Annual Report on Dengue Fever by the Indonesian Ministry of Health (2023). Data on dengue cases per district were obtained from the Health Offices in Makassar City, Gowa District, and Maros District, South Sulawesi Province. The focus of the study is on the abundance of *Ae. aegypti* and *Ae. albopictus*, rather than on the relationship with dengue endemicity, although the selection of areas based on endemicity provides context. The classification of urban and rural areas in this study refers to the villages/urban villages where adult mosquito collection was conducted, based on Regulation Number 120 of 2020 issued by the Head of the Indonesian Central Statistics Agency regarding the Classification of Urban and Rural Areas in Indonesia (Table 1).

Procedures

Sampling adult mosquitoes

The abundance of *Ae. aegypti* and *Ae. albopictus* in this study was collected from 100 residential houses (indoors) and vegetated areas around the settlements (outdoors). Sampling in 100 houses was aimed at targeting *Ae. aegypti*, while the surrounding vegetation was used to capture resting mosquitoes, particularly *Ae. albopictus*.

The tool used for mosquito collection in 100 residential houses (indoors) was a Prokopack aspirator (model: 140) (Figure 2), which has proven effective in *Aedes* adult mosquito surveys indoors (Dalpadado et al. 2022). Mosquito collection was conducted both inside and outside the houses. For outside collection, mosquitoes were gathered around the property, such as the yard, terrace, or other areas that are part of the house and not too far from the main building. Meanwhile, mosquito collection in the surrounding vegetation (outdoors) was carried out using a sweep net and manual aspirator. These tools were selected as they have been used in arbovirus studies on adult mosquitoes (Kuwata et al. 2020). In this study, mosquito collection was carried out in the surrounding vegetation of the settlement, which could serve as a resting site for *Ae. albopictus*, but not around animals (cattle or pigs).

Mosquito collection in 100 residential houses (indoors) was conducted in each settlement (a total of 600 houses) between 08:00 and 16:00 over a period of five to six days, with 20-30 houses visited each day (Vazquez-Prokopec et al. 2009). Meanwhile, mosquito collection in the surrounding vegetation of the settlement (outdoors) was carried out in the morning (06:00-08:00) and late afternoon (16:00-18:00) over three to four days in each settlement. Overall, we needed approximately 10 days per settlement for sampling. There are two observers for 100 houses, one collector, and assisted by one local resident per settlement (indoors). We only set one collector to collect adult mosquitoes in the vegetated area around the settlement (outdoors), but conditions in Lae-Lae and Manuju settlements require us to do it accompanied or assisted by two people; this is more for safety reasons and as needed. The collected mosquitoes were then transported to the Laboratory of the Center for Zoonotic and Emerging Diseases, Faculty of Medicine, Universitas Hasanuddin, Makassar, for identification using a stereo microscope based on the morphological descriptions of *Ae. aegypti* and *Ae. albopictus* mosquitoes (Supriyono et al. 2023).

Observation of mosquito larvae and pupae

Larval and pupal mosquito observations were conducted alongside adult mosquito collections in 600 houses across the six settlements. In both inside and outside the houses, common breeding sites such as water containers were inspected for the presence of mosquito larvae and/or pupae. Each container or site was visually checked, and the number of houses or containers with positive findings was recorded. The observation aimed to detect the number of houses and containers that tested positive for mosquito immatures, but no active collection or species-specific identification of larvae was performed. This was done simultaneously with the adult mosquito capture to provide a comprehensive assessment of mosquito abundance.

The selection of 100 houses in each settlement was based on guidelines outlined in Garjito et al. (2021), bringing the total number of houses observed to 600. In this study, the process involved examining containers or water-holding vessels for mosquito larvae and adult mosquito presence.

Figure 2. Mosquitoes were collected both indoors (houses) and outdoors (vegetation around the settlement). The methods used included: A. Using a sweep net and manual aspirator in the surrounding vegetation; B. Using a Prokopack aspirator indoors; C. Capturing an image of *Ae. aegypti*; D. Identifying mosquitoes with a stereo microscope

Data analysis

Data were analyzed using SPSS version 24. The abundance of adult *Ae. aegypti* and *Ae. albopictus*, both indoors and outdoors, across the six settlements was compared using the Kruskal-Wallis Test. Mosquito abundance was considered significantly different if the p-value was less than 0.05.

The criteria for larval density were determined based on the Breteau index (BI) (Focks 2003):

$$BI = \frac{Number\ of\ positive\ containers\ with\ larva\ and/or\ pupae}{Number\ of\ all\ houses\ inspected} \times 100$$

The density figure (DF) was calculated using the BI values. The larval density index is expressed on a scale from 1 to 9, categorized as follows: low density (DF: 1), medium density (DF: 2-5), and high density (DF: 6-9).

RESULTS AND DISCUSSION

Results

A survey was conducted in 100 houses at each of the six locations in South Sulawesi Province to observe containers containing mosquito larvae or pupae (unknown species) and to calculate the Breteau Index (BI) (Table 2). The BI across the six study locations ranged from moderate to high, with the highest value found in Lae-Lae (BI: 77) and the lowest value in Manuju (BI: 16). Overall, these results confirm the presence of containers positive for mosquito larvae or pupae, and the BI values at all locations indicate a potential risk for dengue transmission that requires attention.

This study recorded the number of adult *Aedes* mosquitoes captured indoors and outdoors at six different locations in South Sulawesi Province (Table 3). The results indicate a variation in the number of adult mosquitoes captured indoors and outdoors across the six settlements. The Lae-Lae location recorded the highest number of adult *Aedes* mosquitoes (921 individuals), with the majority found indoors (712 individuals), suggesting a high risk of mosquito-borne disease transmission in this area. In contrast, Panaikang recorded the lowest number of adult *Aedes* mosquitoes (124 individuals), all of which were found indoors, with no mosquitoes observed outdoors.

The results of the study show variation in the abundance of male and female *Aedes* mosquitoes across six locations based on their habitats, indoors and outdoors. Overall, the number of female *Aedes* mosquitoes was higher than that of males in most locations, especially indoors. The detailed distribution of male and female *Aedes* mosquitoes across the different locations, both indoors and outdoors, is shown in Figure 3.

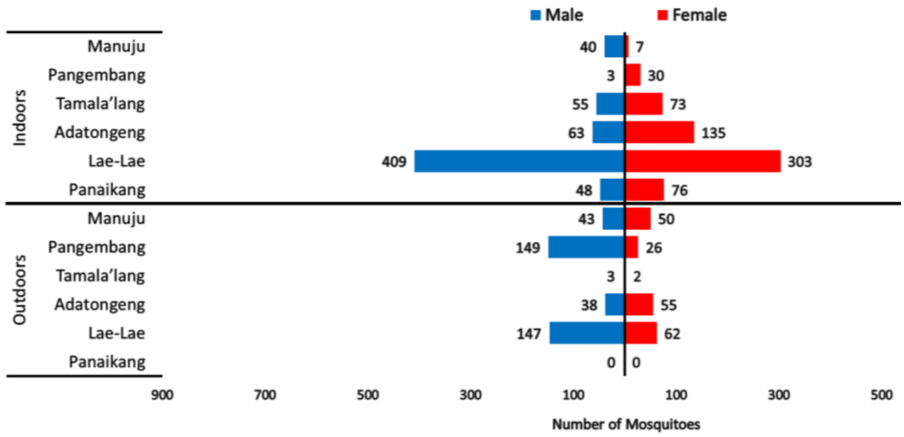

Figure 3. Abundance of male (blue) and female (red) mosquitoes based on habitat across six settlements in South Sulawesi Province, Indonesia in 2023

Table 2. Breteau Index (BI) for larvae based on indoor habitat

Sites	Number of houses surveyed	Number of container positive for larvae or pupae (unknown species)	Houses positive for larvae or pupae (unknown species)	Breteau index (Density figure)
Manuju	100	16	11	16 (Medium)
Pangembang	100	23	17	23 (Medium)
Tamala'lang	100	41	32	41 (Medium)
Adatongeng	100	29	21	29 (Medium)
Lae-Lae	100	77	47	77 (High)
Panaikang	100	44	28	44 (Medium)

Table 3. Total abundance of adult *Aedes* mosquitoes based on indoor and outdoor habitats

Sites	Indoors	Outdoors	Total
Manuju	47	93	140
Pangembang	33	175	208
Tamala'lang	128	5	133
Adatongeng	198	93	291
Lae-Lae	712	209	921
Panaikang	124	0	124

The distribution of adult *Ae. aegypti* and *Ae. albopictus* mosquitoes based on sex and habitat across six study locations showed variations. Overall, *Ae. aegypti* was more abundant indoors, while *Ae. albopictus* was more frequently found outdoors. The detailed distribution of both species across the different locations, including their abundance indoors and outdoors, is shown in Table 4.

The results of this study indicate that *Ae. aegypti* was most abundant indoors at Lae-Lae, with 696 individuals (58.7%), while *Ae. albopictus* was most abundant indoors at Pangembang, with 31 individuals (55.4%). Outdoors, *Ae. aegypti* was most abundant in Lae-Lae, with 32 individuals (80.0%), while *Ae. albopictus* was most abundant in the same settlement, with 177 individuals (33.1%). The abundance of adult *Aedes* mosquitoes showed a habitat-specific pattern between *Ae. aegypti* and *Ae. albopictus*. *Aedes aegypti*, the primary vector for dengue fever, was more dominant indoors, emphasizing the importance of household-based control measures to reduce the risk of disease transmission.

This study evaluates the distribution of abundance of adult *Ae. aegypti* and *Ae. albopictus* based on habitat (indoors and outdoors) in six settlements in South Sulawesi (Table 5). The results indicate that *Ae. aegypti* was more frequently found indoors (1186 individuals; $p<0.01$) compared to outdoors (40 individuals; $p<0.001$). The highest population indoors was observed in Lae-Lae (696 individuals), followed by Adatongeng (198 individuals). Tamala'lang, Panaikang, and Manuju had lower populations, with Pangembang recording the lowest (2 individuals). Outdoors, the abundance of *Ae. aegypti* was very limited, with the highest number found in Lae-Lae (32 individuals). Other locations exhibited minimal abundance, with none found in Manuju and Panaikang.

On the other hand, *Ae. albopictus* was predominantly found outdoors (535 individuals; $p<0.001$), while only a few individuals were found indoors (56 individuals; $p<0.001$). The locations with the highest populations outdoors were Lae-Lae (177 individuals), followed by Pangembang (174 individuals), Manuju (93 individuals), and Adatongeng (91 individuals). No individuals were found outdoors in Tamala'lang and Panaikang. Indoors, the number of individuals was relatively low across all locations, with Pangembang having the highest number (31 individuals), while other locations such as Tamala'lang, Adatongeng, and Panaikang recorded no *Ae. albopictus* indoors.

Table 4. Abundance of adult *Ae. aegypti* and *Ae. albopictus* based on sex, habitat, and settlement locations

Sites	Species	Habitat	Male (%)		Female (%)		Total (%)	
Manuju	*Ae. aegypti*	Indoors	38	(6.3)	0	(0.0)	38	(3.2)
		Outdoors	0	(0.0)	0	(0.0)	0	(0.0)
	Ae. albopictus	Indoors	2	(16.7)	7	(15.9)	9	(16.1)
		Outdoors	43	(12.2)	50	(27.5)	93	(17.4)
Pangembang	*Ae. aegypti*	Indoors	0	(0.0)	2	(0.3)	2	(0.2)
		Outdoors	1	(3.7)	0	(0.0)	1	(2.5)
	Ae. albopictus	Indoors	3	(25.0)	28	(63.6)	31	(55.4)
		Outdoors	148	(41.9)	26	(14.3)	174	(32.5)
Tamala'lang	*Ae. aegypti*	Indoors	55	(9.1)	73	(12.6)	128	(10.8)
		Outdoors	3	(11.1)	2	(15.4)	5	(12.5)
	Ae. albopictus	Indoors	0	(0.0)	0	(0.0)	0	(0.0)
		Outdoors	0	(0.0)	0	(0.0)	0	(0.0)
Adatongeng	*Ae. aegypti*	Indoors	63	(10.4)	135	(23.3)	198	(16.7)
		Outdoors	1	(3.7)	1	(7.7)	2	(5.0)
	Ae. albopictus	Indoors	0	(0.0)	0	(0.0)	0	(0.0)
		Outdoors	37	(10.5)	54	(29.7)	91	(17.0)
Lae-Lae	*Ae. aegypti*	Indoors	402	(66.3)	294	(50.7)	696	(58.7)
		Outdoors	22	(81.5)	10	(76.9)	32	(80.0)
	Ae. albopictus	Indoors	7	(58.3)	9	(20.5)	16	(28.6)
		Outdoors	125	(35.4)	52	(28.6)	177	(33.1)
Panaikang	*Ae. aegypti*	Indoors	48	(7.9)	76	(13.1)	124	(10.5)
		Outdoors	0	(0.0)	0	(0.0)	0	(0.0)
	Ae. albopictus	Indoors	0	(0.0)	0	(0.0)	0	(0.0)
		Outdoors	0	(0.0)	0	(0.0)	0	(0.0)
Total	*Ae. aegypti*	Indoors	606	(100.0)	580	(100.0)	1186	(100.0)
		Outdoors	27	(100.0)	13	(100.0)	40	(100.0)
	Ae. albopictus	Indoors	12	(100.0)	44	(100.0)	56	(100.0)
		Outdoors	353	(100.0)	182	(100.0)	535	(100.0)

Table 5. Comparison of the distribution of abundance of *Ae. aegypti* and *Ae. albopictus* based on habitat and settlement location

Species	Habitat	Manuju	Pangembang	Tamala'lang	Adatongeng	Lae-Lae	Panaikang	Total	*p*
Ae. aegypti	Indoors	38	2	128	198	696	124	1186	0.002*
	Outdoors	0	1	5	2	32	0	40	0.000**
Ae. albopictus	Indoors	9	31	0	0	16	0	56	0.000**
	Outdoors	93	174	0	91	177	0	535	0.000**

Note: *) significant at the 0.01 level; **) significant at the 0.001 level

The results of the study indicate that habitat and location appear to influence the distribution of abundance of both mosquito species. *Aedes aegypti* tends to dominate indoors, reflecting its endophilic nature or resting behavior inside human dwellings. In contrast, *Ae. albopictus* was more frequently found outdoors, consistent with its exophilic behavior or resting in the natural vegetation surrounding the settlements.

Discussion

Overall, the Breteau Index (BI), which falls into the moderate to high category across all locations, indicates that the risk of mosquito-borne disease transmission remains present in the six study locations (Table 2). These findings suggest that the risk of arbovirus transmission is concerning, especially since the larvae can develop into adult mosquitoes that may transmit diseases, depending on the species. If the mosquitoes that hatch are *Aedes* spp., the risk of dengue fever transmission could be higher in these locations.

Ferede et al. (2018) reported that the most common mosquito breeding habitats are tire dumps (57.5%), followed by clay pots (30.0%). Surveillance of dengue fever vectors, particularly *Ae. aegypti*, is largely based on the immature stage index (larvae and pupae). Aryaprema and Xue (2019) emphasized that the Breteau Index (BI) serves as a promising early warning signal for the potential outbreak of dengue. The variation in BI values across different locations reflects differences in environmental conditions, water management, and community behavior in efforts to prevent mosquito breeding. Therefore, vector control interventions need to be tailored to the characteristics of each location, including the reduction of unused water containers, enhancement of mosquito-nest eradication activities, and public education to reduce the risk of *Aedes* spp. breeding in the surrounding environment.

The distribution of adult *Aedes* mosquitoes based on indoors and outdoors habitats shows different patterns at each location (Table 3). In Lae-Lae and Adatongeng, a significant number of mosquitoes were found both indoors and outdoors, indicating the need for vector control that encompasses both environments. In contrast, in Tamala'lang, the majority of mosquitoes were found indoors, while in Pangembang and Manuju, the mosquito concentration was higher outdoors. In Panaikang, the number of mosquitoes recorded was the lowest, with all mosquitoes found indoors and none outdoors. These findings highlight the need for control strategies tailored to the specific environmental characteristics of each location.

Human-made habitats, both indoors and outdoors, serve as breeding grounds for *Aedes* mosquitoes. Dharmamuthuraja et al. (2023) reported that larvae of *Ae. aegypti* and *Ae. albopictus* are more commonly found in artificial habitats than in natural ones. In locations with high mosquito concentrations indoors, such as Lae-Lae, house-based interventions like the use of bed nets or indoor insecticides can be an effective solution (Lenhartid et al. 2020). In contrast, locations like Pangembang and Manuju, which have high mosquito concentrations outdoors, require an environmental management approach to reduce mosquito breeding sites in the surrounding vegetation.

The higher number of female *Aedes* mosquitoes compared to male *Aedes* mosquitoes in most locations, especially indoors, is relevant to the role of female mosquitoes as the primary vectors of diseases (Figure 3). Female *Aedes* mosquitoes are more active in seeking hosts indoors to obtain blood as a protein source for egg production. In contrast, male *Aedes* mosquitoes are more commonly found outdoors, such as in Pangembang and Lae-Lae, because they require nectar as an energy source. Barredo and DeGennaro (2020) explain that female mosquitoes often skip nectar feeding if they have access to a human host during the reproductive period, whereas male mosquitoes need sugar for survival. These findings suggest that the dominance of female mosquitoes indoors increases the risk of disease transmission, such as dengue fever, because only female mosquitoes can transmit the dengue virus.

The presence of female *Ae. aegypti*, female *Ae. albopictus*, and the total number of mosquitoes per habitat (indoors and outdoors) at each location are presented in Table 4. The distribution of *Aedes* mosquitoes shows a specific habitat pattern between *Ae. aegypti* and *Ae. albopictus* in each settlement location across three regions in South Sulawesi Province. In Indonesia, *Ae. aegypti* is the primary vector of the dengue virus, which causes dengue fever, compared to *Ae. albopictus*. This is supported by research from Garjito et al. (2021), which reported that *Ae. aegypti* was more frequently detected carrying the dengue virus (76.4%) compared to *Ae. albopictus* (23.6%) in 15 dengue-endemic provinces in Indonesia. Parra et al. (2018) also found a positive correlation between the increased number of female *Ae. aegypti* mosquitoes and the incidence of dengue fever.

Manuju is a highland area classified as rural, located at an elevation of approximately 210 meters above sea level. The settlement in this region consists of houses that are generally spaced apart, surrounded by tall trees, near customary forests, rice fields, and rivers. This location is in Manuju Village, Manuju Sub-district, Gowa District, and supports the presence of *Ae. albopictus*. A total of 7 female *Ae. albopictus* individuals (15.9%) were found indoors, and 50 female individuals (27.5%) were found outdoors. In contrast, *Ae. aegypti* was not detected in the outdoors habitat, with only 38 male individuals (6.3%) found indoors. This distribution pattern is consistent with the findings of Marina et al. (2021), which showed that *Ae. albopictus* is the dominant species in natural vegetation zones in rural areas. This difference emphasizes the importance of managing the surrounding vegetation environment in rural areas to reduce the *Ae. albopictus* population.

Pangembang is a lowland area, classified as urban, located at an elevation of 43 meters above sea level. The houses in this area are generally spaced apart, with bamboo plants, rice fields, and corn fields. This location is in Pangembang Hamlet, Pucak Village, Tompobulu Sub-district, Maros District. This area supports the dominance of *Ae. albopictus* in the indoors habitat, with 28 female individuals (63.6%) found indoors, and 26 female individuals (14.3%) found outdoors. In contrast, *Ae. aegypti* was found in small numbers, with only 2 female individuals (0.3%) found indoors and none found outdoors. This is consistent with research showing that *Ae. albopictus* is more dominant in areas with natural vegetation, usually found outside the house (Marina et al. 2021). Pucak Village is a rural area that features the Pucak Safari Park. The main economic activities of the local population are corn and rice farming. Most of the houses in this area are wooden constructions with a single room elevated on stilts, featuring permanent openings (windows and doors that remain open, and floors with open structures). The presence of *Ae. albopictus* indoors in Pangembang suggests its ability to adapt to indoor environments. This finding aligns with previous studies. Contreras-Perera et al. (2019), reported that *Ae. albopictus* was found in adult mosquito collections indoors, while Dalpadado et al. (2022), explained that although *Ae. albopictus* prefers outdoor resting places, it is also found indoors. Similarly, Lopez-Solis et al. (2023) reported *Ae. albopictus* adults resting inside urban houses in Mexico, while Westby et al. (2021) *Ae. albopictus* populations in urban and suburban areas were an order of magnitude larger than in rural areas. In South Sulawesi, *Ae. albopictus* has been found in various types of ecosystems (Health Research and Development Agency Ministry of Health 2017). The high number of *Ae. albopictus* indoors in Pangembang highlights the importance of vector control, which includes managing water containers indoors. As a potential vector for arbovirus zoonoses, *Ae. albopictus* has the ability to adapt to breeding sites in newly invaded areas, opportunistic feeding behavior with a preference for human blood, and transmission competence for various arboviruses (Pereira-Dos-Santos et al. 2020). This species has also been reported to spread through the trade of ornamental bamboo plants and used tires (Deblauwe et al. 2022), and is found in tree holes (Chowdhury et al. 2014) as well as in controllable containers and disposable containers (Yuliani et al. 2021). Differences in abundance across urban and rural land use classifications appear to have been observed for this species in certain geographic regions. However, a consistent global pattern may not necessarily exist within its range.

Tamala'lang is a lowland area, classified as urban, located about 14 meters above sea level. The housing is dense, with minimal space between houses, surrounded by rice fields and bamboo plants. It is located in Tamala'lang Hamlet, Lempangang Village, Bajeng Sub-district, Gowa District. The population of *Ae. aegypti* mosquitoes are dominant, with 73 female individuals (12.6%) found indoors and only 2 female individuals (15.4%) found outdoors. No *Ae. albopictus* individuals were detected in either habitat. The dominance of *Ae. aegypti* in Tamala'lang reflects the strong adaptation of this species to urban environments with access to water indoors, despite the presence of vegetation around the settlement. Padonou et al. (2023) reported that *Ae. aegypti* has a wider geographical distribution compared to *Ae. albopictus*. Therefore, vector control in Tamala'lang needs to focus on controlling mosquitoes indoors to break the transmission cycle of the disease. The presence of bamboo vegetation outdoors typically serves as a breeding site for *Ae. albopictus*. However, Tamala'lang is located about 5 km from the coast, making it subject to relatively high wind speeds. Wind speeds range from 41.9-72 km/h under normal conditions, which makes *Ae. albopictus* difficult to find outdoors. The wind blows from the sea to the land during the day and from the land to the sea at night (Gowa District Government 2019). This condition affects the distribution of mosquitoes outdoors, making vector management indoors the top priority in Tamala'lang.

Adatongeng is a lowland area, classified as urban, located about 4 meters above sea level. The residential area in Adatongeng is dense, with very narrow spaces between houses, some vegetation, and a rice field on one side. This location is in Adatongeng Urban Village, Turikale Sub-district, Maros District. The environmental conditions in the Adatongeng residential area support a high population of *Ae. aegypti* indoors, with 135 female individuals (23.3%) found indoors, while only 1 female individual (7.7%) was detected outdoors. On the other hand, *Ae. albopictus* is more frequently found outdoors, with 54 female individuals (29.7%), while no *Ae. albopictus* individuals were detected indoors. This result is in line with the research of Dalpadado et al. (2022), which showed that *Ae. aegypti* tends to rest on fabrics and curtains, followed by furniture, while *Ae. albopictus* is most often found on outdoor plants. Therefore, vector control in Adatongeng needs to focus on managing vegetation around the settlement and managing water containers indoors to break the disease transmission cycle.

Lae-Lae is an island covering 0.18 hectares located in a coastal area and classified as urban. This island is situated near the city center of Makassar, about 4 meters above sea level. The residential area is dense, with almost no space between houses and minimal vegetation, and the area also functions as a tourist destination. Administratively, Lae-Lae is part of Lae-Lae Urban Village, Ujung Pandang Sub-district, Makassar City. The population of *Ae. aegypti* dominates, with 294 female individuals (50.7%) found indoors and 10 female individuals (76.9%) outdoors. The population of *Ae. albopictus* is much smaller, with 9 female individuals (20.5%) indoors and 52 female individuals (28.6%) outdoors. The study shows that physical factors such as distance from the shoreline, water pH, temperature, and the type of water containers significantly affect the habitat characteristics and abundance of *Ae. aegypti* and *Ae. albopictus* larvae (Ratnasari et al. 2020). The abundance of *Ae. aegypti* and *Ae. albopictus* on this island is suspected to be influenced by natural breeding sites, such as abandoned fishing boats collecting rainwater on Lae-Lae Island, and several other factors including a climate conducive to breeding, densely populated houses, the habit of storing clean water indoors, and the low public awareness of the importance of controlling *Ae. aegypti*. These findings are significant, as there have been no previous reports regarding the abundance of adult *Aedes* mosquitoes on this island. Additionally, vector-borne diseases such as dengue fever are endemic health issues in Makassar City. As a comparison, Oliveira et al. (2020) found that *Ae. aegypti* is also present on offshore islands, such as those in the Brazilian Sea, which can be reached in three to four days from the mainland. This indicates that coastal islands are also vulnerable to *Ae. aegypti* colonization. Therefore, mosquito control on Lae-Lae Island should prioritize managing water containers indoors and controlling natural breeding sites such as abandoned boats around the settlement.

Panaikang is an urban area located in a lowland at an altitude of approximately 3 meters above sea level. The residential area is very dense, with minimal space between houses. Additionally, this area has swamps and nipa palm trees on one side of the region. Administratively, Panaikang is part of Panaikang Urban Village, Panakkukang Sub-district, Makassar City. The study results show that this location only supports the presence of *Ae. aegypti*, with a total of 76 female individuals (13.1%) found indoors. No *Ae. aegypti* individuals were detected outdoors, nor was *Ae. albopictus* found in either habitat. This finding is supported by Ortega-López et al. (2024), who reported that *Ae. aegypti* has a significantly higher abundance in urban environments compared to suburban areas. Mosquito control strategies in Panaikang should focus on managing water containers indoors to break the cycle of dengue fever transmission.

This study also evaluated the distribution of abundance of *Ae. aegypti* and *Ae. albopictus* based on habitat (indoors and outdoors) at six locations in South Sulawesi (Table 5). Statistical analysis showed significant differences in the distribution of the two species based on habitat ($p<0.05$). The results revealed distinct distribution patterns for adult *Aedes* mosquitoes at each location, reflecting ecological variations between indoors and outdoors habitats. While these findings suggest potential links to dengue transmission, it is important to note that dengue testing was not performed in this study. Other ecological variations, such as the classification of rural and urban locations, the presence of artificial habitats compared to natural habitats, and vegetation compared to areas with minimal vegetation, were also suspected to influence the distribution patterns of the two species. Different environmental variables contribute to the formation of species distribution patterns that are ecologically distinct (Wouters et al. 2024). Rapid human population growth, the expansion of agricultural activities, and greater urbanization have created ecological changes that significantly impact mosquito vector biology (Ramasamy and Surendran 2016). These findings highlight the importance of a deep understanding of mosquito species' behavior and the distribution of abundance to support more effective, evidence-based dengue control strategies.

One of the limitations of this study is the potential effect of seasonal variations on mosquito abundance, as sampling in different settlements was conducted at different times throughout the year. Mosquito populations are known to fluctuate with environmental factors such as rainfall, temperature, and humidity, which can vary across seasons. These factors may have influenced the number of *Ae. aegypti* and *Ae. albopictus* captured in each location, potentially introducing bias into the results. Although the study aimed to capture a representative snapshot of mosquito populations in each settlement, the varying sampling times might not fully reflect the temporal dynamics of mosquito abundance. Future studies should aim to collect data simultaneously across all locations or during comparable seasonal periods to minimize this limitation. Additionally, longitudinal studies spanning multiple seasons would provide more robust insights into the seasonal patterns of *Aedes* mosquito populations and their implications for vector control strategies.

The distibution of abundance of *Ae. aegypti* in this study shows its dominant endophilic nature, with the majority of individuals found indoors. In contrast, *Ae. albopictus* displays an exophilic nature with a dominant distribution outdoors. A concerning factor is the adaptability of *Ae. aegypti*, which allows this species to be found at all the settlement locations surveyed. On the other hand, *Ae. albopictus* was not detected at the Tamala'lang and Panaikang locations, indicating that its habitat preferences are still limited. However, if control measures are not implemented effectively, the exophilic nature of *Ae. aegypti* could further develop in these areas. Adaptation of *Ae. aegypti* to outdoor habitats has been reported in Kinshasa, where this species demonstrated exophagic and exophilic behavior and utilized outdoor breeding habitats (Manzambi et al. 2023). Similarly, in West Africa, *Ae. aegypti* has shown exophilic and anthropophilic traits (Badolo et al. 2022). This condition presents a greater potential risk if control measures are not well-executed. Meanwhile, *Ae. albopictus* has been found indoors at the Pangembang and Lae-Lae locations, indicating a shift in preference towards human blood over animal blood. In West Africa, both *Ae. aegypti* and *Ae. albopictus* have predominantly been reported as anthropophilic, feeding mainly during the day. However, further research is needed to confirm this (Egid et al. 2022). These conditions underscore the importance of an integrated control approach, considering the adaptive nature of both species to reduce the vector-borne disease transmission risk in this region.

Makassar City, Gowa District, and Maros District are the primary contributors to dengue cases in South Sulawesi during the 2017-2021 period (Saputra et al. 2023). Although integrated vector management programs have been implemented in Makassar City (Wahid et al. 2019), the results of this study indicate that entomological surveillance and vector control efforts still need to be enhanced to address the ongoing risk of dengue transmission.

Based on the findings of this study, the abundance of *Ae. aegypti* and *Ae. albopictus* across six settlement locations in South Sulawesi reveals distinct distribution patterns between indoors and outdoors habitats, influenced by various ecological factors such as vegetation presence and regional classification. The adaptability of *Ae. aegypti*, which enables its presence in all study locations, along with the occurrence of *Ae. albopictus* indoors in several sites, points to an increasingly complex challenge in controlling these species. Furthermore, the potential ecological shift of *Ae. aegypti*, now showing signs of exophilic behavior in certain settlements, raises concerns for future vector control efforts. Therefore, an evidence-based control approach that considers the adaptation and distribution patterns of these mosquito species is essential. This study underscores the importance of strengthening entomological surveillance, managing habitats, and integrating adult mosquito and larval abundance data to enhance the effectiveness of dengue control interventions, particularly in areas such as Makassar City, Gowa District, and Maros District in South Sulawesi Province, Indonesia.

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