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Diversity of disease-carrying mosquito vectors in potential areas of dengue fever in Palembang City, South Sumatra, Indonesia

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Abstract. *Listiono H, Damiri N, Kamaluddin T, Irsan C. 2024. Diversity of disease-carrying mosquito vectors in potential areas of dengue fever in Palembang City, South Sumatra, Indonesia. Biodiversitas 25: 474-481.* Mosquitoes (Diptera: Culicidae) are biting insects commonly found in many areas on earth in subtropics and tropics, especially around residential areas. So far, more than 2500 species have been recorded from various parts of the world. They are the main vectors of many diseases in humans and livestock caused by viruses and parasites. Mosquito diversity and disease transmission are influenced by landscape modifications, namely vectors and pathogens. The study aimed to evaluate the distribution, prevalence and abundance of mosquito species in potential dengue fever districts in Palembang city. The study was conducted in 2 two sub-districts in Palembang City, namely Gandus and Seberang Ulu I that represent housing environment, schools and gardens. Mosquito capture was done during three periods 06.00-10.00, 15.00-18.00, and 19.00-21.00 to align with their active hours. This involved active human landing collection method. 200 ovitraps were set up in both regions to assess the density of mosquitoes. The results showed that the diversity index values in Gandus and the Seberang Ulu I sub-districts were 0.781 and 0.756, respectively. Both values were categorized as low diversity index. Furthermore, the dominance index in Gandus and Seberang Ulu 1 sub-district were 0.105 and 0.031, respectively. It meant that there were no dominant mosquito species in both sub-districts. Based on the results of Independent t-test analysis, it was found that the average number of mosquito populations in Gandus sub-district was 25.07 and Seberang Ulu I sub-district was 13.29. From the results of the analysis it was found that there was no difference in average number of mosquito populations between Gandus and Seberang Ulu I sub-district, with a p-value of 0.367. Further research needs to be directed at uncovering mosquito distribution patterns and their potential as disease vectors, the risk of infectious diseases, and the need for further prevention to reduce the number of disease incidences.

Keywords: DHF potential area, disease vectors, diversity, dominance, mosquitoes

INTRODUCTION

Mosquitos (Diptera: Culicidae) are biting insects that play crucial role in transmitting various pathogens to humans and livestock, making them the most important vector of diseases (Young et al. 2021). The transmitted of mosquitoe-borne diseases is a significant public health concern worldwide (Johnson et al. 2020; Attaullah et al. 2023), with more than 80% of people worldwide risk of infection and accounting for the highest number of vector-borne illnesses in humans (Franklinos et al. 2019). More than 17% of all infectious diseases are vector-borne, causing more than 700,000 deaths annually (Kirik et al. 2021). Mosquitos can transmit diseases such as Malaria, Filarisis, Chikungunya (CG), Dengue Hemorrhagic Fever (DHF), Yellow fever, Japanese Encephalitis (Sunarsih et al. 2021; Nair et al. 2022). *Anopheles*, *Culex*, *Aedes,* and *Mansonia* are the species of mosquitoes capable of carrying diseases (Novianto et al. 2021). Mosquitoes larvae and pupae reside in freshwater, serving a vital role in the food chain while also acting as marker for water quality (Qasim et al. 2014). These insects are ubiquitous and existing in diverse environments like sewage water, freshwater, and stagnant water. Flower vases, plastic pots, drain buckets, and water tanks of various types are commonly mosquito breeding sites (Flaibani et al. 2020; Yang et al. 2020). Many species of mosquitoes can adapt to their specific habitats. For instance, *Aedes* species can adapt to colder regions where their eggs dominate more than in warmer areas (Gadahi et al. 2012). The distribution and survival of mosquitoe species are influenced by human ecology, behavior, and habitats (Schrama et al. 2020).

Indonesia, being one of the largest tropical countries in the world, has a climate that is highly conducive to mosquito breeding. Therefore, controlling the mosquito population in Indonesia is challenging task. More than 2500 species of mosquitoes have been officially recorded throughout the world, and 475 species are found in Indonesia, including *Mansonia* sp., *Anopheles* sp., *Culex* sp., *Aedes* sp., and *Armigeres* sp. These mosquito species are known to carry, many viruses that cause various disease in humans (O'Connor and Sopa 1981; Saraiva et al. 2020; Kirik et al. 2021). For example, *Mansonia* sp., *Anopheles* sp., *Culex* sp., *Armigera* sp. and *Aedes* sp. can act as a vector of *Wuchereria bancrofti* (Cobbold, 1877), *Brugia malayi,* and *B. timori,* the pathogen of lymphatic filariasis in Indonesia. This disease is a global health problem and a cause of physical disability, stigma and poor psychosocial (Abdulmalik et al. 2018; Van't Noordende et al. 2020; Ali et al. 2021; Istianah et al. 2021).

Palembang is a city in Indonesia known for being an endemic area for Dengue Hemorrhagic Fever (DHF). In 2019, there were 697 reported cases of this disease. Nine districts in Palembang were classified as dengue endemic and sporadic areas for dengue (Delita et al. 2021). Despite the ongoing Covid-19 pandemic, dengue fever remains a significant public health issue. As of July 2020, there were already 337 reported cases of dengue in the city (Palembang City Health Office 2020; Delita et al. 2021). The persistent issue of Dengue Hemorrhagic Fever (DHF) in Palembang can be attributed to several factors. As reported by Listiono et al. (2022), other pathogenic vector mosquito species such *Anopheles* sp., *Mansonia* sp., *Armigeres* sp. and *Culex* sp. have also been found in endemic area of dengue fever in Palembang. However, the study did not explain how distribution of these vector. Palembang is situated in a lowland area with an elevation of 3 to 8 meters above sea level. The region experiences relatively high humidity due to the prevailing winds, and their temperature typically ranges from 23.4°C to 31°C. Additionally, Palembang receives an average monthly rainfall of 227.23 mm (Flaibani et al. 2020). These conditions create an ideal environment for breeding *Aedes aegypti* (Linnaeus, 1762) mosquitoes, which are responsible for transmitting dengue fever. Dini et al. (2011) demonstrated a strong correlation between dengue cases and increased air temperature ranging 25.5 to 28.5°C as well as rainfall amounts ranging from 3 to 374 mm, conditions common in Palembang, Indonesia. In addition to the presence of dengue-vectoring mosquitoes, other genera and species of mosquitoes have also been found to serve as vectors for various diseases such as malaria, elephantiasis, and chikungunya (Delita et al. 2021).

To effectively address the upcoming challenges of vector-borne diseases, it is crucial to conduct a comprehensive evaluation of mosquito populations in various environments across different geographic regions (Arroussi et al. 2021). The study aimed to evaluate the range, prevalence and abundance of mosquito species in potential dengue fever districts in Palembang City, South Sumatra, Indonesia.

MATERIALS AND METHODS

Study area

This research was conducted in 2 sub-districts in Palembang City, South Sumatra, Indonesia, namely Gandus and Seberang Ulu I that represent housing environment, schools and gardens. In each each sub-district, we used 5 villages as sample locations (Figure 1).

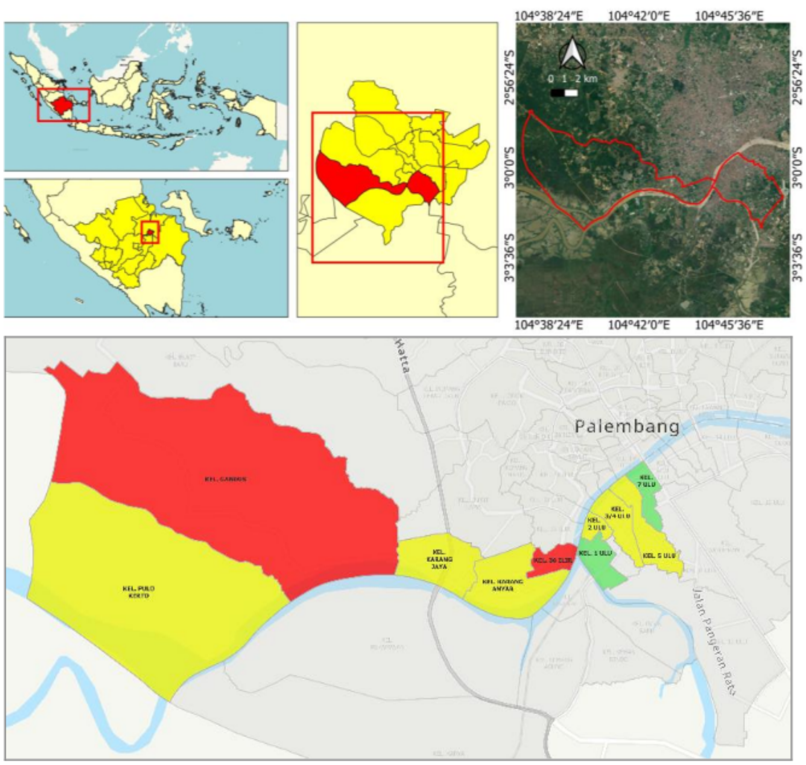

Figure 1. Map of study site in Gandus and Seberang Ulu 1 sub-district, Palembang City, South Sumatra, Indonesia

To identify the mosquito diversity in those areas, we collect adult mosquitoes using active collection, namely searching for mosquitoes in their habitat using an insect net and the Human Landing Collection Method. The land use type of research area was housing, school and gardens area. Several measures were taken to protect researchers from mosquito bites and associated Vector-Borne Diseases (VBDs), such as protective clothing, site selection, training, and monitoring (Kenea et al. 2017). Adult mosquito collection was divided into 3 periods, 06:00-10:00 West Indonesian Time (WIT), 15:00-18:00 WIT, and 19:00-21:00 WIT. The selection of mosquito collection time was based on the active time of most mosquitoes. The obtained mosquitoes were anesthetized in a kill jar with 10% chloroform, counted, and point-mounted for identification, and then stored in the drying box. The identification was conducted at the Entomology Laboratory, Sriwijaya University, Palembang, Indonesia. Adult mosquitoes were identified based on morphological characters and using morphological keys (Rattanarithikul and Panthusiri 2010) and voucher specimens at the Sriwijaya University Laboratory.

To measure the density of mosquitoes and assess adult diversity, we also collected mosquito eggs passively (Sasmita et al. 2021). 200 Ovitraps were installed in both sub-districts. An ovitrap consist of a black plastic container, measuring 7 cm in diameter and 21 cm in height, featuring a central aperture with a diameter of 4 cm in its lid. The inner surface of ovitraps was covered with two kitchen towel (5 cm x 10 cm) and approximately two thirds of ovitraps were filled with water to serve as a suitable oviposition site for female *Aedes* mosquitoes. Ovitraps were spread across various locations: five inside houses (indoors) placed in kitchen, bathroom, bedroom and living room, five in outdoor ovitraps installed in car park, front, side and back veranda. Ten ovitraps placed within schools (classrooms, bathrooms and canteen and their adjoining gardens. The ovitraps were observed once a week in one month. Water and filter paper were changed as necessary. Weekly collection of mosquito eggs in ovitraps was conducted, where the oviposition strips were folded, stored in a ziplock bag and taken to the laboratory. Subsequently the egg-laden strips were placed in a tray with clean water. The hatching process was observed until the larvae emerged. The hatched larvae were then quantified and identified with the assistance of an identification book (WHO 2020). Simpson's Index (D) was used to determine the species that dominated the mosquito community at each site (region). The species diversity index calculation using the Shannon- Wiener (H') formula is as follows:

Table 1. Ovitrap index criteria (Food and Environment Hygiene Department 2023)

Ovitrap Index	Score	Criteria
Level 1: IO<5 %	1	Very low
Level 2: 5%≤IO<20 %	2	Low
Level 3: 20%≤IO<40 %	3	Medium
Level 4: IO≥40 %	4	High

$$H' = \sum pi \ Ln \ pi$$

$$\mathbf{Pi} = \frac{\mathbf{ni}}{\mathbf{N}}$$

Where:
H' : Shanon-Wiener Diversity Index
Pi : The ratio of the number of individuals of all species to the whole species
ni : Number of species caught
N : Total number of individuals of all species caught

According to Michael (1990), the criteria for the diversity index as follows: H'≤ 1: Low diversity, 1<H'<3: Moderate diversity; and H'≥ 3: High diversity.

The Simpson Dominance Index value (D) is used as a comparison to the Shannon-Wiener Diversity Index value (H'). The Simpson Dominance Index (D) is a measure used to assess the dominance or relative concentration of species within a community. In contrast, the Shannon-Weiner Diversity Index (H') measures the species diversity at a site. Communities with a high dominance index will show a low diversity index value. The formula is as follows:

$$\mathbf{D} = \sum_{i=1}^{S} \left(\frac{ni}{N}\right)$$

If -0<D<0.5: No species dominates, -0.5≥D<1: There are species that dominate. The criteria Ovitrap Index can be seen in the Table 1.

Data were analyzed by using the Independent Samples Test or Mann-Whitney analysis. If the data were normally distributed use the Independent Samples Test; if the data is not, then use the Mann-Whitney Test (Hastono 2018). Mosquitoes species distribution data obtained in Gandus and Seberang Ulu I, the DHF potential area were drawn onto a map using ArcGIS Pro Ver 3.1 developed by the Environmental Systems Research Institute Inc (ESRI).

RESULTS AND DISCUSSION

Diversity of mosquitoes in Gandus and Seberang Ulu I, The potential DHF area in Palembang City

The results of observing and identifying the diversity of mosquitoes in DHF endemic areas obtained 4 genera and 15 species, while in non-endemic areas obtained 5 genera and 14 species of mosquitoes (Table 2, Figure 2). Figure 2 shows the distribution of mosquito populations. *Aedes* spp. mosquitoes (red) appear to have a higher abundance compared to other mosquito species such as *Mansonia* spp. (yellow), *Anopheles* spp. (green), *Culex* spp. (blue), and *Armigeres* sp. (purple).

Mosquito diversity and dominance index

The Index Diversity (H') of mosquitoes in both Gandus Sub-district and Seberang Ulu I Sub-district is presented in Table 3.

Table 2. Mosquito diversity in Gandus and Seberang Ulu 1 Sub-districts in Palembang City, South Sumatra, Indonesia

Genera	Species	Mosquito diversity			
		Gandus Sub-district		Seberang Ulu I Sub-district	
		Total	Percentage (%)	Total	Percentage (%)
Aedes	*A. aegypti* (Linnaeus, 1762)	154	28.67	67	12.46
	A. albovictus (Skuse, 1894)	34	6.36	17	3.16
	A. albolineatus (Theobald, 1904)	12	2.23	6	1.11
Mansonia	*M. annulifera* (Theobald, 1901)	97	18.06	23	4.28
	M. uniformis (Theobald, 1901)	21	3.91	17	3.16
	M. Indiana (Edwards, 1930)	6	1.11	5	0.93
	M. annulata (Leicester, 1908)	3	0.55	1	0.18
Anopheles	*A. triptoides*	9	1.67	14	2.60
	A. barbirostris (Wulp, 1884)	7	1.30	11	2.04
	A. umbrosus (Theobald, 1903)	2	0.37	1	0.18
Culex	*C. quenquefasciatus* (Say, 1823)	4	0.74	12	2.23
	C. tripteroides	1	0.18	4	0.74
	C. gelidus (Theobald, 1901)	1	0.18	2	0.37
Armigeres	*A. subalbatus* (Coquillett, 1898)	0	0	6	1.11

Table 3. Diversity and dominance index of mosquitoes (Diptera: Culidae) Gandus and Seberang Ulu I Sub-districts in Palembang City, South Sumatra, Indonesia

Species	Gandus Sub-district				Seberang Ulu I Sub-district			
	Pi	LnPi	H'	D	Pi	LnPi	PiLnPi (H')	D
Aedes spp.	0.272	-1.301	-0.353	0.074	0.151	-1.888	-0.283	0.022
Mansonia spp.	0.172	-1.755	-0.301	0.030	0.077	-2.559	-0.197	0.005
Anopheles spp.	0.024	-3.709	-0.089	0.001	0.043	-3.130	-0.134	0.001
Culex spp.	0.008	-4.808	-0.038	0.000	0.030	-3.498	-0.104	0.000
Armigeres spp.	0	0		-	0.008	-4.779	-0.038	0.000
Total			0.781	0.105			0.756	0.031

Note: Pi: Number of individuals, LnPi: Natural logarithm of the number of individuals, PiLnPi: Multiplying the number of individuals by the natural logarithm of the number of individuals, D: Dominance index, H: Diversity index

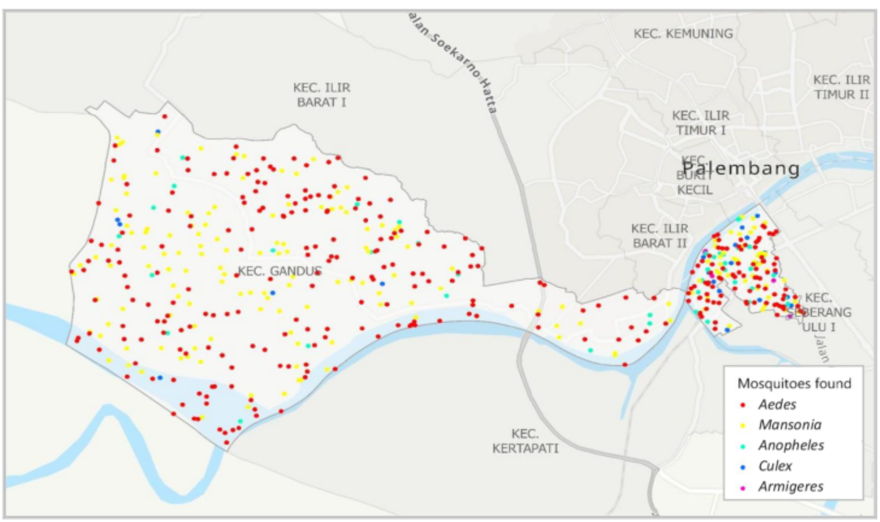

Figure 2. Map of the distribution of mosquito species in potential area of DHF in Palembang City, South Sumatra, Indonesia

Table 4. Mosquito diversity Gandus and Seberang Ulu 1 Sub-districts, in Palembang City, South Sumatra, Indonesia based on indoor and outdoor locations

Location	Genera	Mosquito species	Man Hour Density (MHD)	
			Indoor	Outdoor
Gandus	*Aedes*	*A. aegypti*	92	62
		A. albovictus	18	16
		A. albolineatus	8	4
	Mansonia	*M. annulifera*	42	55
		M. uniformis	7	14
		M. indiana	4	2
		M. annulata	2	1
	Anopheles	*A. triptoides*	4	5
		A. barbirostris	3	4
		A. umbrosus	2	0
	Culex	*C.quenquefasciatus*	1	3
		C. tripteroides	1	0
		C. gelidus	0	1
	Armigeres	*A. subalbatus*	0	0
Seberang Ulu I	*Aedes*	*A. aegypti*	38	29
		A. albovictus	9	8
		A. albolineatus	4	2
	Mansonia	*M. annulifera*	10	13
		M. uniformis	11	6
		M. indiana	2	3
		M. annulata	0	1
	Anopheles	*A. triptoides*	9	5
		A. barbirostris	7	4
		A. umbrosus	1	0
	Culex	*C.quenquefasciatus*	7	5
		C. tripteroides	1	3
		C. gelidus	1	1
	Armigeres	*A. subalbatus*	4	2

Table 5. Descriptive analysis of average number of mosquito populations based on genera in the Gandus and Seberang Ulu I Sub-districts, Palembang City, South Sumatra, Indonesia

	Sub-district	N	Mean	SD	SE mean
Total of mosquito population	Gandus	14	25.07	44.947	12.013
	Seberang Ulu I	14	13.29	16.882	4.512

In Table 3, it can be seen that the diversity and dominance index in Gandus Sub-district obtained an overall Diversity Index value of 0.781, which means a low diversity index, and a Domination Index value of 0.105, which means that there are no dominant mosquito species, whereas in Seberang Ulu 1 Sub-district's overall Diversity Index value is 0.756, which means the diversity index is low. Furthermore, the Dominance Index value is 0.031, meaning no dominant mosquito species. These findings indicate that mosquito populations in these two Sub-districts show the same characteristics in terms of diversity and dominance. A low diversity index indicates a limited number of mosquito species, while a low dominance index indicates a more balanced distribution.

Mosquito diversity based on indoor and outdoor and mosquitos population in Gandus and Seberang Ulu I are presented in Tables 4, 5, 6 and Figure 3. Based on the results of the Independent t-test analysis, it was found that the average number of mosquito populations in the Gandus Sub-district was 25.07 and the Seberang Ulu I Sub-district was 13.29. From the result of the analysis, it was found that there was no difference in average number of mosquito populations between Gandus and Seberang Ulu I Sub-districts with a p-value of 0.367.

Mosquito density in Gandus and Seberang Ulu I Sub-districts area

Observation results showed that in Gandus Sub-district, the average number of ovitraps with positive Aedes eggs was 7 ovitraps each sub-district with an average number of eggs per ovitraps of 115.6. The average number of eggs that hatch into larvae per ovitraps was 107 larvae. Meanwhile, in Seberang Ulu I Sub-district, the average number of positive eggs was 4.2 ovitraps in each Sub-district, with an average egg of 87 eggs per ovitraps. The average number of eggs hatched was 81.8 larvae per ovitrap.

In the Gandus Sub-district (comprising 5 subdistricts: Gandus, Pulokerto, Karang Jaya, Karang Anyar and 36 Ilir), the Index of Ovitrap (IO) for *A. aegypti* falls within the medium-to-high range, varying from 25% to 45%). Conversely, in Seberang Ulu I (encompassing 5 sub-districts namely 1 Ulu, 2 Ulu, 3, Ulu 4 Ulu, and 5 Ulu), the Ovitrap Index was categorized as low-to-medium ranging from 14% to 25%. The study findings in Gandus reveal that the IO in three villages was situated in the category 20%≤IO<40 % (medium category) and two villages in Gandus and 36 Ilir exhibit ≥40 % (high category). In Seberang Ulu I area, the IO of two villages was 5%≤IO<20% (low category), while three villages demonstrated an IO 20%≤IO<40% (medium category). The mosquito density map for Gandus and Seberang Ulu I Sub-district can be seen in Figure 3.

Table 6. Independent analysis of t-test samples for mosquito population numbers based on genera in the Gandus and Seberang Ulu I Sub-districts, Palembang City, South Sumatra, Indonesia

		Levene's test for quality of variance		T-test for equality of mean						
		F	Sig	t	df	Sig (2-tailed)	Mean difference	Std error difference	95% Confidence interval of the difference	
									Lower	Upper
Total of mosquito population	Equal variance assumed	**4.454**	**0.045**	0.918	26	0.367	11.786	12.832	-14.591	38.162
	Equal variance not assumed			0.918	16.596	0.372	11.786	12.786	-15.338	38.909

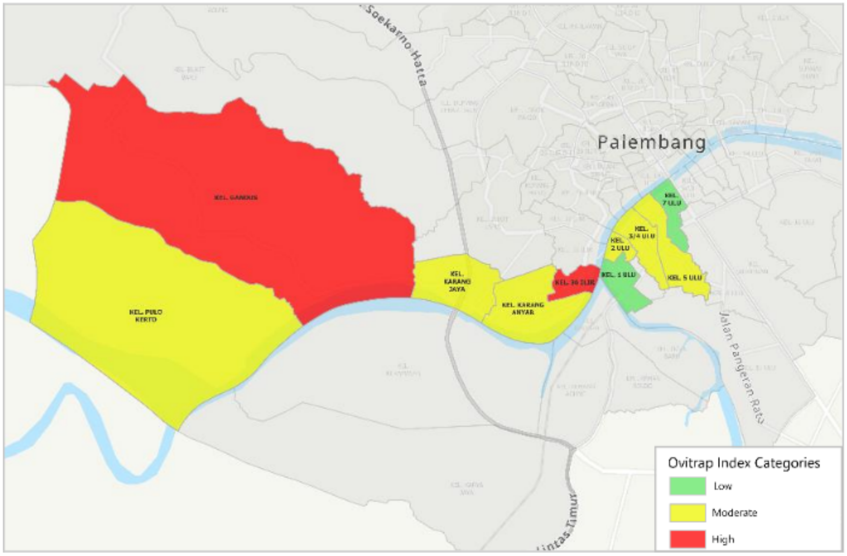

Figure 3. Map of dengue vector density in Gandus and Seberang Ulu 1 areas in Palembang City, South Sumatra, Indonesia

Figure 3 shows that the density of *Aedes* spp. in the Gandus area observed 3 sub-disricts with moderate density (Yellow) and 2 sub-districts with high density (Red). In the Seberang Ulu I area, there were 2 sub-districts with low density (Green) and 3 sub-districts with moderate density (Yellow).

Discussion

The presence and abundance of mosquitoes have a crucial impact on disease transmission and the overall ecological state of a given environment. Mosquitoes serve as a significant disease vector, and their diversity and distribution directly influence the disease transmission patterns (Schrama et al. 2020). Variations in the weather pattern and how the land is utilized can notably influence on the number and existence of mosquitoes. As a result, this also affects the way mosquito-borne diseases spread. Understanding how vectors like mosquitoes interact with their environment and react to these factors will enhance our ability to forecast the potential danger posed by diseases transmitted by mosquitoes (Rakotoarinia et al. 2022). This research was conducted in potential Dengue Fever (DHF) areas. This study identified 5 genera and 14 mosquito species, all of which can act as disease vectors. This result is in line with Listiono et al. (2022), but the previous researchers did not examine the spread and distribution of mosquito species. *Aedes aegypti* had the highest population. However, the presence of other mosquito species that also act as disease vectors is a concern because if the environment supports their development, it will cause significant problems in the future. Anopheles mosquitoes are vectors of malaria, while *Mansonia*, *Culex,* and *Armigera* mosquitoes are important vectors of elephantiasis or filariasis (Triwahyuni et al. 2020). These two diseases are also important in a tropical country like Indonesia, which has high air temperatures, always gets sunlight, high rainfall and more frequent and warmer air temperatures with an average annual temperature reaching 30°C (Schrama et al. 2020). Air temperature and the number of rainy days significantly affect on the dynamics of DHF (Delita et al. 2021). Various species, such as *C. quinquefasciatus* and *M. uniformis,* have been identified as vectors for transmitting Filarialis. This disease can cause physical disabilities, mental, and social impacts, as well as financial losses (Ughasi et al. 2012; Souza-neto et al. 2018; Nchoutpouen et al. 2019; Guerrero et al. 2021). Malaria disease is transmitted through female *Anopheles* mosquito. There have been found 24 species of *Anopheles* in Indonesia, which can act as vectors of the Malaria pathogen (Ndoen et al. 2012; Sunarsih et al. 2021). According to the World Health Organization's report (2022), there are presently four serotypes of the dengue virus: DENV-1, DENV-2, DENV-3 and DENV-4. It is widely held that recuperation from dengue infection provides enduring immunity to specific serotype responsible for the infection. Nonetheless, any immunity that develops against different serotypes following recovery is only partial and temporary. Consequently, if an individual experiences a subsequent or secondary infection caused by a different serotype, it elevates the likelihood of developing severe dengue fever.

Based on the results, the diversity index value in Gandus Sub-district was 0.781 (low), while the Dominance Index value was 0.105, which meant that there was no mosquito species dominated. Furthermore, the Diversity Index value in Seberang Ulu Sub-district 1 was 0.756 (low), and the Dominance Index value was 0.031, which means that no mosquito species dominate. These findings suggest that the mosquito population in both Sub-districts with the potential of DHF exhibit similar characteristics in terms of diversity and dominance. Mosquito population characteristics are important, but the classification of area as an endemic or non-endemic DFH is also influenced by a complex interplay of factors, including the presence of competent vectors, environmental conditions, and human behavior. It is possible for different areas with similar mosquito populations to have varying DHF endemicity due to differences in these contributing factors.

Aedes aegypti is commonly found nesting near places that contain water, such as bathtubs, neglected swimming pools, and other containers filled with stagnant water. This shows that the main breeding sites for *A. aegypti* mosquitoes are in containers inside, around houses, or in public places. This mosquito breeding place is in a pool of water accommodated in a place or container (Triwahyuni et al. 2020). Humidity, environmental conditions, and rainfall have a significant influence on the incidence of DHF, where increased rainfall and humidity are in line with the increase in cases of DHF (Garjito et al. 2021; Ghiffari et al. 2021; Attaullah et al. 2023). According to Alfiyanti and Siwiendrayanti (2021), the distribution of DHF cases is more prevalent in low-altitude plains and areas of high population density. This is in line with the topography of the Gandus Sub-district, which is a low-lying area where most of the population lives around the Musi River basin, Palembang City. This condition will further exacerbate the environmental situation with the increase in used containers and cans carried away by water currents, which can become breeding grounds for *A. aegypti* mosquitoes. The Gandus Sub-district covers 3,250 ha and contains 20 rivers. Of the Sub-district area, 40 percent is swamp. The land in the research location is still a lot of swamp and bush, with high rainfall, reaching 3000 mm per year. This area is suitable for the development of mosquitoes that cause dengue fever. The population of *Aedes* mosquitoes is higher compared to other mosquitoes. This is because these mosquitos have the ability to adapt to various environments, possess high competitiveness, and their eggs are tolerant to high temperatures. Furthermore, population density is a contributing factor that correlates positively with the occurrence of DHF.

In conclusion, two diversity index values were found in Gandus and Seberang Ulu I Sub-districts that were categorized as low diversity index. the dominance index in those areas were 0.105 and 0.031, respectively. It was found that there was no difference in the average number of mosquito populations between Gandus and Seberang Ulu I, with a p-value of 0.367. Further research is needed to uncover mosquito distribution patterns and their potential as disease vectors, the risk of infectious diseases, and further prevention is needed to reduce the number of disease incidences.

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