JPPIPA 9(Special Issue) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Environmental Vulnerability against the Presence of *Anopheles* spp. with Malaria Cases in North Jakarta

Sinthania Karunia Magdalena Tampubolon[1*], Mursid Raharjo[2], Sulistiyani[2]

[1]Master of Environmental Health, Faculty of Public Health, Diponegoro University, Semarang, Indonesia
[2]Faculty of Public Health, Diponegoro University, Semarang, Indonesia

Received: September 18, 2023
Revised: November 23, 2023
Accepted: December 25, 2023
Published: December 31, 2023

Corresponding Author:
Sinthania Karunia Magdalena Tampubolon
sinthaniadr@gmail.com

DOI: 10.29303/jppipa.v9iSpecialIssue.5359

Abstract: There are several locations in DKI Jakarta which have the potential become breeding places for *Anopheles* spp larvae. The aim of this study was to analyze environmental vulnerability to the presence of *Anopheles* spp. larvae with malaria cases using a geographic information system approach. This study was an observational study with a cross sectional design. This study was carried out in March – June 2023 in North Jakarta City, DKI Jakarta. The sample consists of data from all malaria patients from 2020-2023 in North Jakarta. The global positioning system coordinates were taken at the addresses of malaria patients. In addition, data on the presence of *Anopheles* spp. obtained from larval surveys conducted in Cilincing and Penjaringan Sub-Districts and the coordinates for the habitat of *Anopheles* spp. larvae. The GPS points obtained were then used for spatial analysis. The distribution of malaria cases was random, while the distribution of *Anopheles* larvae was dispersed. Buffering zone >1000 m from the breeding site indicated that it does not have the potential in malaria transmission due to malaria patients were at a long distance from the breeding site of *Anopheles* spp. and flight distance of *Anopheles* spp. not exceeding 1000 m.

Keywords: *Anopheles* spp.; Malaria; Mosquito; *Plasmodium*; Spatial

Introduction

One of the public health issues in the world is malaria with an estimated number of cases of 247 million in 2021. Malaria is a disease transmitted by *Anopheles* spp. mosquitoes and caused by *Plasmodium* spp. (Ashley et al., 2018; WHO, 2022). In 2020, the number of malaria endemic areas was 196 out of 514 districts in Indonesia and the morbidity rate reached 0.9% per 1000 population (Kemenkes RI, 2021). Currently, *Plasmodium* spp. that can infect humans and cause clinical symptoms are *Plasmodium falciparum, P. vivax, P. ovale, P. malariae* and *P. knowlesi* (Escalante and Pacheco, 2019; Barber et al., 2021).

Malaria transmission occurred due to it is transmitted by *Anopheles* sp. which have *Plasmodium* sp. and there are factors such as environment, season, community behavior and the behavior of *Anopheles* spp. in biting which supports the transmission (Watmanlusy et al., 2019; WHO, 2022; Rahayu et al., 2023). Malaria transmission is also reported to occur frequently due to congenital or imported cases from endemic to non-endemic areas. It was reported in previous study that imported malaria in Jakarta mostly occurs in May, July, December and patients are mostly travelers and soldiers (Lederman et al., 2006). Imported malaria was also found in North Sumatra from 2019-2020 and in Trenggalek, East Java. (Fahmi et al., 2022; Arwati et al., 2018). In other hand, cases of imported malaria occurred in Gunung Kidul Regency, Special Region of Yogyakarta in 2019, which previously received a malaria elimination certificate in 2014. In addition, there are two villages which are malaria receptive areas with an *Anopheles* spp. larval habitat index which is high or exceeds the quality standards of Kemenkes RI. No. 50/2017 and found *Anopheles* spp. mature. *Anopheles* spp. found in these two villages is *An. vagus, An. maculatus, An. aconitus* and the habitats found are ponds, irrigation canals, rice fields,

How to Cite:
Tampubolon, S.K.M., Raharjo, M., & Sulistiyani, S. (2023). Environmental Vulnerability against the Presence of Anopheles spp. with Malaria Cases in North Jakarta. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 878–884. https://doi.org/10.29303/jppipa.v9iSpecialIssue.5359

rivers, river basins, cow footprints and lakes (Mulyawati et al., 2022).

In 2021, all cities and districts in DKI Jakarta Province have eliminated malaria and in 2023 DKI Jakarta Province has received a malaria elimination certificate. In addition, DKI Jakarta Province is categorized as an area free of indigenous malaria, however, most malaria cases are imported malaria or case from malaria endemic areas such as Papua Province and other areas that are declared not yet malaria free (Kemenkes RI, 2021). However, there are several locations in DKI Jakarta that have the potential to become breeding sites for *Anopheles* spp. larvae. (Magdalena et al., 2023; Wahyudi et al., 2023). The factors that support the occurrence of transmission are that DKI Jakarta is a center of dynamic economic, social, cultural and high activity and has a very diverse population in terms of educational background, employment, economic status, social status and other diversity which has great potential for outbreak include the transmission and spread of malaria (Raharjo, 2011).

In order to describe vulnerability maps and prevent and overcome malaria transmission, various accurate data that are comprehensive and obtained from a systematic and accountable methodology are very necessary. One method for obtaining the data in question can use a device known as a geographic information system (GIS) (Hutrianto and Syakti, 2019; Gwitira et al., 2020; Purwanto&Paiman, 2023). In several areas, malaria case data mapping has been carried out. The results of the measurements and mapping are considered quite effective in providing information which is ultimately used as the main material in policy making for health policy makers and local governments. Based on this, a study is needed on regional analysis of the presence of *Anopheles* spp. larvae in North Jakarta with a GIS approach in an effort to maintain malaria elimination in the City of North Jakarta.

Method

This study is an observational study with a cross sectional study design. The study was carried out in March – June 2023 in North Jakarta City, DKI Jakarta. The sample consists of data from all malaria patients from 2020-2023 in North Jakarta. Data on all malaria patients was obtained from hospital reports in North Jakarta. Then the global positioning system (GPS) coordinates were taken for the addresses of malaria patients in North Jakarta. In addition, data on the presence of *Anopheles* spp. in habitat obtained from larval surveys conducted in Cilincing and Penjaringan Sub-Districts. Then the GPS coordinates were taken for the habitat of *Anopheles* spp larvae. In the habitat, environmental variables such as temperature, salinity and pH are also measured. The GPS points obtained are then used for spatial analysis (Ofgeha, 2023).

Spatial analysis was carried out using ArcGIS which includes a map and buffer of the presence of *Anopheles* spp. larvae, a map and buffer of malaria incidence. The data obtained was plotted into a shape file map, then plotted with thematic maps per region in the study. The description of the distribution of malaria incidence and the existence of breeding places can be analyzed to determine the estimated direction of malaria transmission in each region, so that the level of vulnerability of each region can be measured (Ofgeha, 2023). Correlation analysis was carried out to determine the relationship between environmental variables and the presence of *Anopheles* spp larvae.

Result and Discussion

Malaria is a disease that is spread globally and is often found in tropical areas. Malaria can cause death in society if it is not handled properly. Based on surveillance data from the DKI Jakarta Provincial Health Service, the malaria cases that occurred in Jakarta were imported malaria cases. Based on data on malaria cases in North Jakarta City for 2020-2023, the cases are spread across Cilincing, Koja, Tanjung Priuk, Kelapa Gading and Penjaringan sub-districts. There are several factors that influence the occurrence of malaria cases in an area, one of which is the presence of vectors and breeding sites for *Anopheles* spp. (Mahendran et al., 2020). The results of examining the potential habitat of *Anopheles* spp. In Marunda Village there are three habitats. The density of larvae of *Anopheles* spp. The results obtained are presented in Table 1.

Table 1. Larval density based on habitat type in North Jakarta

Location	Habitat type	+/- Larva Anopheles spp.	Density/Water container
Marunda village	Pond 1	Positive	2/10
	Pond 2	Negative	0/10
	Pond 3	Positive	6/10
	Pond 4	Positive	7/10
	Pond 5	Positive	3/10
	Rice filed	Negative	10/10
	Fish pond 1	Positive	0/10
	Fish pond 2	Positive	15/10
	Fish pond 3	Positive	1/10

The results of examining the potential habitat of *Anopheles* spp. in Kamal Muara Village, Penjaringan District there are five habitats consisting of swamps,

ditches, lagoons, fish ponds and mangroves. However, there were no *Anopheles* spp larvae found in this habitat. In addition, the larval habitat index of *Anopheles* spp. in Marunda Village is 78%. North Jakarta's location in the coastal area of DKI Jakarta has a variety of aquatic habitats for *Anopheles* spp., of which the most numerous are former ponds. So this habitat influences the existence of suitable locations or places for *Anopheles* to breed. However, the results of this study differ from Mahdalena and Ni'mah (2016) in that the habitat of *Anopheles* spp. in Lengkiti District, South Sumatra, swamps, ponds, puddles, rivers, ditches were found. This habitat is spread across 13 villages, while the *Anopheles* spp. those caught included *An. aconitus, An. annularis, An. barbirostris, An. kochi, An. nigerrimus, An. schueffneri, An. vagus, An. umbrosus, An. philippinensis, An. maculatus, An. minimus*. Suyono et al. (2021) added that the breeding place for *Anopheles* spp. found in Sikka Regency include lakes, reservoirs, ponds, ditches, rice fields, springs, puddles, rivers and puddles of the permanent type as well as lagoons of the temporary type. There were 15 positive breeding sites for larvae. There are still patients spread over a radius of <500 meters from the breeding place.

Figure 1. Habitat of *Anopheles* spp. larvae in North Jakarta

The map of malaria incidence in the North Jakarta area is overlaid with a 500 meter buffer zone from 2020 to 2023. Spatially, it can be seen in Figure 2. The results of the buffer analysis of the distribution of malaria cases show that in a zone with a radius of less than 500 meters the distribution is random. The distance used as a buffer distance is based on the estimated flight distance of *Anopheles* spp. mosquitoes as a vector of *Plasmodium* sp. cause of malaria. In addition, the results of buffer analysis of the distribution of *Anopheles* spp. and potential habitat for the development of *Anopheles* spp. The aim is to determine the distribution estimates and dispersed patterns.

Based on spatial statistical analysis of Average Nearest Neighbor (ANN) based on ArcGIS software, the output results were obtained with a Z-score value = 1.634, which means that malaria incidence is grouped in certain areas. This pattern was generated from the observed mean distance value of 1,315.91 meters and the expected mean distance value of 1,046.38 meters. The analysis results also show that the z-score value is 1.634 and p-value = 0.102 which does not show significance for the neighborhood ratio hypothesis. Therefore, the distribution pattern of malaria in North Jakarta City is random. Based on theory, if the average nearest neighbor ratio < 1 then the distribution pattern shows clustered. However, if the average nearest neighbor ratio is > 1 then the distribution pattern shows dispersed.

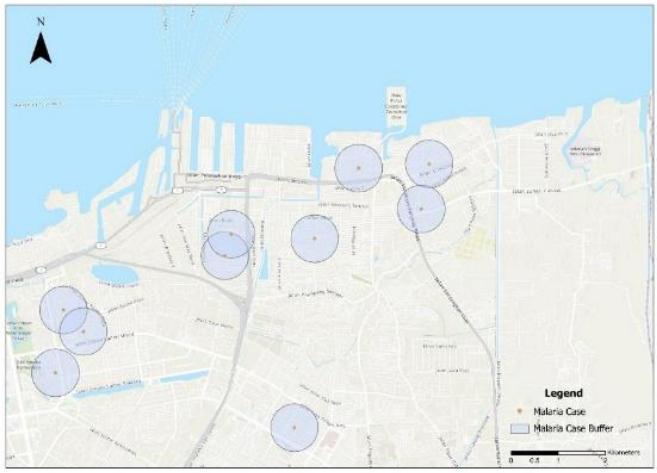

Figure 2. Map of malaria case in North Jakarta from 2020 – 2023 with *zone buffer* 500 meter

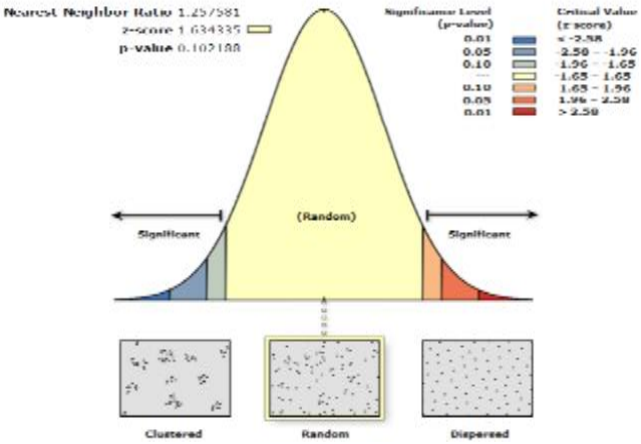

Figure 3. Average Nearest Neighbor Summary malaria cases in North Jakarta 2020-2023

Larvae of *Anopheles* spp. found in several habitats in Cilincing Sub-District and potential habitat for the development of *Anopheles* spp. larvae also found in Penjaringan Sub-District. The distribution pattern of *Anopheles* spp. in North Jakarta City is dispersed. As in previous study conducted by Nababan and Umniyati (2018), based on spatial analysis there were three clusters of malaria cases in Purworejo and only one cluster was

statistically significant. The distance of the breeding place of 2 km from people's homes can be a risk factor for malaria cases because the mosquito's flight distance in search of blood or food is furthest in the range of 2-3 km. However, the results of this study show that the distribution pattern between the presence of *Anopheles* spp. and malaria cases are different.

Different results were shown by study by Yunicho (2020) that the habitat found for *Anopheles* spp. distributed within a radius of 500 meters from the location of malaria patients in Bulukumba. Overlay analysis also shows that areas or houses located around the location of malaria patients within a radius of 500 meters are thought to be at risk of contracting malaria. Distribution of *Anopheles* spp. from the North Jakarta area overlaid with a buffer zone of 500 meters in 2023, spatially it can be seen in Figure 4.

Table 2. Average Nearest Neighbor Summary malaria cases in North Jakarta 2020-2023

Average nearest neighbor summary	
Observed mean distance	1315.9121 meters
Expected mean distance	1046.3836 meters
Nearest neighbor ratio	1.257581
z-score	1.634335
p-value	0.102188

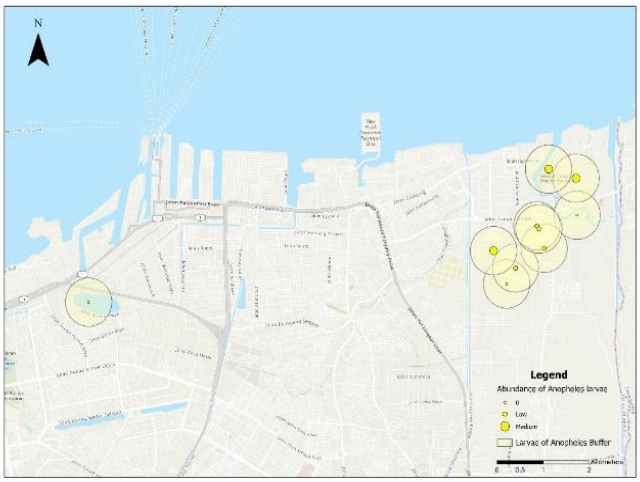

Figure 4. Map of distribution of *Anopheles* spp larvae in North Jakarta in 2023 spatially with a buffer zone of 500 meters

Based on spatial statistical analysis of average nearest neighbor (ANN) based on ArcGIS software, the output results were obtained with a Z-score = 4.302. This pattern was generated from the observed mean distance value of 1273.29 meters and the expected mean distance value of 744.14 meters. The analysis results also show that the z-score value is 4.302 and p-value = 0.000017 which shows significance for the neighborhood ratio hypothesis. Therefore, the distribution pattern of the presence of Anopheles spp larvae. in North Jakarta City it is dispersed. Based on theory, if the average nearest neighbor ratio < 1 then the distribution pattern shows clustered. However, if the average nearest neighbor ratio is > 1 then the distribution pattern shows dispersed.

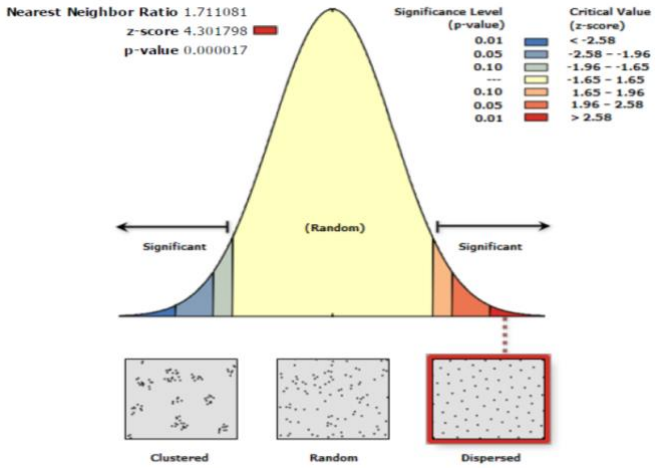

Figure 5. Average Nearest Neighbor Summary of the presence of *Anopheles* spp larvae in North Jakarta in 2023

Based on the distribution map of *Anopheles* larvae and malaria cases (Figure 5), it can be explained that the place where *Anopheles* spp larvae develop as many as 7 points and potential habitat as many as 14 points. The results of the analysis show that all potential habitats found in the North Jakarta area are located at a distance of >500 m. In a zone >500m, breeding places have the potential to prevent malaria transmission. However, buffering in the zone >1000 m from the breeding place found in this study shows that it does not have the potential to result in malaria transmission because malaria patients in North Jakarta are too far away from *Anopheles* spp. from found breeding sites. The buffer for malaria patients aims to find out how far the possibility of transmission of infections that can be transmitted by *Anopheles* spp. which is indigenous. The direction of transmission is estimated and calculated from malaria patients who are still within the mosquito's flight distance. Based on buffer analysis in the <500 m zone, malaria transmission cannot cross the boundaries of other sub-district areas. The results of examining environmental variables in the potential habitat of Anopheles spp. in Marunda Village, North Jakarta are presented in Table 3.

Table 3. Average nearest neighbor summary of the presence of *Anopheles* spp. larvae in north Jakarta in 2023

Average Nearest Neighbor Summary	
Observed mean distance	1273.2849 meters
Expected mean distance	744.1406 meters
Nearest neighbor ratio	1.711081
z-score	4.301798
p-value	0.000017

Furthermore, the relationship between environmental variables and the presence of Anopheles spp. carried out using correlation analysis. Based on the analysis carried out, the pH variable had no effect and was related to the presence of *Anopheles* spp. larvae (p> 0.05). In addition, the relationship between pH and the presence of Anopheles spp. is negative. The results of this study are different from research conducted by Zamil et al. (2021) that water pH has a significant relationship to the density of *Anopheles* spp. larvae and the direction is positive. The results are different because it is thought that there are differences in water quality and habitat type. Previous research explains that the incidence of malaria is influenced by the environment, behavior, knowledge, attitudes, preventive measures, socio-economics, demographics. These environmental factors are closely related to temperature and pH variables, while the incidence of malaria is closely related to the presence of Anopheles spp. as a malaria vector (Castro, 2017; Sadoine et al., 2018; Lewinscaa et al., 2021).

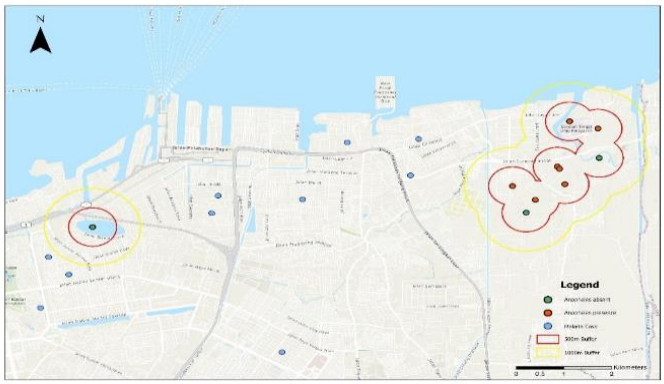

Figure 6. Geographic distribution map of Anopheles sp. larval habitat and malaria cases in North Jakarta

The salinity variable has no effect and is related to the presence of Anopheles spp larvae. (p> 0.05). In addition, the relationship between salinity and the presence of Anopheles spp. is positive. The temperature variable has no effect and is related to the presence of Anopheles spp larvae. (p> 0.05). The relationship between temperature and the presence of *Anopheles* spp. is negative. Life cycle of *Anopheles* spp. as a vector is greatly influenced by environmental conditions such as abiotic and biotic. Statistically, there was no significant influence (p> 0.05) of the variables pH, salinity and temperature in the habitat of *Anopheles* spp. larvae with the presence of larvae. The relationship which is not strong and has a negative pattern also does not represent a significant influence on the presence of *Anopheles* spp larvae. Higher temperatures in water habitats accelerate larval growth and help the growth of microorganisms and algae which are a food source for *Anopheles* spp larvae. Salinity factors also support the growth and development of *An. merus* larvae. Conductivity, TDS and canopy cover are some of the important factors that influence the development and abundance of *An. merus* larvae in their habitat. Habitat type also influences the abundance of *An. merus* larvae, which prefers ponds and fish ponds, but cannot grow in swamps and animal footprints (Kipyab et al., 2015; Ndiaye et al., 2020).

Tabel 4. pH, Salinity, and water temperature habitat of *Anopheles* spp larvae.

Location	Habitat type	Larvae of *Anopheles* spp.	pH	Salinity	Variable Tenperature
Kelurahan Marunda	pond 1	Positive	9	9	28
	pond 2	Negative	8.5	8	30
	pond 3	Positive	8.1	7	30
	pond 4	Positive	8.2	5	29.8
	pond 5	Positive	8.3	7	30
	Rice filed	Negative	7.8	1	30
	Fish pond 1	Positive	9	1	34
	Fish pond 2	Positive	9.3	1	33.1
	Fish pond 3	Positive	9.3	1	33.3

Habitat type, presence of aquatic plants, shade plants, temperature and presence of larval predators of *Anopheles* spp. is a variable that influences the presence of larvae in the environment (Aklilu et al., 2020; Hessou-Djossou et al., 2022). The presence of *Anopheles* spp. in the environment is one of the risk factors for malaria transmission in the area and can be eliminated using nanosilver organophosphate and carbamate to support malaria elimination efforts in the future (Brugueras et al., 2020; Raharjo et al., 2023) and also use the biolarvacide to reduce *Anopheles* spp. larvae and combat malaria (Moniharapon et al., 2023).

Conclusion

The distribution of malaria incidence in North Jakarta City is random and the distribution of *Anopheles* larvae in North Jakarta is dispersed. In a zone >500m, breeding places have the potential to prevent malaria transmission. Buffering in the zone >1000 m from the breeding place found in this study shows that it does not have the potential to cause malaria transmission because malaria sufferers in North Jakarta are too far away from *Anopheles* spp. from found breeding sites.

Acknowledgments
We thank to all staff who support this study.

Author Contributions
Conceptualization, S.K.M.T., M.R and S.; methodology, S.K.M.T.; software, S.K.M.T. and M.R.; validation, M.R and S.; formal analysis, S.K.M.T.; investigation, S.K.M.T. and M.R.; resources, S.K.M.T.; data curation, S.K.M.T., M.R., S.; writing—original draft preparation, S.K.M.T.; writing—review and editing, S.K.M.T., M.R and S.; visualization, S.K.M.T.; supervision, M.R and S.; project administration S.K.M.T; funding acquisition, S.K.M.T and M.R. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

References

Aklilu, E., Kindu, M., Gebresilassie, A., Yared, S., Tekie, H., & Balkew, M. (2020). Environmental Factors Associated with Larval Habitats of Anopheline Mosquitoes (Diptera: Culicidae) in Metema District, Northwestern Ethiopia. *Journal of arthropod-borne diseases*, 14(2), 153–161. https://doi.org/10.18502/jad.v14i2.3733

Arwati, H., Yotopranoto, S., Rohmah, E. A., Syafruddin, D. (2018). Submicroscopic malaria cases play role in local transmission in Trenggalek district, East Java Province, Indonesia. *Malaria Journal*, 17(1): 2. https://doi.org/10.1186/s12936-017-2147-7.

Ashley, E. A., Pyae Phyo, A., & Woodrow, C. J. (2018). Malaria. *Lancet*, 391(10130), 1608–1621. https://doi.org/10.1016/S0140-6736(18)30324-6

Barber, B. E., Grigg, M. J., Cooper, D. J., van Schalkwyk, D. A., William, T., Rajahram, G. S., & Anstey, N. M. (2021). Clinical management of *Plasmodium knowlesi* malaria. *Advances in parasitology*, 113, 45–76. https://doi.org/10.1016/bs.apar.2021.08.004

Brugueras, S., Fernández-Martínez, B., Martínez-de la Puente, J., Figuerola, J., Porro, T. M., Rius, C., Larrauri, A., & Gómez-Barroso, D. (2020). Environmental drivers, climate change and emergent diseases transmitted by mosquitoes and their vectors in southern Europe: A systematic review. *Environmental research*, 191, 110038. https://doi.org/10.1016/j.envres.2020.110038

Castro M. C. (2017). Malaria Transmission and Prospects for Malaria Eradication: The Role of the Environment. *Cold Spring Harbor perspectives in medicine*, 7(10), a025601. https://doi.org/10.1101/cshperspect.a025601

Escalante, A. A., & Pacheco, M. A. (2019). Malaria Molecular Epidemiology: An Evolutionary Genetics Perspective. *Microbiology spectrum*, 7(4), 10.1128/microbiolspec.AME-0010-2019. https://doi.org/10.1128/microbiolspec.AME-0010-2019

Fahmi, F., Pasaribu, A. P., Theodora, M., & Wangdi, K. (2022). Spatial analysis to evaluate risk of malaria in Northern Sumatera, Indonesia. *Malaria journal*, 21(1), 241. https://doi.org/10.1186/s12936-022-04262-y

Gwitira, I., Mukonoweshuro, M., Mapako, G., Shekede, M. D., Chirenda, J., & Mberikunashe, J. (2020). Spatial and spatio-temporal analysis of malaria cases in Zimbabwe. *Infectious diseases of poverty*, 9(1), 146. https://doi.org/10.1186/s40249-020-00764-6

Hessou-Djossou, D., Djègbè, I., Ahadji-Dabla, K. M., Nonfodji, O. M., Tchigossou, G., Djouaka, R., Cornelie, S., Djogbenou, L., Akogbeto, M., & Chandre, F. (2022). Diversity of larval habitats of *Anopheles* mosquitoes in urban areas of Benin and influence of their physicochemical and bacteriological characteristics on larval density. *Parasites & vectors*, 15(1), 207. https://doi.org/10.1186/s13071-022-05323-6

Hutrianto, Syakti, F. (2019). Sistem informasi geografis penderita malaria pada Kelurahan Cereme Taba Kota Lubuklinggau. *Jurnal Teknologi Informasi dan Komunikasi*, 10(2): 178-188. https://doi.org/10.31849/digitalzone.v10i2.3134.

Kemenkes RI. (2021). Laporan situasi terkini perkembangan program pengendalian malaria di Indonesia tahun 2020. Jakarta.

Kipyab, P. C., Khaemba, B. M., Mwangangi, J. M., & Mbogo, C. M. (2015). The physicochemical and environmental factors affecting the distribution of *Anopheles merus* along the Kenyan coast. *Parasites & vectors*, 8, 221. https://doi.org/10.1186/s13071-015-0819-0.

Lederman, E. R., Sutanto, I., Wibudi, A., Ratulangie, L., Rudiansyah, I., Fatmi, A., Kurniawan, L., Nelwan, R. H., & Maguire, J. D. (2006). Imported malaria in Jakarta, Indonesia: passive surveillance of returned travelers and military members postdeployment.

Journal of travel medicine, 13(3), 153–160. https://doi.org/10.1111/j.1708-8305.2006.00034.x

Lewinscaa, M.Y., Raharjo, M., Nurjazuli. (2021). Faktor risiko yang mempengaruhi kejadian malaria di Indonesia: review literatur 2016-2020. *Jurnal Kesehatan Lingkungan*, 11(1):16-28. https://doi.org/10.47718/jkl.v11i1.1339.

Magdalena, S. K., Raharjo, M., Sulistiyani. (2023). Analysis of the presence of *Anopheles* larvae in the city areas in DKI Jakarta on the risk of indigenous malaria cases in 2022. *Majalah Kesehatan Indonesia*, 4(1);33-38. DOI: 10.47679/makein.2023137.

Mahdalena V, Ni'mah T. (2016). Ekologi nyamuk Anopheles spp. di Kecamatan Lengkiti, Ogan Komering Ulu, Sumatera Selatan tahun 2004-2015. *Spirakel*, 8(2): 27-36. DOI: 10.22435/spi.v8i2.6167.27-36.

Mahendran, R., Pathirana, S., Piyatilake, I. T. S., Perera, S. S. N., & Weerasinghe, M. C. (2020). Assessment of environmental variability on malaria transmission in a malaria-endemic rural dry zone locality of Sri Lanka: The wavelet approach. PloS one, 15(2), e0228540. https://doi.org/10.1371/journal.pone.0228540.

Moniharapon, D. D. ., Unitly, A. J. A. ., & Silahooy, V. B. . (2023). Biolarvicide Activity of Male Breadfruit Flower Causes Mortality of Anopheles sp. Mosquito Larvae Malaria Vector. Jurnal Penelitian Pendidikan IPA, 9(9), 7699–7704. https://doi.org/10.29303/jppipa.v9i9.4246.

Mulyawati, A., Sukesi, T. W., Mulasari, S. A, Setiawan, Y. D., Yuliani, Y., Patmasari, Y., Girsang, T.A., Damayanti, I.L. (2022). Analisis situasi luas wilayah reseptif malaria di Kabupaten Gunungkidul Daerah Istimewa Yogyakarta tahun 2021. Sanitasi: *Jurnal Kesehatan Lingkungan*, 15(1): 47-60. https://doi.org/10.29238/sanitasi.v15i1.1448.

Nababan, R., Umniyati, S. R. (2018). Faktor lingkungan dan malaria yang memengaruhi kasus malaria di daerah endemis tertinggi di Jawa Tengah: analisis sistem informasi geografis. *Berita Kedokteran Masyarakat*, 34(1):11-18. https://doi.org/10.22146/bkm.26941.

Ndiaye, A., Niang, E. H. A., Diène, A. N., Nourdine, M. A., Sarr, P. C., Konaté, L., Faye, O., Gaye, O., & Sy, O. (2020). Mapping the breeding sites of *Anopheles gambiae* s. l. in areas of residual malaria transmission in central western Senegal. *PloS one*, 15(12), e0236607. https://doi.org/10.1371/journal.pone.0236607

Ofgeha G. Y. (2023). Spatial analysis of malaria hotspots in Dilla sub-watershed: Western Ethiopia. *PloS one*, 18(4), e0273271. https://doi.org/10.1371/journal.pone.0273271.

Purwanto, A. ., & Paiman, P. (2023). Flood Risk Spatial Modeling Based on Geographical Information Systems and Remote Sensing in the Pemangkat Regensi . Jurnal Penelitian Pendidikan IPA, 9(11), 9554–9563. https://doi.org/10.29303/jppipa.v9i11.5264.

Raharjo, M. (2011). Malaria vulnerability index (MLI) untuk manajemen risiko dampak perubahan iklim global terhadap ledakan malaria di Indonesia. *Vektora: Jurnal Vektor dan Reservoir Penyakit*, 3(1):54-80.

Raharjo, M., Subagio, A., Sulistiyani. (2023). Synthesis of nanosilver, organophosphate ($C_{10}H_{19}O_6PS_2$), and carbamate (CO_2NH_3) for *Anopheles* larva control in malaria endemic area on Covid-19 pandemic. *AIP Conference Proceedings,* 3(1):2683.040007. https://doi.org/10.1063/5.0126509

Rahayu, N., Suryatinah, Y., & Ferdina, A. R. (2023). Strengthening Malaria Migration Surveillance at Village Level in Tanah Bumbu Regency, South Borneo, Indonesia. Jurnal Penelitian Pendidikan IPA, 9(11), 9733–9740. https://doi.org/10.29303/jppipa.v9i11.4609.

Sadoine, M. L., Smargiassi, A., Ridde, V., Tusting, L. S., & Zinszer, K. (2018). The associations between malaria, interventions, and the environment: a systematic review and meta-analysis. *Malaria journal*, 17(1), 73. https://doi.org/10.1186/s12936-018-2220-x

Suyono, R., Salmun, J. A. R., Ndoen, H. I. (2021). Analisis spasial tempat perindukan nyamuk, kepadatan larva dan indeks habitat dengan kejadian malaria di Kecamatan Waigete Kabupaten Sikka. *Media Kesehatan Masyarakat*, 3(1):1-11. https://doi.org/10.35508/mkm.v3i1.3146.

Wahyudi, Raharjo, M., Sulistiyani. (2023) Malaria vector surveillance in Kepulauan Seribu as threat in DKI Jakarta. *Jurnal eduHealth*; 14(1): 208-215.

Watmanlusy, E., Raharjo, M., Nurjazuli, N. (2019). Analisis spasial karakteristik lingkungan dan dinamika kepadatan Anopheles sp. pengaruhnya terhadap kejadian malaria di Kecamatan Seram Barat Kabupaten Seram Bagian Barat Maluku. *Jurnal Kesehatan Lingkungan Indonesia,* 18(1):12-18. https://doi.org/10.14710/jkli.18.1.12-18.

World Health Organization. (2022). World malaria report 2022: 20 years of global progress and challenges. Geneva, Switzerland.

Yunicho. (2020). Spasial kasus malaria dan sebaran spesies larva Anopheles di wilayah endemis malaria Kabupaten Bulukumba. *Afiasi: Jurnal Kesehatan Masyarakat*, 5(1): 1-10. DOI: 10.31943/afiasi.v5i1.84.

Zamil, N. A. A. (2021). Karakteristik habitat lingkungan terhadap kepadatan larva *Anopheles* spp. *Journal*

health and Science; Gorontalo journal health & Science Community, 5(1):229-242. https://doi.org/10.35971/gojhes.v5i1.10266.