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Larvae-Free Rate *Aedes sp*: The Effect of Temperature, Humidity and Rainfall in Bengkulu City, Indonesia

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Abstract
Background: Bengkulu's tropical climate is very suitable for Ae. aegypti and Ae. albopictus mosquito breeding. Temperature, humidity and rainfall affect mosquito breeding and dengue virus proliferation in mosquitoes, which in turn had an effect on the dengue infections. Dengue prevention strategy currently focuses on vector control with the Larvae Free Rate (LFR) parameter. This study aimed to determine environmental factors affecting the LFR in 2022 in Bengkulu City, Indonesia.
Methods: This research used a cross-sectional study design with time series analysis. Time series was used to analyze and interpret sequential data points collected over the interval of time. Secondary data about LFR was obtained from the Bengkulu City Health Service, and climate variables from the Climatology Station of the Bengkulu Meteorology, Climatology, and Geophysics Agency. Data analysis was conducted through simple linear regressions.
Results: The average of LFR in Bengkulu City in 2022 was 78.13% (below the national target), with the highest in December (87.85%) and the lowest in May (68.53%). The average temperature, humidity, and rainfall were 26.88°C (moderate), 83.5% (moderate), and 328.96% (high), respectively. The simple linear regression analysis showed that the effect of temperature, humidity, and rainfall was significant to LFR with the respective p-values of 0.010; 0.612, and 0.173).
Conclusion: Temperature influenced the LFR by 58,5% but humidity and rainfall have no effect on LFR of *Aedes spp.* in Bengkulu City in 2022. High temperatures will increase the risk of transmission of dengue virus infection by 3-5%.

Keywords: Dengue, Environmental Factors, Temperature, Humidity, Larvae-Free Rate

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Introduction

Dengue Hemorrhagic Fever (DHF) is an infection caused by the Dengue virus. The Dengue virus is spread through the bite of infected female *Aedes aegypti* or *Aedes albopictus* mosquitoes.[1] The Dengue virus is characterised into four serotypes, namely DENV-1, DENV-1, DENV-3, and DENV-4. DENV-3 serotype is often found in Indonesia and is associated with severe manifestations.[2] Data in 2022 recorded 143,266 cases with 1,237 deaths due to Dengue infection in Indonesia.[3] Bengkulu Province, which is located on the coastal area, is one of the cities where Dengue is endemic. Based on a report from the Bengkulu Province Central Statistics Agency (2022), Bengkulu City is included in the high-risk area category and contributes to the highest increase in Dengue cases in Bengkulu Province, with a morbidity rate of 162 per 100,000 population.[4]

Social environmental factors, such as people's habits in maintaining environmental cleanliness and physical environmental factors, such as air temperature, humidity and rainfall can influence the prevalence of Dengue infection in an area.[5–7] This is supported by previous research which found that higher temperatures can elevate the life cycle of mosquitoes. Optimal air humidity for mosquito breeding ranges from 70%–90%, and it shows a positive correlation between rainfall and *Aedes spp.* populations.[8–10] This phenomenon will ultimately result in a larger mosquito population. These factors are related to the mosquito breeding process which ultimately increases the vector density.[11–13]

Efforts to prevent Dengue fever still focus on vector control.[14] Vector control is measured by the Larvae Free Rate (LFR). Chemical control is still the most popular for dengue control programs in Bengkulu City. Adult vector mosquito control by fogging is still the main choice in dengue fever control. These control efforts are only effective if the targeted mosquitoes are still vulnerable to the insecticides used. Apart from being an indicator, LFR is also used as a parameter for successful vector control. The LFR standard value based on the Environmental Health Quality Standards is ≥95%. If the LFR value is < 95%, it indicates that the number of Dengue fever transmission in the area is still high; whereas if the LFR value is ≥95%, it indicates that the number of vectors in an area is under control, so that Dengue transmission can be reduced. However, according to the Indonesian Ministry of Health (2021), LFR nationally as of 2019 has not reached this target.[14] In 2021, LFR in Bengkulu City has also not reached the national target, namely 85.16%.[15] In this case, it can be said that Bengkulu City is not completely free from Dengue infection.

Research on the influence of temperature, humidity and rainfall on LFR has not been carried out much in Indonesia, especially for Bengkulu City in a coastal area which is a favorite place for *Aedes spp.* mosquitoes to breed.[16] Based on this, researchers identify the effect of temperature, humidity and rainfall on LFR in Bengkulu City. This research is expected to be able to analyze LFR for good environmental maintenance in order to improve LFR in Bengkulu City in accordance with national targets. In addition, Meteorology, Climatology, and Geophysics Agency and the Bengkulu City Health Service must work together to increase public awareness of disease transmission during prime season through early warning initiatives. This study aimed to determine environmental factors in Bengkulu City, Indonesia, will affect LFR in 2022.

Methods

This research is quantitative cross-sectional research with a time series approach. Time series was used to analyze and interpret sequential data points collected over interval of time. The information used is secondary data, data about LFR was obtained from the Bengkulu City Health Service, and climate variables from the Climatology Station of the Bengkulu Meteorology, Climatology, and Geophysics Agency in 2022. Data collection of this research lasted for about 1 month in October 2023. Independent variables in the research are temperature, humidity, and rainfall in Bengkulu City, while the dependent variable is LFR in Bengkulu City. After the data is collected, bivariate data analysis was carried out

using SPSS v25 with a simple linear regression test.

Results

Larvae Free Rate

In table 1, LFR data is presented for monthly during 2022. The highest LFR value in Bengkulu City in 2022 was in December (87.85%) and the lowest was in May (68.53%). The average LFR value in Bengkulu City in 2022 was 78.13%. In the data obtained from the Bengkulu City Health Service, there was empty data in October and November 2022, because in those months there were no LFR reports from the Community Health Center surveillance so that the LFR data for that month was considered to have a value of 0. Based on research surveys in several The Community Health Center in Bengkulu City stated that there was no LFR data for that month.

In table 1, monthly temperature data in Bengkulu City in 2022 is presented. The highest temperature in Bengkulu City in 2022 was in May at 27.4℃ and the lowest temperature was in June at 26.2℃. The average temperature in Bengkulu City in 2022 is 26.88℃; this value is included in the medium category based on the Meteorology, Climatology, and Geophysics Agency category.

In table 1, monthly humidity data in Bengkulu City in 2022 is presented. The average humidity in Bengkulu City during 2022 was 83.5%. The average humidity in Bengkulu City is included in the moderate category based on the Meteorology, Climatology, and Geophysics Agency category. The highest humidity in Bengkulu City in 2022 was in June at 87% and the lowest was 81% in February.

In Table 1, monthly rainfall data in Bengkulu City is presented in 2022. In June 2022, the heaviest rainfall was recorded at 585 mm, while the smallest occurred in July at 218 mm. Rainfall in January was quite low and tended to be stable until May. In June, rainfall increased significantly and from July to December rainfall tended to fluctuate. The average rainfall in Bengkulu City in 2022 was 328.96 mm in the high rainfall category.

Data analysis

The data was analyzed using SPSS v25 with a simple linear regression test, it was found that the p-value of the temperature variable on LFR was 0.010 with an R square of 0.585, the p-value of humidity on LFR was 0.612, the p-value of rainfall on LFR was 0.173. R square is the proportion of the variance in the dependent variable that is explained by the independent variables. Based on the results of the regression test, it was found that the temperature variable influenced the LFR variable with an influence of 58.5%, while humidity and rainfall had no influence on LFR.

Table 1. Larva Free Rate (LFR), Temperature, Humidity, and Rainfall in Bengkulu City

	Larva Free Rate (%)	Temperature (℃)	Humidity (%)	Rainfall (mm)
January	76.61	27.1	83	242
February	71.85	26.9	81	232
March	81.37	27.1	82	237
April	71.18	27.3	82	282
May	68.53	27.4	83	277
June	83.61	26.2	87	585
July	82.95	26.8	83	218
August	72.14	26.7	85	521
September	87.18	26.4	85	342
December	87.85	26.4	84	353.6

Table 2. Results of Simple Linear Regression Analysis

Dependent variable	Independent variable	*p-value*	*R square*
LFR	Temperature	0.010	0.585
	Humidity	0.612	-
	Rainfall	0.173	-

SPSS 25 Data Processing Results, 2023

Discussion

Effect of Temperature on LFR

According to Sarwita, Alisjahbana, and Agustian (2018), one of the environmental factors that influences the reproduction of *Aedes aegypti* mosquito larvae is temperature.[17] Mosquito population density, biting speed, length of the gonotrophic cycle, and vector size are influenced by temperature during the life cycle and period mosquito incubation.[18] Vector breeding is most effective in the temperature range of 25°C to 27°C, and usually requires a duration of 12 days. Sarwita, Alisjahbana, and Agustian (2018) reported that the life cycle of the *Aedes aegypti* mosquito was reduced by an average of 7 days at temperatures between 32°C and 35°C.[17] According to additional research, the species *Aedes spp*. can grow and develop between 28°C and 32°C. Even though the temperature is outside this range, the larvae of *Aedes spp.* have the ability to adapt to various environmental conditions so that larvae can survive by reducing their metabolic rate.[19,20]

Based on data obtained from the Climatology Station of Bengkulu Meteorology, Climatology, and Geophysics Agency, Bengkulu City had an average air temperature of 26.88°C in 2022. Temperatures of 24°C–39°C plays an important role in the development, survival, and feeding behavior of mosquitoes for promotes viral replication in the vector.[21] The ability to adapt to temperature depends on the mosquito species and geographic location, such as tropical, subtropical, and equatorial regions.[22] Temperatures in the tropics, which range from 30°C, tend to accelerate the replication of the virus in the mosquito's body. High rainfall can increase the formation of puddles as a breeding place for mosquitoes and increase air humidity. Thus, temperature and climate factors have a direct impact on the activity and ability of vectors to reproduce.

Bengkulu City is an area on the coast. The air in coastal areas was being relatively hot with air temperatures tending to be stagnant throughout the year.[23] Areas in Bengkulu City that are most at risk because they have higher temperatures than other areas include Teluk Segara District, Ratu Samban District, Ratu Agung District, and Gading Cempaka District. High air temperatures can also be caused by densely populated residential factors.[24] This indicates that Bengkulu City in 2022 had an optimal high temperature for the development of *Aedes spp.* mosquito larvae.

This research is strengthened by the findings of Marcellia, Umniyati, and Wijayanti (2019) which showed that air temperature is the ecological factor that has the greatest influence on the density of *Aedes spp.* mosquito larvae.[25] These findings are in line with previous research conducted by Minarti *et al*. (2021) which states that temperature has a major impact on dengue fever.[26] This shows that temperature has the potential to influence the transmission of dengue fever through the role of the vector *Aedes spp*.

Effect of Humidity on LFR

The results showed that there was no relationship between humidity and LFR in Bengkulu City in 2022. This occured because of variations in humidity during 2022 did not fluctuate too much. Apart from humidity, there are many things that can affect LFR, including water reservoirs, the physicochemical environment of vectors, and human activities.[27–29]

Humidity affects mosquito breeding because of the sensitivity of mosquito vectors to humidity. The ability of mosquitoes to survive will be reduced in arid environments.[30] According to Septian

et al. (2017), optimal air humidity for mosquito breeding ranges from 70%–90%.[9,31] Within this specified range of values, mosquito larvae are able to survive at optimal air temperatures and humidity levels, and are protected from extreme cold and heat.[32] This can increase the chances of mosquitoes living so that they can transmit viruses such as the Dengue virus. The average humidity in Bengkulu City is 83.5% and this value is the optimal humidity for mosquito breeding. However, apart from humidity, there are other factors that influence the reproduction of *Aedes spp* mosquitoes.

This research is in line with research by Yahya, Ritawati, and Rahmiati (2019) and according to Restiaty *et al*. (2022) which states that there is no statistically significant correlation between air humidity and larval population.[33,34] Mosquitoes can be said to be vectors if they meet several requirements, including density, mosquito life span, interaction with humans, source of transmission, and susceptibility (resistance) to parasites.[22]

Effect of Rainfall on LFR

The results showed that there was no relationship between rainfall and LFR in Bengkulu City in 2022. According to Tarmana (2017), rainfall ranging from 100-300 millimeters is conducive to the transmission of Dengue fever through the *Aedes spp.* mosquito as vector.[35] Small and continuous rainfall will have the potential to increase mosquito breeding places because it will create puddles of water in water reservoirs around the house, thereby will increasing the mosquito population.[36,37] An increase in mosquito population will have implications for increased Dengue virus transmission, so that the incidence of dengue fever is also relatively increasing.[38] However, high rainfall can damage mosquito breeding places because water will overflow from water storage containers and flow out. This phenomenon causes the movement of mosquito eggs and larvae which ultimately has an impact on reducing the vector population.[36,39] There was no influence of rainfall on LFR in this study, which could be due to the relatively high rainfall value in Bengkulu City. This situation allows vector breeding sites to be eliminated. The findings of this research are in line with research by Rahma (2023) which did not find any correlation between rainfall and LFR[40–42]

This research can still be developed using various research designs, methodologies, locations, and times. Apart from that, it can be considered to use primary data so that the research results can be maximized and significant because the current research results still cannot represent the entire research area.

Conclusion

The average LFR in Bengkulu City in 2022 was 78.13% (below the national target), the highest was in December (87.85%) and the lowest was in May (68.53%). In Bengkulu City in 2022, the average temperature, humidity, and rainfall were 26.88°C (moderate), 83.5% (moderate), and 328.96% (high), respectively. Temperature had an effect on LFR by 58.5%, meanwhile humidity and rainfall had no effect on LFR of *Aedes spp.* in Bengkulu City in 2022. The trend of changes in air temperature, humidity, and rainfall every month can be the basis for consideration in developing an effective dengue transmission prevention plan through vector control. This research can still be developed using various research designs, methodologies, locations, and times. It is recommended to use primary data as the current research results can not represent the entire study area.

Author Contribution

ZSA analyzed and interpreted the data. LFVG and Suwarsono performed the review interpreted the data, DT analyzed. All authors read and approved the final manuscript.

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