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Aedes aegypti Larvae and Their Association with Air Temperature and Water pH in Cipadung Kulon, Bandung

Agung Sutriyawan[1*], Rohmatul Fajriyah[2], Kariyam Kariyam[2]

[1]Master's Student of Statistics Program, Faculty of Mathematics and Natural Sciences, Universitas Islam Indonesia, Yogyakarta, Indonesia,
[2]Department of Statistics, Faculty Mathematics and Natural Sciences, Universitas Islam Indonesia, Yogyakarta, Indonesia

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ABSTRACT

Background: Dengue remains a significant public health problem in Indonesia, particularly in urban and semi-urban areas. Bandung City continues to experience increasing dengue cases annually. Understanding the environmental factors associated with *Aedes aegypti* larvae and their spatial distribution is important to support targeted vector control strategies. This study aimed to describe the spatial distribution of *Aedes aegypti* larvae and to examine its association with air temperature and water pH levels.
Methods: The study employed a cross-sectional design with an analytical approach. It was conducted in Cipadung Kulon Subdistrict, Bandung City, from May - July 2024. A total of 95 households were selected using proportional and systematic random sampling techniques. Data were collected through direct observation. Spatial distribution was presented descriptively, while associations between variables were analyzed using the *chi-square test.*
Result: Among 95 households, 71.6% (68/95) were positive for *Aedes aegypti* larvae. Air temperature was significantly associated with larval presence (p = 0.035; PR = 1.43). Households with optimum air temperature (25–30°C) had a higher prevalence of larvae compared to those with suboptimal temperature. Water pH levels were also significantly associated with larval presence (p = 0.002; PR = 1.60), with higher prevalence observed in households with pH levels of 6.0–7.5.
Conclusion : The presence of *Aedes aegypti* larvae at the household level was associated with air temperature and water pH. Maintaining proper environmental conditions in water storage containers and strengthening community-based vector control practices are important to reduce larval habitats.

Keywords: *Aedes aegypti*; air temperature; dengue; spatial distribution; water pH

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*Corresponding author, agung.epid@gmail.com

Introduction

Dengue remains a significant health problem in tropical and subtropical regions, including Indonesia, with the number of cases continuing to increase every year. In 2023, there were more than 6.5 million cases of dengue and around 7,300 deaths in more than 80 countries, with Southeast Asia being the most affected region.[1] In Indonesia, in 2022, there were 143,266 cases of dengue and 1,237 deaths, with the provinces of North Kalimantan, East Kalimantan, and Bali recording the highest number of cases.[2] West Java, as one of the provinces in Indonesia, also experienced an increase in the incidence of dengue in 2024, with an incidence rate of 122 cases per 100,000 population, higher than the previous year. Cases of dengue in West Java have increased every three years, with the highest incidence rates in the cities of Sukabumi, Bandung, and Bogor.[3]

The city of Bandung, which is part of an endemic area for dengue, has seen an increase in dengue cases from 1,856 cases in 2023 to 6,879 cases in 2024, with the incidence rate rising from 72.93 per 100,000 people in 2023 to 209 per 100,000 people in 2024.[4] Dengue cases in Bandung City have been found in all districts, with the highest number of cases occurring in Rancasari, Buahbatu, and Coblong districts. Panyileukan district, with 214 cases in 2024, also shows a significant number of cases. Environmental factors, particularly open water storage areas that serve as breeding grounds for *Aedes aegypti* mosquitoes, play a significant role in the spread of this disease. Although various efforts such as Mosquito Nest Eradication Movement (3M Plus) have been made, dengue remains a problem that has not been fully resolved.[2] The severity of this disease varies, and without prompt treatment, dengue can be fatal.[5,6] It is imperative that research is conducted on the environmental factors that influence the distribution of *Aedes aegypti* mosquito larvae in Cipadung Kulon Subdistrict. This research is crucial for supporting the control of the disease, identifying further risk factors and designing more effective interventions.

The use of Geographic Information Systems (GIS) in public health is growing to visualise health data spatially, enabling the identification of disease patterns and associated environmental risk factors. GIS is used to analyse the distribution of disease vectors, such as *Aedes aegypti*, to design more effective and targeted interventions.[7] Previous research in the city of Bandung has shown that environmental factors, such as temperature and water pH levels, play an important role in the distribution of *Aedes aegypti* mosquito larvae.[8] Several studies have also found that optimal temperatures between 24.3°C and 31.8°C support the survival of *Aedes aegypti* larvae, while water pH levels between 6.0 and 7.5 is also ideal for larvae development.[9,10] Research in several countries, such as Mexico and Saudi Arabia, also shows that water temperature and pH have a significant relationship with the presence of mosquito larvae, which supports the importance of monitoring environmental conditions in controlling dengue.[11,12]

In addition, the spatial distribution of *Aedes aegypti* mosquito larvae is heterogeneous and influenced by various factors, including the environmental conditions of their breeding sites. In São Paulo, Brazil, higher surface temperatures and social vulnerability are associated with a high frequency of *Aedes aegypti* larval habitats.[13] Research in Cali, Colombia, shows that mosquito breeding sites are highly dynamic and influenced by regional characteristics.[14] In Jazan, Saudi Arabia, seasonal variability affects larval prevalence, with cooler temperatures in January and December resulting in higher larval prevalence, while warmer temperatures in April and May reduce it.[12] This shows that water temperature and pH not only affect larval survival, but also contribute to spatial variation, which is important for designing effective dengue prevention and control strategies.

Despite the fact that prior studies have addressed environmental factors such as air temperature and pH that influence the distribution of *Aedes aegypti* mosquito larvae, there remains a paucity of understanding regarding the spatial relationship between

these factors and the prevalence of dengue in urban areas, particularly in Cipadung Kulon Village, Bandung City. A substantial body of research has been dedicated to the analysis of general risk factors, with a paucity of studies that have incorporated a detailed examination of environmental factors in endemic regions characterised by high population density.[15] In addition, although Geographic Information Systems (GIS) have been used to map the distribution of disease vectors, there has been no study that specifically utilises GIS to analyse the spatial distribution of *Aedes aegypti* mosquito larvae in Cipadung Kulon Village, which is an area with a high number of dengue cases. This study aims to describe the spatial distribution of *Aedes aegypti* larvae and to examine its association with air temperature and water pH levels, in order to provide a better understanding of environmental factors influencing larval presence. The results of this study are expected to provide practical recommendations for dengue control at the micro level, as well as to utilise GIS technology to identify high-risk areas that require immediate intervention. Additionally, this study is expected to serve as a reference for mosquito vector control policies in urban areas with dynamic and densely populated environmental characteristics.

Methods

Participants and Study Design

This study employed a cross-sectional analytical survey with spatial analysis. This research was conducted in Cipadung Kulon Village, Bandung City, from May to July 2024. The research location was selected based on routine dengue surveillance data from the Bandung City Health Office, which indicated a low Larvae Free Rate and a consistently high dengue incidence in Cipadung Kulon.

The population in this study included all households registered under the Household Register (KK) system in Cipadung Kulon Village, Bandung City, totalling 4,444 households. The minimum sample size was calculated using the WHO sample size calculator for a single population proportion. The formula applied was $n = Z^2 \times p(1-p) / d^2$, where $Z = 1.96$ for a 95% confidence interval, $p = 0.50$ (assumed prevalence, used to obtain the maximum required sample size in the absence of prior local estimates), and $d = 0.10$ (precision). The initial calculation yielded $n_0 = (1.96^2 \times 0.50 \times 0.50) / 0.10^2 = 96.04$. Considering the finite population of $N = 4{,}444$ households, the sample size was adjusted using $n = n_0 / [1 + (n_0 - 1)/N]$, resulting in $n \approx 94.0$, which was rounded up to 95 households.

The sampling procedure in this study used multistage random sampling, conducted in two sequential stages. In the first stage, households were proportionally allocated across Household Registers (KK) using proportional random sampling. The number of households selected from each register was determined by the formula $n_i = (N_i / N) \times n$, where N_i is the total households in register i, N is the total households in Cipadung Kulon (4,444 households), and n is the required sample size (95 households). This ensured that each register contributed a sample reflecting its population size. In the second stage, systematic random sampling was applied within each Household Register list. The sampling interval was calculated as $k = N_i / n_i$. A random starting point between 1 and k was selected using a random number table/application, and subsequent households were chosen by adding the interval (k) until the allocated sample for that register was fulfilled. To ensure consistency and minimize measurement bias, each selected household was observed for one primary water storage container (WSC) (e.g., bathtub, bucket, or drum). Thus, a total of 95 households and 95 primary WSCs were included. The geographic coordinates of each sampled household were recorded, georeferenced, and visualized in the spatial distribution map to represent study sites and larval positivity.

The dependent variable in this study was the presence of *Aedes aegypti* mosquito larvae found in water storage containers (WSC) in the sample houses, classified as positive (if at least one larva was found) or negative (if no larvae were detected). The independent variables were air temperature and water pH measured around each inspected WSC. Air temperature was selected instead of water temperature for

methodological and ecological reasons: in field conditions, air temperature reflects the ambient microclimate surrounding WSCs and serves as a stable proxy that indirectly governs container water temperature and larval habitat suitability. This approach also allows consistent assessment across containers with varying sizes, materials, and exposure to sunlight. The optimal temperature range for larval development is 25–30°C, while temperatures outside this range (<25°C or >30°C) are considered suboptimal. Water pH was categorized as potential (6.0–7.5) or non-potential (<6.0 or >7.5), as pH within the potential range supports larval survival and development.

Measurements and Procedure

Mosquito larvae data collection is carried out through visual observation of places that have the potential to become breeding grounds for *Aedes aegypti*, such as bathtubs, buckets, flower vases, and other containers that often contain water. Larvae inspection is performed using a small net, pipette, and flashlight. If larvae are not visible, wait for 30 seconds to 1 minute to confirm their presence, and tap the container as larvae typically attach to the walls of water storage containers. Additionally, to determine the location of mosquito larvae in each sample house, use the Google Maps app to record the coordinates by tapping the location and clicking 'Save Location.' The coordinate data from Google Maps is then imported into Google Earth software and exported to ArcGIS software for further analysis.

For air temperature measurements, use a thermo-hygrometer by pressing the on/off button, then set the device to Celsius mode. Place the device near the water storage container being inspected and leave it for 1–5 minutes to obtain the temperature measurement results, which are then recorded on the observation sheet. Air temperature was selected as the primary environmental variable rather than water temperature for methodological and ecological reasons. In field conditions, air temperature reflects the ambient microclimate surrounding water storage containers and serves as a stable proxy that indirectly shapes container water temperature and larval habitat suitability. For water pH levels measurements, use a pH meter that has been calibrated beforehand to ensure accurate results. Subsequently, place the device into the water in the storage area being inspected, press the on button, and wait 1–5 minutes until the pH reading stabilises. The pH measurement results are then recorded on the observation sheet.

Statistical Analysis

Descriptive spatial distribution mapping of *Aedes aegypti* larvae was conducted using ArcGIS software. Geographic coordinates of sampled households were plotted as point features, and larval status was coded as a binary attribute (1 = positive, 0 = negative). The resulting map visualized the distribution of larval-positive and larval-negative households across the study area. This spatial approach was limited to descriptive visualization and did not include inferential spatial statistical analyses (e.g., Kernel Density Estimation, Moran's I, or hotspot analysis).

Univariate analysis was conducted to describe each variable, including the presence of *Aedes aegypti* larvae, air temperature, and water pH levels, using frequency distributions. Bivariate analysis was performed using the chi-square test to assess the association between independent variables (air temperature and water pH levels) and the dependent variable (presence of *Aedes aegypti* larvae). The strength of association was expressed as the Prevalence Ratio (PR), calculated from 2×2 contingency tables by comparing the proportion of larval positivity between exposure and non-exposure groups. 95% confidence intervals (95% CI) were also reported. Statistical significance was set at $p < 0.05$.

Ethical Clearance

Ethical approval for this study was obtained from the Health Research Ethics Commission, Bhakti Kencana University

(Approval No. 084/09.KEPK/UBK/VII/2024).

Result

Figure 1 presents the descriptive spatial distribution of *Aedes aegypti* larvae based on observations from 95 households. Each point represents a sampled household, categorized as larval-positive or larval-negative. Households were classified as positive if at least one water storage container within the household was found to contain larvae. The map shows that 71.6% of households (68/95) were positive for *Aedes aegypti* larvae, while 28.4% (27/95) were negative. Larval-positive households are distributed across the study area, indicating a heterogeneous pattern of larval presence. This spatial visualization is intended to provide a descriptive overview of larval distribution rather than to perform inferential spatial analysis.

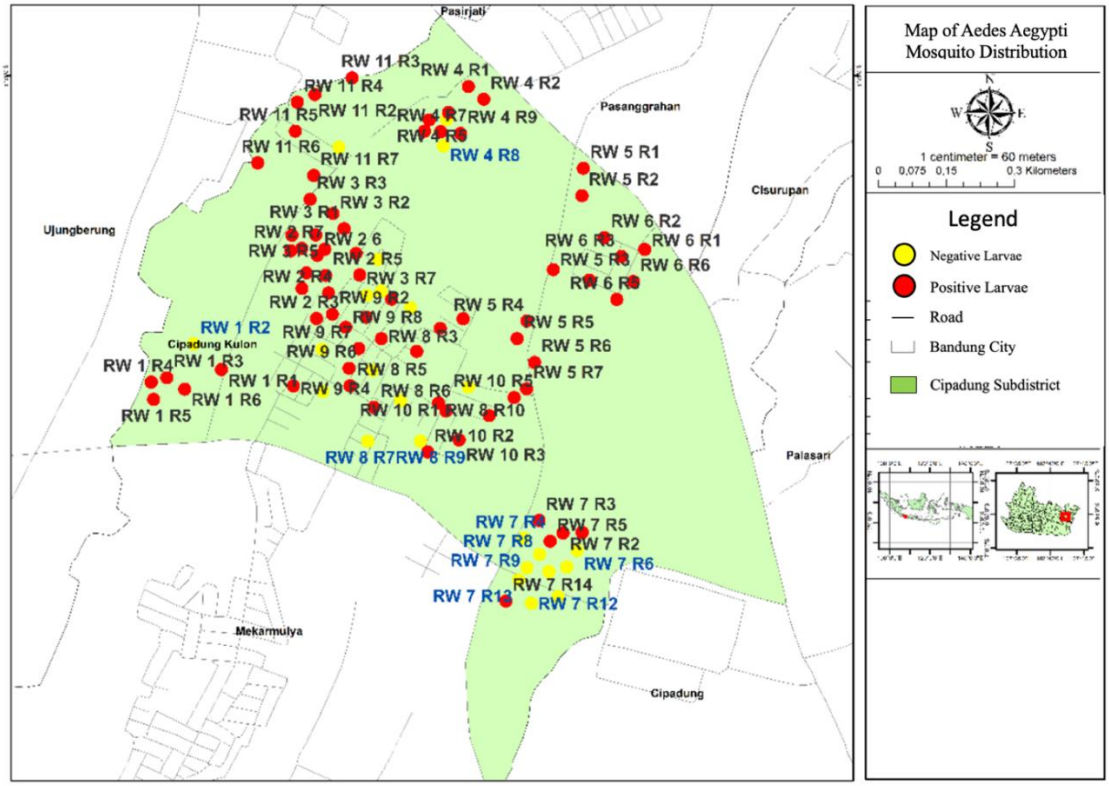

Figure 1. Descriptive Spatial Distribution of *Aedes aegypti* Larvae

Table 1 shows that among the inspected households (n = 95), 71.6% (68/95) were positive for *Aedes aegypti* larvae, while 28.4% (27/95) were negative. In terms of environmental conditions, 69.5% (66/95) of households were classified as having optimum air temperature (25–30°C), while 30.5% (29/95) were categorized as suboptimal. For water pH levels, 60.0% (57/95) of households had water within the potential pH range (6.0–7.5), whereas 40.0% (38/95) were categorized as non-potential.

Table 1. Frequency Distribution of Inspected Houses, Inspected Water Reservoirs, Air Temperature, and Water pH Levels

Variable	n	%
Inspected Houses (n=95)		
Positive Larvae	68	71,6
Negative Larvae	27	28,4
Air Temperature (n=110)		
Optimum (25-30°C)	66	69,5
Suboptimal (<25°C atau >30°C)	29	30,5
Water pH Levels (n-110)		
Potential (6,0-7,5)	57	60
Non-potential (<6,0 atau >7,5)	38	40

Figure 2 shows the distribution of positive and negative water storage containers, with the positivity proportion highlighted for each container type. For example, 75% of bathtubs (39/52), 60% of buckets (15/25), and 77% of plant pots (13/16) were found to contain *Aedes aegypti* larvae.

Table 2 shows that air temperature is significantly associated with the presence of *Aedes aegypti* larvae (p = 0.035; PR = 1.43; 95% CI: 1.01–2.03). Households with optimum air temperature (25–30°C) had a 1.43 times higher prevalence of larval presence compared to those with suboptimal temperatures (<25°C or >30°C). Similarly, water pH levels were significantly associated with the presence of *Aedes aegypti* larvae (p = 0.002; PR = 1.60; 95% CI: 1.16–2.21). Households with potential water pH levels (6.0–7.5) had a 1.60 times higher prevalence of larval presence compared to those with non-potential pH levels (<6.0 or >7.5).

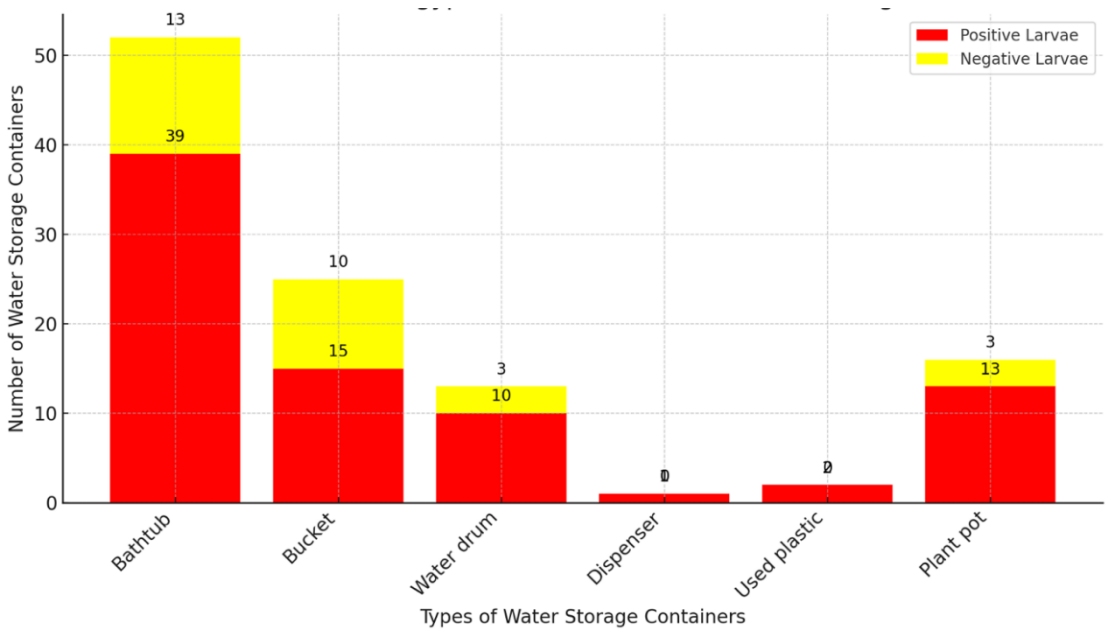

Figure 2. Distribution of *Aedes aegypti* larvae in Different Water Storage Containers

Table 2. Relationship between air temperature and water pH levels with the presence of *Aedes aegypti* mosquito larvae

Environment	*Aedes Aegypti* Larvae				Total		*P-Value*	PR (95% CI)
	Positive		Negative					
	n	%	n	%	n	%		
Air Temperature								
Optimum	52	78.8	14	21.2	66	100	0.035	1.428 1.005-2.029
Suboptimal	16	55.2	13	44.8	29	100		
Water pH Levels								
Potential	48	84.2	9	15.8	57	100	0.002	1.600 1.160-2.208
Non-potential	20	52.6	18	47.4	38	100		
Total	68	71.6	27	28.4	**95**	**100**		

Discussion

The descriptive spatial mapping in Cipadung Kulon Village indicates that open water storage containers (WSCs) particularly bathtubs, buckets, and water drums—remain the main breeding sites for *Aedes aegypti*. This is reflected by the high larval positivity at the household level (71.6%). These findings are consistent with evidence showing that larval habitats with favorable physical conditions, especially optimal pH and temperature, are associated with larval presence,[9] and that poorly managed or reused water containers contribute to larval distribution.[16] Urban settings with relatively higher ambient temperatures,[17] along with high population density and the availability of uncovered containers.[18] may further influence the observed distribution. Overall, these findings suggest that larval occurrence is closely related to environmental conditions and household water storage management.

This study found that households with optimum air temperature (25–30°C) had a higher prevalence of *Aedes aegypti* larvae compared to those with suboptimal temperature. This finding is consistent with previous studies showing that temperature is associated with mosquito development and survival.[19] Higher ambient temperatures may accelerate larval metabolism and development, thereby supporting larval persistence in breeding habitats.[20] Findings from Bukittinggi also reported that higher air temperatures are associated with increased larval presence and dengue risk.[21]

However, it is important to note that this association does not imply a direct causal relationship. The effect of air temperature on larval presence may be influenced by other environmental and household factors, such as container type, exposure to sunlight, water storage practices, and housing conditions, which were not controlled for in this study. Air temperature outside the optimum range may negatively affect multiple mosquito life stages. Elevated temperatures can slow development, disrupt metabolic processes, and increase mortality rates.[22,23] Eggs, in particular, hatch optimally at temperatures between 25–30°C, while higher temperatures may inhibit embryonic development and reduce adult emergence. These findings are consistent with observations from Cirebon, West Java, where higher temperatures were associated with reduced larval development and adult mosquito presence.[24]

Several studies also highlight that water temperature within containers has a more direct physiological effect on larval development. For example, research in Jakarta reported that higher water temperatures (especially >27°C) are associated with faster larval development.[25] In the present study, although water temperature was not measured, air temperature may serve as an ecological proxy influencing the microenvironment of water containers.

Water pH in this study was also significantly associated with larval presence, with higher prevalence observed in households with water pH within the range of 6.0–7.5. This finding aligns with studies in Brazil showing that extreme acidic conditions can cause larval mortality, while near-neutral pH supports larval survival.[26] Studies in Makassar and Nigeria similarly reported that pH values close to neutral are associated with higher larval abundance.[27,28]

Consistent findings were also reported in Cirebon, West Java, where larval presence was more frequent at pH 7 compared to more acidic or alkaline conditions.[24] nder suboptimal pH conditions, larval food sources such as plankton may decline, which could reduce larval survival,[29] However, a study in South Jakarta found no significant association between pH and larval presence, suggesting that additional water quality factors, such as chlorine content, may also play an important role.[30] This indicates that pH is an important, but context-dependent, factor influencing larval habitats.

These findings suggest that routine household container management is essential to reduce larval habitats. Containers should be regularly cleaned, drained, and covered, particularly in environments with conditions that are associated with larval presence, such as optimum temperature and near-neutral pH. Community-based interventions focusing on

improving water storage hygiene remain important strategies for reducing mosquito breeding sites and dengue transmission risk.

This study has several limitations. First, the analysis was limited to bivariate chi-square testing without multivariable adjustment; therefore, potential confounding factors such as container type, water management practices, housing density, and sunlight exposure were not controlled for, which may influence the observed associations. Second, the spatial component was limited to descriptive mapping and did not include inferential spatial statistical analysis. Third, the study was conducted in a single neighborhood, which may limit generalizability. Finally, measurements of environmental variables may vary depending on the time of observation. Future studies are recommended to incorporate multivariable analysis and additional environmental and behavioral factors to better understand the determinants of larval distribution.

` Conclusions

This study found that the presence of *Aedes aegypti* larvae at the household level was associated with environmental factors, particularly air temperature and water pH levels. Households with optimum air temperature (25–30°C) and water pH levels within the range of 6.0–7.5 had a higher prevalence of larval presence compared to those with suboptimal conditions. These findings highlight the importance of maintaining proper environmental conditions in water storage areas as part of dengue vector control efforts. Practical household-based interventions, such as regularly draining and scrubbing water storage containers, keeping containers tightly covered, and eliminating unused items that can collect water, remain essential. Strengthening community participation through routine 3M Plus practices is also important to reduce potential breeding sites. Further studies are recommended to explore additional environmental and behavioral factors associated with larval distribution in different settings.

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