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Analysis of the Fly Population in the Community Around the Landfill Area through Ex Post Facto Approach

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***Abstract*— Flies cohabit with humans, particularly in areas with poor sanitation, producing health problems. Flies serve as vectors for spreading a variety of harmful bacteria, either directly or through food. This research aims to use an ex post facto approach to determine the amount of diversity and distribution patterns of flies in Gampong Jawa, Banda Aceh City, Indonesia. Furthermore, this study can be used as a reference for the sorts of diseases distributed in the community and a factor in fly population control models for the prevention of infectious diseases in the area. The parameters chosen were the diversity index and the fly distribution pattern. Based on the results obtained, the diversity index tended to be low. The moderate diversity index was reached only in clusters 2 (1.02) and 3 (1.08) in the first-day morning, cluster 2 (1.2) in the second-day morning, cluster 3 (1.18) in the morning, and cluster 4 (1.01) in the afternoon of the third-day observation. In terms of distribution pattern parameters, the results obtained for uniform and clumped distribution patterns are the same when seen from the four clusters observed. According to the findings of this study, the fly diversity index in Gampong Jawa is still low, and the distribution pattern is homogeneous and clumped. As a result, to avoid pathogen transmission, a fly control model must be developed.**

***Keywords*— Fly population; pathogen vectors; ex post facto; diversity index; distribution pattern.**

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I. INTRODUCTION

Flies are one type of arthropod belonging to the order Diptera [1]–[3]. Flies also play a major role in human health problems, such as agents or mechanical vectors of disease transmission, especially foodborne diseases, perching on food [4]–[10]. Several kinds of flies that are involved in health issues act as vectors for disease transmission and biological transmission, such as types of viruses that mature in insects (invertebrate hosts) to complete their life cycle before transmission to vertebrate hosts (animals and human) [11]. Various types of microorganisms are found in flies' bodies, such as *Enterobacter aerogenes, Escherichia coli, Proteus sp., Bacillus sp., Serratia marcescens, Ascaris spp., Entamoeba spp., Ancylostoma spp., Trichuris spp., Penicillium spp., Aspergillus spp.,* and *Candida spp.* [12]–[15].

Flies are the most numerous and widely distributed insect species on the planet. Flies can be found in tropical and subtropical climates in rural and urban locations. Flies develop from eggs to adults in 7 to 21 days at 25 to 35°C, and the eggs hatch after 8-12 hours. The eggs will hatch and develop into larvae in 3-7 days, depending on the temperature. The period necessary for the metamorphosis of adult flies varies depending on temperature and other factors in different places of the world. The average period for flies to metamorphose ranged from 44 days at an ambient temperature of 16°C to 10 days at a temperature of 30°C [16]. Environmental factors often influence the growth rate of flies. Temperature is a significant environmental factor for the growth of fly populations, particularly in the tropics, which have a great diversity of species. Flies thrive in the tropics due to the favorable temperature, humidity, and availability of food [17].

The existence of flies is very close to human life and sustains life by eating human waste. Flies can be found in many places, especially landfill areas [18], [19]. This is because flies, like organic materials, are consumed by humans, such as sugar, milk, and other foods. In addition, flies were attracted to the smell of human blood and feces [20]–[22].

The behavior of eating organic matter in animal and human waste and other organic waste is the initial stage of a fly polluting any place it infests. Flies also have a habit of defecating and vomiting on the surface where they perch [23]. This behavior causes the emergence of diseases and other infectious diseases. The transmission activity of pathogenic agents from flies to humans is largely determined by the ability of flies to transfer infectious agents to their hosts, commonly known as vector competence [24], [25]. Flies can operate as disease vectors, which means they can carry or transmit disease from one location to another. Mechanical vectors and biological vectors are the two types of vectors. If the disease agent in the vector's body does not change, it is referred to as a mechanical vector. A biological vector is one in which the disease agent undergoes modifications (multiple numbers, cycle changes, or both) in the vector's body [26].

In Indonesia, extraordinary events such as diarrhea, gastroenteritis, and dysentery often occur. Poor sanitation contributes to an increase in the number of fly populations, one of the vectors for disease spread [27]. A lack of monitoring and surveillance activities by the health program manager, particularly in the management of disease spread and control, is evidence of a lack of attention to the impact of fly problems [12].

Gampong Jawa Village, Banda Aceh City, is an area with a high population density and is close to the landfill site of Banda Aceh City. The Gampong Jawa landfill was constructed in 1990, and garbage processing is done in an open dumping mode, which means rubbish is just thrown into the landfill site, causing pollution. The community is confronted with the problem of solid waste, particularly in urban residential areas. Garbage collected in Gampong Jawa is material garbage that is no longer being used, or that has been left over from the course of human activities, both domestic and industrial. The rising garbage output in Gampong Jawa results from the growing population and community activities. The impact of conventionally managed garbage utilizing the open dumping approach makes this area ideal for fly breeding. It impacts the increasing incidence of infectious diseases prevalent in Gampong Jawa. The sanitary landfill method of decentralizing garbage at a landfill far from the city center attempts to limit the number of open spaces that can become sources of infectious diseases. Although the landfill is located far from the city center, the issue has not yet been remedied, which means that letting the waste degrade on its own is still a hazard to the local ecosystem. The issues include air pollution caused by odor, water pollution caused by improper leachate handling, and disease outbreaks produced by organic waste.

Diversity measures the integration of biological communities by calculating and considering the number of populations incorporated with a relative abundance [28]. The distribution pattern is described as frequency, and numerous techniques use spatial patterns. The spatial distribution of the population is controlled by the species' capacity to disperse, interactions between individuals, and habitat preference. Associating these ecological processes with spatial patterns is critical for comprehension and prediction. These data will demonstrate the pattern established in the sample, often known as spatial statistics. Spatial statistics is a method for analyzing distribution data (spatial autocorrelation). The flies captured by adhesive plastic boards for data recovery are primarily stable. Spatial autocorrelation is critical for determining the distribution pattern of an area's characteristics and the interrelationships between areas within it. Moran's Index and the Local Indicator of Spatial Autocorrelation are two approaches for detecting spatial autocorrelation (LISA) [29]–[31].

The diversity and distribution patterns of flies are important indicators of the pattern of development of the fly community in Gampong Jawa, which will impact the type of disease and the number of patients suffering from illness in the Gampong Jawa. Therefore, this study was carried out to obtain information about the level of diversity of fly species and distribution patterns; as a result, this study is expected to serve as the foundation for developing fly population control models to prevent disease transmission caused by flies.

II. Materials and Method

A. Study Area and Data

The research was conducted in Gampong Jawa, Banda Aceh City, Indonesia (Figure. 1). This type of research is quantitative research using an ex post facto approach [32]. The ex post facto method or causal-comparative research is a study directed at determining the causal relationship by observing the effects and then formulating the causal factors based on the results of the data collected [33]–[35]. Ex post facto design is a design used to analyze an existing phenomenon or condition by gathering and analyzing data. The analysis results can expose the phenomenon under study and be utilized as a basis for making research-based decisions.

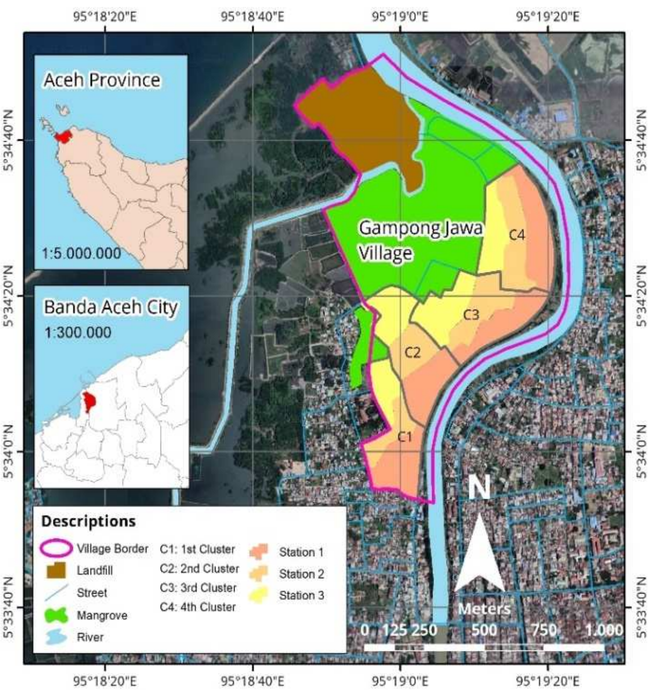

Fig. 1 Research Area

The use of this design is based on the existence of a landfill site that affects the fly population because it is an ideal area for fly activity and breeding. Four clusters (observation points) are determined based on the cluster's distance to the landfill. The range of flies is also used to determine cluster sampling, and flies' cruising range mainly relies on food supply. Flies can travel enormous distances, reaching a distance of 15 kilometers in 24 hours. Most flies stay within 1.5 kilometers of their breeding habitats, although others can travel up to 50 kilometers. The 1.5 km fly distance is used to define cluster sampling. Each cluster consists of three stations, with each station divided into three plots.

B. Data Sampling and Analyzing

Purposive sampling was utilized to acquire the data. Data were collected at the observation site by the research goals. The procedure for data collection was to determine the location of the cluster sampling. Data collection is carried out three times a day (morning, noon, and afternoon) which is carried out in three replications (days) sampling in each cluster. In each of the plots determined, flies were sampled using flypaper put on the ground or a flat surface. The collected samples were sprayed with 70% alcohol and labeled, and the samples were sorted based on morphology and identification. The data were tabulated and analyzed using the Shannon-Wiener equation for the diversity index [36]–[38] and the distribution pattern with the Morisita index equation [39]–[41].

Diversity is commonly associated with distinctions in color, size, appearance, and number of individuals. A community is said to have high diversity if it is made up of several species with the same or nearly the same abundance. In contrast, if a community is made up of a few species and only a few are dominating, then species diversity is low [42]. The diversity index of flies can be analyzed using the following Shannon-Wiener Eq. 1.

$$H' = - \Sigma \text{ pi ln pi} \tag{1}$$

Diversity index criteria:
H' < 1 : Low level of diversity
H' 1-3 : Moderate level of diversity
H' > 3 : High level of diversity

Distribution pattern is the pattern of movement between individuals within a population boundary. Population movement is the distribution of individuals with three basic patterns: random, uniform, and clumped. The pattern of distribution is determined by the physiochemical qualities of the environment as well as the biological characteristics of the organism. The diversity of species has no bearing on dispersal patterns. It is divided into three categories based on the type of distribution: uniform distribution, random distribution, and clustered distribution. Uniform distribution is the distribution of individuals in certain places in the community; random distribution is the distribution of individuals in several places and clustered in other places, and clumped distribution is defined as the distribution of individuals in several clustered in other places. The distribution of individuals in groups, which is rarely seen separately, is called clump distribution. The distribution pattern of flies can be analyzed using the *Morisita* index Eq. 2.

$$\text{Id} = \frac{\text{N } \Sigma X^2 - \Sigma X}{(\Sigma X)^2 - \Sigma X} \tag{2}$$

The values of Mu and Mc are determined using the following equation:

$$\text{Mu} = \frac{\chi^2 0{,}975 - n + \Sigma x_i}{(\Sigma x_i) - 1} \tag{3}$$

$$\text{Mc} = \frac{\chi^2 0{,}025 - n + \Sigma x_i}{(\Sigma x_i) - 1} \tag{4}$$

Morisita's standard degree (Ip) is then determined using the following equation:

$$\text{Id} \geq \text{Mc} > 1; \text{Ip} = 0{,}5 + 0{,}5\left(\frac{Id - Mc}{n - Mc}\right) \tag{5}$$

$$\text{Mc} > \text{Id} \geq 1; \text{Ip} = 0{,}5\left(\frac{Id - 1}{Mc - 1}\right) \tag{6}$$

$$1 > \text{Id} > \text{Mu}; \text{Ip} = -0{,}5\left(\frac{Id - 1}{Mu - 1}\right) \tag{7}$$

$$1 > \text{Mu} > \text{Id}; \text{Ip} = -0{,}5 + 0{,}5\left(\frac{Id - Mu}{Mu}\right) \tag{8}$$

Distribution pattern criteria:
Ip < 0 : Uniform dipersion
Ip = 0 : Random dispersion
Ip > 0 : Clumped dispersion

III. Result and Discussion

A. Total Samples Tabulation

A total of 970 samples were obtained from all clusters. Data on the number of samples based on the day and time of observation are shown in Table 1.

TABLE I
FLY SAMPLES OBTAINED FROM OBSERVATION CLUSTERS

Observations		Clusters			
		1	**2**	**3**	**4**
1st day	Morning	39	28	34	21
	Noon	14	9	29	47
	Afternoon	21	8	47	76
2nd day	Morning	46	34	31	39
	Noon	18	10	34	33
	Afternoon	15	8	47	63
3rd day	Morning	17	7	21	24
	Noon	14	9	29	20
	Afternoon	12	17	29	20

The identification of fly communities in Gampong Jawa showed eight species: *Musca domestica*, *Sarcophaga pubicornis, Lucilia illustris, Condylostylus occidentalis Lucilia coeruleiviridis*, *Hermetia illucens*, *Helichocaetus discifer*, and *Scholastes lonchifera*. Four of the eight collected species can be found across the observation cluster. The four species are *Musca domestica, Sarcophaga pubicornis, Lucilia illustris,* and *Lucilia coeruleiviridis. Hermetia illucens* is the next species not found in cluster *1. Condylostylus occidentalis* is a species that can only be found in two clusters. Clusters 1 and 2 are the furthest away from the landfill. The other two species, Helichocaetus *discifer* and Scholastes *lonchifera*, can only be found in cluster 2, located at the center of the Gampong Jawa communal settlement.

B. Diversity Level

Diversity is a measure of the integration of biological communities that are calculated and considered by calculating and taking into account the number of populations that are incorporated into the average abundance, also known as relative abundance. Diversity is frequently associated with distinctions in color, size, appearance, and number of individuals. A community is said to have great diversity if it comprises several species with the same or nearly the same abundance. In contrast, if a community is made up of a few species and just a few of those species are dominating, then species diversity is minimal. The value of the diversity index of the fly community in each cluster ranged between low and moderate. The data analysis results related to the diversity level of flies based on the diversity index are presented in Table 2.

TABLE II
DIVERSITY INDEX (H') OF FLY

Cluster	Replication	Observation		
		Morning	Noon	Afternoon
1	1st	0,64	0,26	0,85
	2st	0,49	0,35	0,68
	3rd	0,85	0,86	0,98
2	1st	1,02	0,64	0,74
	2st	1,2	0,64	0,66
	3rd	0,8	0,68	0,47
3	1st	1,08	0,77	0,44
	2st	0,63	0,13	0,18
	3rd	1,18	0,55	0,33
4	1st	0,99	0,31	0,54
	2st	0,86	0,3	0,76
	3rd	0,17	1,01	0,83

Based on the analysis of the Shannon-Wiener diversity index, the level of fly diversity in the Gampong Jawa area, Banda Aceh tends to be low (H' <1), especially in cluster 1. This is compared to cluster 1, which is the farthest observation location from the landfill. In this cluster only 5 different fly species were found and generally dominated by *Musca domestica* species. The five species consist of *Musca domestica*, *Sarcophaga pubicornis*, *Lucilia illustris*, *Condylostylus occidentalis*, and *Lucilia coeruleiviridis*. Based on observations made 3 times for 3 days, the observations showed that the lowest diversity index was always observed during the day. This is also in line with the low population observed during the day. In addition, from the observations of cluster 1, it is located in a riverbank area with several community gardens. This shows that agricultural intensification can encourage a decrease in the fly population in an area [43], [44].

While in cluster 2, the level of diversity was relatively low compared to cluster 1, but in replicates 1 and 2, the level of diversity was moderate (H' 1-3), is at the time of observation on the first morning with an H' value of 1.02 and the second morning with an H' value of 1.20, and then dropped the next day. All of the flies in this cluster have been identified based on the identification findings. This shows that the environment in cluster 2 can support the life of the fly community because all fly species find food and a place to breed there. *Musca domestica*, *Sarcophaga pubicornis*, *Lucilia illustris*, *Condylostylus occidentalis*, *Lucilia coeruleiviridis*, *Hermetia illucens*, *Helichocaetus discifer*, and *Scholastes lonchifera* were the flies in Cluster 2. The level of diversity tends to fluctuate because cluster 2 is in the middle of a residential area that is spread out into several alleys. The cause of fly diversity tends to fluctuate, believed to be due to daily community activities that attract flies; 50% of the fly population is around humans due to poor household waste management [11], [45]. In addition, housing conditions that tend to be shady and damp are favored by flies because of environmental factors such as those that are very supportive for flies to breed [46], [47].

Cluster 3 was located in the plastic waste-processing area managed by the village community. The community uses this location to gather inorganic garbage that can still be sold to used goods collectors. In this cluster only 5 fly species were found, including *Musca domestica*, *Sarcophaga pubicornis*, *Lucilia illustris*, *Lucilia coeruleiviridis*, and *Hermetia illucens*. The level of fly diversity in cluster 3 tended to be low, but there was a spike in the morning to a moderate level, in the first-morning observation with an index of 1.08, and the third-morning observation of 1.18. The level of diversity indicates the presence of fly species in this area [28].

Similarly to the data obtained in cluster 4, located at a 300 m from the landfill, one of the data sets has a moderate level of diversity, while the others have a low level of diversity. In this cluster, *Musca domestica* species still dominates compared to the other four species. Besides *Musca domestica*, *Sarcophaga pubicornis*, *Lucilia illustris*, *Lucilia coeruleiviridis*, and *Hermetia illucens* species were also found in cluster 4. The difference in the diversity index value indicates differences in environmental characteristics at the four research sites, so differences appear in the existing fly communities [48]. Figure 2 describes the diversity level of flies in each cluster based on the time of observation.

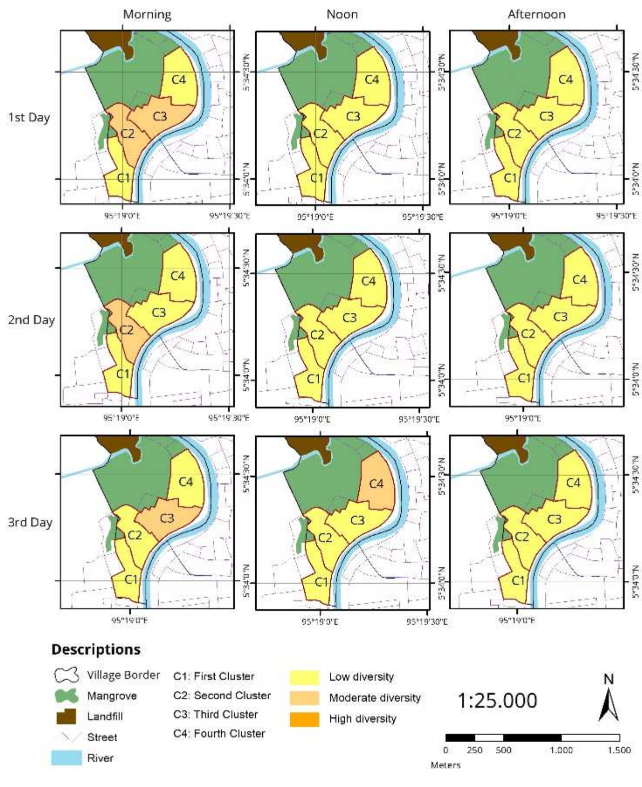

Fig. 2 Mapping the Level of Fly Diversity

According to research data, the level of diversity of flies (Diptera) in the Gampong Jawa area of Banda Aceh is low, as evidenced by observations from many clusters spread around the area. Because the level of diversity of flies is controlled by environmental variables that can affect the growth and development of flies, the influence of different locations and habitats is expected to be a separate variable for determining the level of diversity of flies in a region [49], [50]. These results indicate that, of the four observational clusters, *Musca domestica* is the most commonly encountered species with the highest amount of variety when compared to other fly species identified in all observational clusters. A fly control model must be developed to control the Musca domestica population in the Gampong Jawa community.

C. Distribution Pattern

The distribution pattern, also known as the dispersion pattern, is a broad description of the fly community's distribution in the environment as a pattern of spacing between individuals inside the community boundaries. The distribution of individuals in a community has three fundamental patterns: random, uniform, and clumped. The results of data analysis related to the distribution pattern of flies based on the morisita's standard degree (Ip) are presented in Table 3.

TABLE III
MORISITA'S STANDARD DEGREE (IP) OF FLY

Cluster	Replication	Observation		
		Morning	**Noon**	**Afternoon**
1	1st	0,5665	0,6363	0,1594
	2st	0,8004	0,0310	0,5049
	3rd	0,1203	-0,4763	-0,3847
2	1st	-0,0550	0,0620	-0,0641
	2st	0,5226	-0,4617	-0,0641
	3rd	0,1594	-0,5042	-0,4828
3	1st	0,0164	-0,3892	0,0097
	2st	-0,4964	-0,2263	-0,1091
	3rd	-0,2931	0,0128	0,4360
4	1st	-0,3420	-0,4629	0,4184
	2st	0,5011	0,1690	0,5078
	3rd	-0,4489	-0,4104	-0,0256

The distribution pattern of flies in cluster 1 as the cluster with the farthest location from the landfill, tended to clump, although data that showed the distribution pattern changed to a uniform pattern in the noon (Ip -0,4763), and in the afternoon (Ip -0,3847) for the third replication. Based on the location of cluster 1, which is located far from the landfill, it is possible for the flies that cause group distribution to occur because the food points are only in certain places, so many flies move in groups to find food in certain locations. The distribution pattern's value shows that insects' dispersion plays an important role in various ecosystems [51], [52].

Based on the investigation findings, the distribution pattern of flies in cluster 2 tended to be uniform, although several times the distribution pattern changed to a clumped pattern, such as in the morning of the 2nd, 3rd, and noon of the 1st replicates. The location of cluster 2, which is around the community activity area, causes the distribution pattern to change. In-depth observations of the movement of the distribution pattern of flies are required. Long-term ecological studies are required to track ecosystem changes through time, and such research necessitates standardized and optimized methodologies. Research should focus on key geographic areas, ecosystems, and habitats [53].

The same phenomenon was also found in cluster 3; although it can be said that the distribution pattern of flies in this cluster was uniform, there were changes in several replications and observation times. The clumped pattern occurred in the first replication in the morning (Ip 0,0164), and afternoon (Ip 0,0097), and then occurred again in the 3rd replication in the noon (Ip 0,0128), and afternoon of the observation (Ip 0,4360).

Observations in cluster 4, which is located at a radius of 300 m from the landfill, showed a distribution pattern that tended to be regular, wherein the 1st replication of the distribution pattern tended to be uniform, while in the 2nd replication, the distribution pattern became clumped from morning to afternoon and changed back in the third replication to a uniform pattern. This shows that the distribution pattern can change according to environmental conditions [54]. In most situations, the resulting distribution pattern is one of the most distinguishing properties of the fly community, allowing us to characterize it, and it is a benchmark in observing the distribution of flies and is an important trait of ecology. Figure 3 depicts a description of the distribution pattern of the fly community in each cluster based on the period of observation.

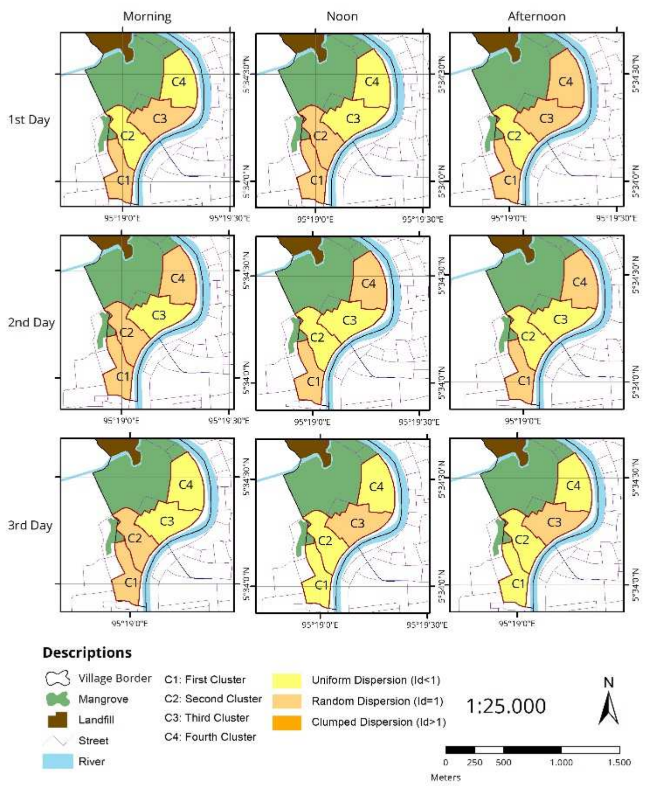

Fig. 3 Mapping the Distribution Pattern of Fly

The mobility pattern between individuals within population limits is defined as the distribution pattern [55]. The examined fly distribution pattern revealed that the distribution of flies in the Gampong Jawa area was the same between uniform and clumped distribution patterns based on location and time of observation (1:1). In most situations, the results of the distribution pattern analysis are one of the most distinctive properties in fly populations and an important property of ecology [56]. However, it is observed that each cluster tends to be different, except for the first cluster, which shows a distribution pattern in groups more often than a uniform or random pattern. This could be due to the different characteristics of each cluster, resulting in a different distribution pattern.

The clumped distribution pattern can be driven by a variety of factors, one of which is the environmental parameters suitable for the fly's life; this implies that a fly community can only live in certain habitats with sufficient environmental circumstances. Variances cause the distribution pattern in responses to local ecosystems. Because individuals in the population tend to form groups of variable sizes, the clustered distribution pattern with varying degrees of grouping is the most common form of distribution.

Meanwhile, the uniform distribution pattern occurs because all individuals in the same habitat compete for both food and shelter. The uniform distribution pattern is generated by individuals competing with one another for food and shelter [57]. These animals are separated due to fierce rivalry for food and shelter. The existence of food sources and environmental sanitation have a substantial influence on the dispersion of flies in the environment. Thus, measures to manage sanitation in the community are required to reduce the rate of flies reproducing in the Gampong Jawa community.

IV. Conclusion

Gampong Jawa, Banda Aceh city is a community residential area that has the closest access to the Banda Aceh City landfill. Thus, the potential for diseases caused by pathogens carried by flies is quite high. Although the study results show that the level of diversity of flies tends to be low, it needs to be anticipated. Therefore, before the level of diversity continues to increase, it is necessary to develop a fly control model to prevent the transmission of pathogens from flies to humans. The results of this study can be used as a reference to determine the fly control model.

Nomenclature

Eq	equation
Fig	figure
H'	diversity index
Id	morisita index
In	natural logarithm
Ip	morisita's standard degree
Mu	morisita's index for clumped dispersion
Mc	morisita's index for uniform dispersion
N	total number of individual
pi	number of individual in each species
X	number of individual per sample

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