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Distribution Pattern Of Dengue Fever Cases Based On The Distribution Of Aedes Aegypti With Wolbachia In Bontang City In 2023–2024

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Abstrak

Penelitian ini bertujuan untuk menganalisis distribusi spasial kejadian demam berdarah dengue (DBD) serta implementasi program Aedes aegypti ber-Wolbachia di Kota Bontang. Penelitian menggunakan desain deskriptif dengan pendekatan ekologi dan analisis spasial berbasis data sekunder tahun 2023–2024. Sebelum intervensi, nilai incidence rate (IR) tinggi ditemukan di beberapa kelurahan seperti Gunung Telihan, Bontang Lestari, Berbas Pantai, dan Kanaan yang menunjukkan adanya hotspot penularan. Pada fase awal program, IR masih bersifat fluktuatif dan bahkan meningkat di wilayah seperti Berbas Tengah dan Gunung Telihan. Namun, pada periode selanjutnya terjadi penurunan IR di beberapa wilayah berisiko tinggi, terutama Gunung Telihan dan Kanaan. Distribusi nyamuk ber-Wolbachia menunjukkan peningkatan bertahap di beberapa kelurahan seperti Belimbing, Kanaan, dan Tanjung Laut, meskipun masih terdapat fluktuasi di beberapa lokasi. Secara keseluruhan, program Wolbachia menunjukkan potensi dalam menurunkan kejadian DBD meskipun distribusinya belum merata di seluruh wilayah.

Abstract

This study aims to analyze the spatial distribution of dengue incidence and the implementation of the Aedes aegypti Wolbachia program in Bontang City. A descriptive ecological design with a spatial analysis approach was used, utilizing secondary data from the Bontang City Health Office during 2023–2024. Prior to the intervention, high incidence rates (IR) were observed in several sub-districts, particularly Gunung Telihan, Bontang Lestari, Berbas Pantai, and Kanaan, indicating active transmission hotspots. During the early phase of the program, IR remained fluctuating, with increases observed in areas such as Berbas Tengah and Gunung Telihan. However, in subsequent periods, a general decline in IR was identified in several high-risk areas, including Gunung Telihan and Kanaan. The distribution of Wolbachia-infected mosquitoes showed a gradual increase over time, especially in sub-districts such as Belimbing, Kanaan, and Tanjung Laut, although fluctuations were still observed in some locations. Overall, the findings suggest that the Wolbachia program contributed to reducing dengue transmission, despite variations in its spatial distribution across sub-districts.

INTRODUCTION

Dengue hemorrhagic fever (DHF) is a tropical disease that poses a major threat to human health, particularly in tropical and subtropical countries. It is caused by the dengue virus, which is transmitted through the bite of the Aedes aegypti mosquito. Dengue fever remains endemic in Indonesia, frequently causing outbreaks and outbreaks with high mortality rates (Hariyanti et al., 2023). This disease carries significant morbidity and a very high mortality rate, particularly in children and adults with pre-existing health conditions. This high morbidity also results in lost work productivity and a reduced quality of life due to the need for intensive medical care. The high mortality rate from dengue fever in various regions demonstrates the importance of addressing this problem (Hermania & Hary Cahyati, 2023). Cases reported to the World Health Organization (WHO) increased from 505,430 in 2000 to 5.2 million in 2019. Since early 2023, dengue fever transmission has spread further, coupled with an unexpected surge in cases, resulting in a historic high of over 6.5 million cases and over 7,300 dengue-related deaths (WHO, 2024).

Since its first discovery in Indonesia in 1968, the incidence of dengue fever has continued to rise. From 2020 to 2022, the dengue fever pattern fluctuated significantly, unlike anything we have ever experienced before. This may be due to the coronavirus pandemic in Indonesia. Furthermore, the initial symptoms of dengue fever and COVID-19 are also similar (Ministry of Health of the Republic of Indonesia, 2022a). Dengue fever cases in Indonesia continue to increase, reaching 73,518 cases in 2021, with a death toll of 705. In 2022, there were 131,265 cases with a death toll of 1,183. Between January and July 2023, 42,690 people were infected with dengue fever, and 317 died (Coordinating Ministry for Human Development and Culture, 2023). The number of dengue fever (DHF) cases in 2024 increased significantly compared to the previous year. Throughout 2023, 114,720 cases were recorded. Meanwhile, as of April 1, 2024, there had been 46,168 cases of dengue fever with 350 deaths (Indonesian Ministry of Health, 2024). East Kalimantan ranked sixth out of 38 provinces in Indonesia in 2022, with 5,887 cases (Indonesian Ministry of Health, 2022a). According to data recorded by the East Kalimantan Provincial Health Office, there were 5,841 cases with 39 deaths due to dengue fever throughout 2022. In 2021, there were 2,898 cases with 22 deaths. The 2022 and 2021 cases indicate an increase in dengue cases compared to the previous year (East Kalimantan Communication and Information Office, 2023).

The frequency of dengue fever cases in Bontang City tends to fluctuate annually, but has remained quite high in recent years. According to data from the Bontang City Central Statistics Agency (2023), there were 588 cases recorded in 2021, 307 cases in 2022, and 459 cases in 2023. In Indonesia, the use of Wolbachia in Aedes aegypti mosquitoes to control dengue fever is still a novelty and has been implemented in Bantul and Sleman Regencies, Yogyakarta Special Region Province. This initiative was spearheaded by the Eliminate Dengue Project (EDP) Global in collaboration with an Australian university. Eliminate Dengue Indonesia is a joint research program led by the Faculty of Medicine, Gadjah Mada University, and funded by the Tahija Foundation (Irfandi, 2018).

Wolbachia technology has become an integral part of the National Dengue Fever Control Strategy in Indonesia and has entered the implementation phase in five key cities: Semarang, West Jakarta, Bandung, Kupang, and Bontang. The implementation of the Wolbachia Implementation Pilot Project as an Innovation for Dengue Fever Control marks a significant step forward in combating the disease transmitted by the Aedes aegypti mosquito (Ministry of Health, 2023b). Several previous studies have shown that the control and determinants of dengue fever (DHF) incidence are complex, encompassing both biological interventions and environmental and demographic factors. A quasi-experimental study conducted by Indriani et al. (2020) in Yogyakarta City demonstrated that the distribution of Wolbachia-infected Aedes aegypti mosquitoes reduced dengue hospitalizations by up to 76% compared to control areas. This finding is supported by research conducted by Utarini et al. (2021) using a cluster randomized controlled trial (CRCT) in the AWED study, which demonstrated that Wolbachia intervention effectively reduced dengue cases by 77% and hospitalization rates by up to 86%. It was even effective against four dengue virus serotypes commonly found in Indonesia. Furthermore, an ecological study by Chandra (2019) in Jambi City revealed that environmental factors such as humidity, rainfall, and population density influence dengue incidence, with rainfall being the dominant factor, while temperature and the larval-free rate (ABJ) did not show a significant effect. Furthermore, research by Ar Rafi et al. (2024) using a Geographic Information System (GIS) approach in Tembalang District showed that there was a significant relationship between population density and dengue fever incidence, although the correlation level was relatively low, and identified the highest incidence rate (IR) variation in 2019.

A Geographic Information System (GIS) is a computer-based system used to collect, store, analyze, and display data related to geographic locations on the Earth's surface. In the health context, GIS enables the spatial visualization of various health information, such as disease distribution, health facility locations, immunization coverage, and early detection of potential outbreaks.The use of GIS in the health sector significantly assists the government and relevant agencies in monitoring and planning more effective public health interventions. For example, in the case of infectious diseases like Dengue Hemorrhagic Fever (DHF), GIS can be used to map affected areas, identify vulnerable areas, and design more accurate area-based prevention and response strategies. Based on this, this study aims to map the distribution areas of Wolbachia-infected Aedes aegypti based on the presence of larvae, DHF incidence, and the distribution patterns of DHF cases in Bontang City and Provides an overview of the distribution of DHF cases based on the incidence rate of DHF during the Wolbachia program, also Provides an overview of the distribution pattern of DHF cases based on the presence of Wolbachia-infected Aedes aegypti mosquitoes before and during the implementation of the Wolbachia program.

METHOD

This research method uses a quantitative approach with a descriptive research design based on ecological studies. The aim is to describe the distribution patterns of dengue hemorrhagic fever (DHF) and its relationship to the implementation of the Wolbachia program at the population level. The ecological approach was chosen because this study focuses on analyzing the relationship between regional-level exposures, such as the spread of Wolbachia-infected Aedes aegypti, and health outcomes in the form of DHF incidence at the population level. Furthermore, this study utilizes Geographic Information Systems (GIS) as the primary analytical tool to visualize the spatial patterns of disease spread, using QGIS software version 3.40.10.

This study was conducted from October 2025 to March 2026, using secondary data collected from 2023 to 2024. The study location is Bontang City, East Kalimantan, the first region in the province to implement Wolbachia-based DHF control technology. This location was selected based on the relevance of the ongoing intervention program, allowing for analysis before and during program implementation.

The variables in this study consist of independent and dependent variables. The independent variable was the distribution area of Wolbachia-infected Aedes aegypti mosquitoes, differentiated based on the program implementation stage in several sub-districts. Meanwhile, the dependent variables included dengue fever incidence, measured using the incidence rate (IR), the presence of Wolbachia-infected Aedes aegypti mosquito larvae, and the distribution pattern of dengue cases before and during the program. These variables were measured using secondary data categorized based on specific criteria, such as low and high IR and the success of larvae presence based on the number of pupal sheaths.

Table 1. Operational Definition of Research

No	Variable	Operational Definition	Measurement Method	Objective Criteria	Data Scale
		Independent Variable			
1	Distribution area of *Aedes aegypti* infected with Wolbachia	Locations within Bontang City where the dengue control program using *Aedes aegypti* infected with Wolbachia is implemented	Secondary data	15 Sub districts in Bontang City	Nominal
		Dependent Variables			
2	Dengue Incidence Rate (IR)	Number of dengue cases recorded by the Bontang City Health Office	Secondary data	Low IR = < 49 per 100,000 population High IR = ≥ 49 per 100,000 population (Ministry of Health of Indonesia, 2020)	Ordinal

No	Variable	Operational Definition	Measurement Method	Objective Criteria	Data Scale
3	The presence of *Aedes aegypti* with Wolbachia	Monitorint results	Secondary data	Low frequency = <60% Medium frequency = 60 – 70% High frequency = >70% (WMP, 2022)	Nominal

The population in this study was all Wolbachia-infected Aedes aegypti mosquitoes in Bontang City. The sampling technique used total sampling, meaning the entire population was used as the research sample. Therefore, the entire administrative area, consisting of three sub-districts and 15 sub-districts, was analyzed comprehensively without exception. This approach was chosen to obtain a comprehensive picture of the distribution of dengue cases and the scope of Wolbachia program implementation throughout the study area.

Data collection was conducted through document review utilizing secondary data obtained from the Bontang City Health Office. The data collected included the distribution of Wolbachia-infected Aedes aegypti, dengue fever incidence data in the form of a recapitulation of cases from 2023–2024, and data on the presence of mosquito larvae obtained from pupa skin survey reports. Furthermore, spatial data, in the form of an administrative map of Bontang City, was obtained from the national geospatial portal to support GIS analysis. All collected data then underwent processing stages including editing, coding, entry, and tabulation to ensure data quality and consistency before analysis.

Data analysis in this study was conducted using univariate and spatial methods. Univariate analysis was used to describe the frequency distribution of each variable in tabular and percentage form. The data processing techniques in this study were carried out through several stages, namely editing, coding, entry, and tabulating. The editing stage was carried out by re-examining secondary data to ensure completeness, accuracy, and consistency of data over a two-year period, including the accuracy of writing numbers and spelling. Next, the coding stage was carried out by grouping variables into certain categories, such as the incidence rate (IR) of dengue fever which was divided into low IR (<49 per 100,000 population) and high IR (≥49 per 100,000 population), and the presence of mosquito larvae which was categorized based on the number of pupal casings (0 = <50/failed and 1 = ≥50/successful). The coded data was then entered into Microsoft Excel to facilitate the analysis process. The final stage was tabulating, which is the presentation of data into tabular form per variable for easier understanding, which was then summarized in the form of frequency distributions and percentages.

RESULT AND DISCUSSION

This research was conducted in the Bontang City area. Bontang City is located between 117°23' East Longitude - 117°38' East Longitude and 0°01' North Latitude - 0°12' North Latitude. The administrative map of Bontang City can be seen in Figure 1.

Figure 1. research area map

Before the implementation of the Wolbachia program, the distribution of dengue incidence rate (IR) in Bontang City showed considerable variation across sub-districts, indicating uneven transmission intensity. The highest IR was observed in Gunung Telihan (312.61), accompanied by the highest number of cases (43), highlighting this area as a major transmission hotspot. Other sub-districts with relatively high IR included Bontang Lestari (160.13), Berbas Pantai (139.35), and Kanaan (113.46), despite having smaller populations, suggesting a higher individual risk of infection. In contrast, areas such as Tanjung Laut recorded the lowest IR (40.17), indicating relatively lower transmission. Detailed Data can be Seen in table 2.

Table 2. Distribution of dengue fever incidence rates from May to August 2023

No.	Sub Distrigct (Kelurahan)	Population	Dengue Cases	IR
1	Kel. Tg Laut	17,428	7	40.17
2	Kel. Tg.Laut Indah	15,015	13	86.58
3	Kel. Berbas Tengah	17,375	16	92.09
4	Kel. Berbas Pantai	10,764	15	139.35
5	Kel. Satimpo	8,851	7	79.09
6	Kel. Bontang Lestari	4,996	8	160.13
7	Kel. Bontang Kuala	5,184	4	77.16
8	Kel. Bontang Baru	12,819	13	101.41
9	Kel. Api-Api	18,138	14	77.19
10	Kel. Gn. Elai	17,414	13	74.65
11	Kel. Loktuan	22,644	13	57.41
12	Kel. Guntung	5,282	5	94.66
13	Kel. Belimbing	14,029	8	57.02
14	Kel. Gn. Telihan	13,755	43	312.61
15	Kel. Kanaan	4,407	5	113.46

The spatial distribution maps ini Figure 2 illustrate the relationship between dengue incidence rate (IR) and the implementation area of the Aedes aegypti Wolbachia program in Bontang City. Prior to the intervention (May–August 2023), the incidence rate map shows that most sub-districts were categorized as high IR (≥49 per 100,000 population), indicated by the dominant red color across the region. This suggests that dengue transmission was widespread, with several areas such as Gunung Telihan, Bontang Lestari, and Berbas Pantai identified as high-risk clusters. In contrast, the map of Wolbachia distribution indicates that nearly all sub-districts in Bontang City were included in the intervention program, as shown by the uniform coverage across the study area. The overlap of these two maps demonstrates that the Wolbachia implementation was strategically applied in areas with high dengue transmission intensity, indicating a targeted public health response aimed at reducing dengue incidence in high-risk locations.

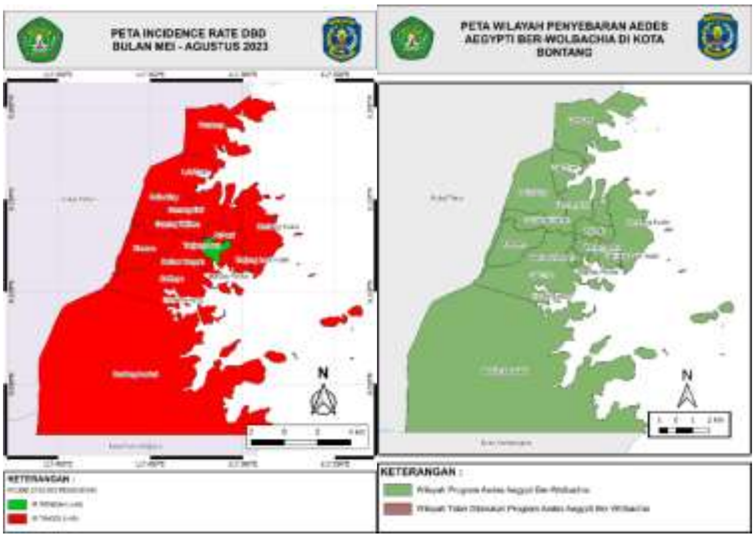

Figure 2. Map of the Incident Rate and Distribution Area of Wolbachia-Infected Aedes Aegypti Mosquitoes May–August 2023

The distribution of dengue incidence rate (IR) during the implementation of the Wolbachia program in Bontang City from 2023 to 2024 shows a dynamic and fluctuating pattern across sub-districts. In the early phase of the program (September–December 2023), several areas such as Guntung (189.32) and Gunung Telihan (138.13) already exhibited relatively high IR values. This trend intensified in the following period (January–April 2024), where a significant increase was observed in multiple sub-districts, particularly Gunung Telihan (308.35), Berbas Tengah (249.77), and Kanaan (201.43), indicating that dengue transmission remained high during the initial phase of Wolbachia implementation. However, in the subsequent periods (May–August 2024 and September–December 2024), a general decline in IR was observed in many areas. Notably, Gunung Telihan decreased from 308.35 to 71.71, and Kanaan dropped substantially to 22.38 by the end of 2024. Despite this overall downward trend, some sub-districts such as Guntung and Loktuan continued to show relatively high IR values, suggesting persistent localized transmission.

Table 3. Distribution of Dengue Incidence Rate (IR) During Wolbachia Program in Bontang City (2023–2024)

No	Sub-district	IR Sep–Dec 2023	IR Jan–Apr 2024	IR May–Aug 2024	IR Sep–Dec 2024
1	Tg Laut	11.47	174.14	16.97	39.61
2	Tg Laut Indah	53.28	45.98	13.13	45.98
3	Berbas Tengah	115.11	249.77	79.47	56.76
4	Berbas Pantai	46.45	81.46	73.30	119.11
5	Satimpo	45.19	22.28	44.57	55.71
6	Bontang Lestari	40.03	177.65	138.17	59.21
7	Bontang Kuala	19.29	114.15	190.25	57.07
8	Bontang Baru	54.61	69.24	146.18	53.85
9	Api-Api	11.02	92.44	114.19	59.81
10	Gunung Elai	34.45	28.32	84.96	79.29
11	Loktuan	75.07	117.60	87.11	117.60
12	Guntung	189.32	168.06	93.37	149.39
13	Belimbing	85.53	154.66	154.66	119.51
14	Gunung Telihan	138.13	308.35	121.90	71.71
15	Kanaan	113.45	201.43	89.52	22.38

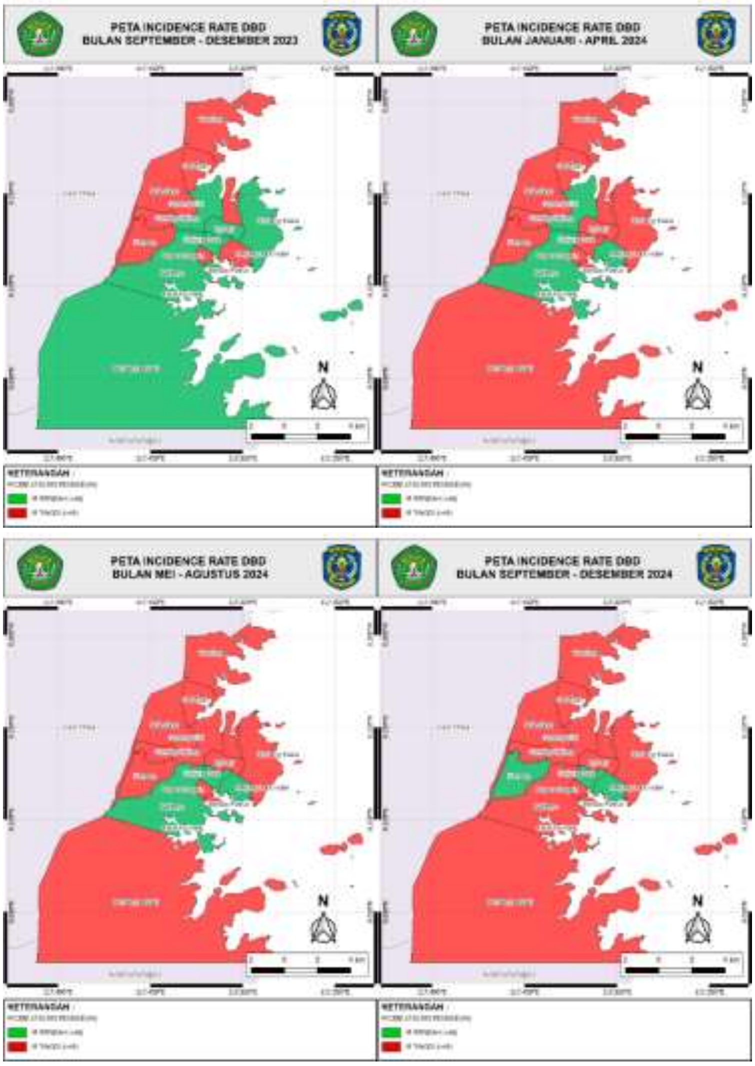

Figure 3. Map of the Distribution of Dengue Incidence Rate (IR) During Wolbachia Program in Bontang City (2023–2024)

The percentage of Wolbachia-infected Aedes aegypti mosquitoes is the result of monitoring the presence of Wolbachia-infected Aedes aegypti mosquitoes captured in each sub-district of Bontang City. The BAWIS team conducted monitoring by capturing mosquitoes in homes at observation locations using sweep net traps. The target number of mosquitoes captured at each location depended on each sub-district, with a target of 100 Aedes aegypti mosquitoes per sub-district. The trapped Aedes aegypti mosquitoes were then tested to identify the presence of Wolbachia.

The monitoring results categorized the percentage of Wolbachia-infected Aedes aegypti mosquitoes into three categories: low frequency (approximately 60%), medium frequency (60-70%), and high frequency (approximately 70%). Bontang City has 15 sub-districts. All sub-districts in Bontang City are implementing a dengue control program using Wolbachia-infected Aedes aegypti technology. Monitoring is carried out 6 times in certain months. The monitoring of *Aedes aegypti* Wolbachia in Bontang City was conducted in six phases at different time points. Monitoring I was carried out on 30 November 2023 in Bontang Utara and on 2 January 2024 in Bontang Selatan and Bontang Barat. Monitoring II took place on 16 January 2024 in Bontang Utara and on 22 March 2024 in Bontang Selatan and Barat, followed by Monitoring III on 20 January 2024 in Bontang Utara and on 22 April 2024 in Bontang Selatan and Barat. Monitoring IV was conducted on 5 June 2024 in Bontang Utara and on 5 August 2024 in Bontang Barat, while data for Bontang Selatan were not available during this phase. Monitoring V was carried out in October 2024, specifically on 8 October in Bontang Utara, 14 October in Bontang Barat, and 23 October in Bontang Selatan. The final phase, Monitoring VI, was conducted simultaneously across all areas on 18 December 2024.

Table 4. Distribution of *Aedes aegypti* Wolbachia (%) Across Monitoring Periods in Bontang City

No	Sub-district	Monitoring I (%)	Monitoring II (%)	Monitoring III (%)	Monitoring IV (%)	Monitoring V (%)	Monitoring VI (%)
1	Tg Laut	0.00	87.04	75.00	-	45.12	28.13
2	Tg Laut Indah	8.70	20.69	0.00	-	-	0
3	Berbas Tengah	2.60	15.87	19.23	-	33.33	29.63
4	Berbas Pantai	1.90	6.78	6.52	-	-	13.79
5	Satimpo	20.00	-	-	-	-	-
6	Bontang Lestari	50.00	15.00	85.71	-	62.07	14.81
7	Bontang Kuala	14.63	0.00	-	-	-	77.78
8	Bontang Baru	11.11	32.00	11.11	23.08	-	36.36
9	Api-Api	4.50	0.00	22.03	58.97	45.83	20
10	Gunung Elai	0.00	0.00	16.67	36.84	26.47	19.44
11	Loktuan	0.00	0.00	0.00	10.71	-	12.07
12	Guntung	35.29	15.00	-	-	-	14.29
13	Belimbing	50.00	82.86	41.49	54.86	85.29	78.57

No	Sub-district	Monitoring I (%)	Monitoring II (%)	Monitoring III (%)	Monitoring IV (%)	Monitoring V (%)	Monitoring VI (%)
14	Gunung Telihan	8.30	11.76	25.00	65.08	61.11	21.28
15	Kanaan	50.00	27.91	26.09	87.95	46.30	34.62

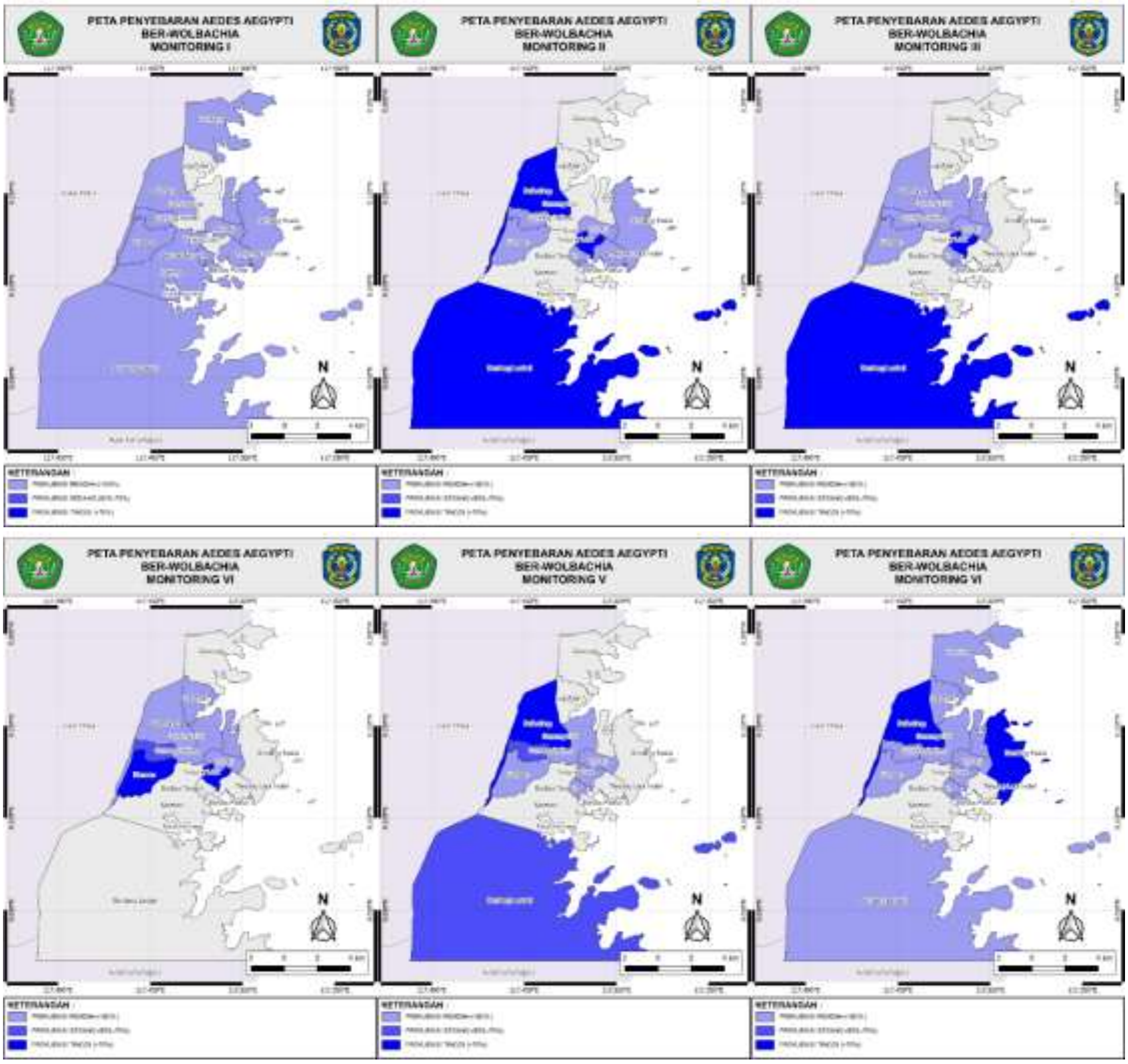

Figure 4. map of The Distribution of *Aedes aegypti* Wolbachia (%) Across Monitoring Periods in Bontang City

As presented in Table 4 and figure 4, the distribution of Aedes aegypti infected with Wolbachia across six monitoring periods in Bontang City demonstrates a fluctuating yet overall increasing trend over time. Monitoring I was conducted between 30 November 2023 (Bontang Utara) and 2 January 2024 (Bontang Selatan and Barat), where most sub-districts still showed low Wolbachia prevalence, including several areas with 0%. Monitoring II (16 January 2024 and 22 March 2024) and Monitoring III (20 January 2024 and 22 April 2024) indicated a gradual increase in several locations, although distribution remained uneven. A more substantial rise was observed during Monitoring IV (5 June 2024 and 5 August 2024), particularly in sub-districts such as Kanaan and Gunung Telihan, where Wolbachia prevalence exceeded 60%. This trend continued in Monitoring V (8, 14, and 23 October 2024), with some areas reaching above 80%, such as Belimbing. However, in the final monitoring phase (Monitoring VI, conducted on 18 December 2024), fluctuations were still observed, with some sub-districts maintaining high prevalence while others declined or remained at 0%.

Before the Wolbachia program was implemented, the incidence rate (IR) for dengue fever in Bontang City from May to August 2023 indicated a very high disease burden. According to data from the Bontang City Health Office (2023), Gunung Telihan Village recorded the highest IR at 312.61. This high incidence rate indicates that the natural Aedes aegypti mosquito population in Bontang City is highly effective in transmitting the dengue virus to the community.

Entering the initial implementation period (September 2023–April 2024), the Indicide Rate (IR) in Bontang City remained fluctuating. In fact, some areas, such as Berbas Tengah Village, experienced a spike in cases. This spike in cases during the initial release phase is a normal phenomenon. This is because the Wolbachia-infected mosquito population is in the dispersal and mating phase with wild mosquito populations and requires time to reach a stable frequency threshold (above 80%) to effectively cripple the mosquito's ability to transmit the Dengue virus (Utarini et al., 2021). Furthermore, the World Health Organization (2024) stated that before Wolbachia-infected mosquitoes truly dominate an area, environmental factors such as high rainfall still have a strong influence on the life cycle and hatching of Dengue-carrying mosquitoes.

The decline in IR rates that began to be seen in 2024 is closely related to the biological mechanism by which Wolbachia bacteria inhibit Dengue virus replication. Biologically, Wolbachia bacteria compete with the virus for essential nutrients (such as cholesterol and lipids) in the mosquito's body and activate the mosquito's innate immune system. This process prevents the virus from multiplying optimally, drastically reducing vector competence. The mosquito's ability to transmit the virus to humans through saliva becomes very low, or "blocked" (World Mosquito Program, 2024; Utarini et al., 2021).

Between September and December 2024, the program's effectiveness demonstrated tangible results, with areas highly susceptible to dengue fever, such as Mount Telihan and Kanaan, experiencing a drastic reduction in IR (Bontang Health Office, 2024). The stability of this decline indicates the success of the population replacement strategy, where Wolbachia-infected mosquitoes successfully interbred with wild mosquito populations and passed the bacteria on to the next generation. This success confirms findings (Utarini et al., 2021) that Wolbachia technology is a sustainable vector control method because it does not require continuous reintroduction after the population reaches equilibrium.

The success in Bontang City reinforces the findings of the Applying Wolbachia to Eliminate Dengue (AWED) study, which demonstrated that this intervention can reduce dengue fever incidence by up to 77% (Utarini et al., 2021). With controlled dengue fever rates by the end of 2024, this is clear evidence that this innovative program is a crucial step in protecting public health, particularly in East Kalimantan. Nevertheless, surveillance of dengue fever and Wolbachia-infected mosquito populations in the field remains necessary to monitor the stability of Wolbachia frequencies in the wild. This ensures long-term protection for the community against the threat of virus mutation, genetic changes in vectors, and the impacts of extreme climate change in the future (Ministry of Health of the Republic of Indonesia, 2023b).

Unlike other areas, Gunung Telihan Village is a hotspot with a very high level of vulnerability and burden of dengue fever transmission. This is evidenced by the high Incidence Rate (IR), which reached 312.61 from May to August 2023 and peaked again at 308.35 from January to April 2024, with 43 cases. The high transmission rate in this early phase is directly proportional to the large mosquito population in the environment, with the average pupa skin number consistently showing very high values from September 2023 to August 2024, at 114 to 130.3 pupa skins.

During May 2023 to April 2024, the presence of Wolbachia-infected Aedes aegypti mosquitoes in Gunung Telihan remained very low, ranging from 0 to 3 mosquitoes. The slow spread of Wolbachia bacteria into the wild mosquito population during this early phase is the reason why dengue cases remain high. Dengue virus transmission suppression does not occur instantly after the Wolbachia program is implemented. A reduction in new cases will be seen when the number of Wolbachia-carrying mosquitoes in the wild reaches a certain threshold. This process aligns with research (Utarini et al., 2021), which states that the protective effect (reduction in dengue cases) begins to be clearly visible when the frequency or prevalence of Wolbachia-carrying mosquitoes (wMel strain) in a residential area reaches more than 80%. Wolbachia-carrying mosquito populations need time to reproduce and dominate the local mosquito population, only then can the virus-blocking effect (pathogen interference) spread and provide comprehensive protection to the community in the area.

This was evident in May–August 2024, when the Wolbachia-carrying mosquito population finally surged significantly, reaching 41. The impact of this Wolbachia dominance was immediately visible in the sharp decline in cases to 17 incidents (IR dropped to 121.9), despite the pupa skin density being at its peak of 130.

CONCLUSION

Overall, the findings of this study indicate that the implementation of the Wolbachia program in Bontang City was associated with changes in dengue transmission patterns over time. Prior to the intervention, dengue incidence was relatively high and concentrated in several high-risk sub-districts, indicating active transmission hotspots. During the early phase of implementation, incidence rates remained fluctuating and in some areas even increased, reflecting the transitional period required for Wolbachia to establish within the mosquito population. As the program progressed, a general decline in incidence rates was observed in several previously high-risk areas, coinciding with the increasing prevalence of Wolbachia in Aedes aegypti populations. Although the distribution of Wolbachia showed variability and was not uniformly stable across all sub-districts, the overall trend suggests that the intervention contributed to reducing dengue transmission. These results highlight the potential effectiveness of Wolbachia as a sustainable vector control strategy, while also emphasizing the importance of continuous monitoring to ensure long-term stability and impact.

REFERENCES

Ar Rafi, N. H., Nugraha, A. L., & Yusuf, M. A. (2024). Pemetaan Incidence Rate (IR) Demam Berdarah Dengue (DBD) di Kecamatan Tembalang tahun 2018-2022. *Jurnal Geodesi Undip*, *8*(1), 170–179.

Badan Pusat Statistik Kota Bontang. (2023). *Jumlah Kasus DBD Menurut Kecamatan (orang), 2021-2023*. https://bontangkota.bps.go.id/indicator/30/188/1/kasus-dbd.html

Chandra, E. (2019). Pengaruh Faktor Iklim, Kepdatan Penduduk dan Angka Bebas Jentik (ABJ) Terhadap Kejadian Demam Berdarah Dengue (DBD) di Kota Jambi. *Jurnal Pembangunan Berlanjutan*, *1*(1), 1–15.

Depkes RI. (2005). *Pencegahan dan Pemberantasan Demam Berdarah Di Indonesia*. Dirjen PPM & PLP.

Diskominfo Kaltim. (2023). *Dinkes Upayakan Tekan Prevalensi Kasus DBD*. https://diskominfo.kaltimprov.go.id/kesehatan/dinkes-upayakan-tekan-prevalensi-kasus-dbd

Hariyanti, F., Raharjo, M., & Joko, T. (2023). Analisis Faktor Yang Berhubungan Dengan Kejadian Demam Berdarah Dengue di Kabupaten Demak. *Jurnal Silatene*, *0*(0), 100–113. https://doi.org/10.29238/sanitasi.v16i2.1855

Hermania, C., & Hary Cahyati, W. (2023). Kejadian DBD di Kota Semarang Tahun 2019-2021. *HIGEIA (Journal of Public Health Research and Development)*, *7*(3), 376–385. https://journal.unnes.ac.id/sju/index.php/higeia/article/view/65192

Indriani, C., Tantowijoyo, W., Rancès, E., Andari, B., Prabowo, E., Yusdi, D., Ansari, M. R., Wardana, D. S., Supriyati, E., Nurhayati, I., Ernesia, I., Setyawan, S., Fitriana, I., Arguni, E., Amelia, Y., Ahmad, R. A., Jewell, N. P., Dufault, S. M., Ryan, P. A., … Utarini, A. (2020). Reduced dengue incidence following deployments of Wolbachia-infected *Aedes aegypti* in Yogyakarta, Indonesia: A quasi-experimental trial using controlled interrupted time series analysis. *Gates Open Research*, *4*(May), 1–16. https://doi.org/10.12688/gatesopenres.13122.1

Irfandi, A. (2018). Kajian Pemanfaatan Wolbachia terhadap Pengendalian DBD (STUDI LITERATUR DAN STUDI KASUS PEMANFAATAN WOLBACHIA DI YOGYAKARTA). *Forum Ilmiah*, *15*(2), 276–289. https://ejurnal.esaunggul.ac.id/index.php/Formil/article/view/2364

Kemenkes RI. (2017). Pedoman Pencegahan Dan Pengendalian Demam Berdarah Dengue Di Indonesia. *Pedoman Pencegahan Dan Pengendalian Demam Berdarah Di Indonesia*, *5*, 1–128. https://drive.google.com/file/d/1IATZEcgGX3x3BcVUcO_l8Yu9B5REKOKE/view

Kemenkes RI. (2020). *Rencana Aksi Kegiatan (RAK)*.

Kemenkes RI. (2022a). Membuka Lembaran Baru. In *Laporan Tahunan 2022 Demam Berdarah Dengue*.

Kemenkes RI. (2022b). *Demam Berdarah Dengue*. https://ayosehat.kemkes.go.id/topik/demam-berdarah-dengue

Kemenkes RI. (2023a). *Keputusan Direktur Jenderal Pencegahan dan Pengendalian Penyakit Nomor HK. 02. 02/C/573/2023 tentang Petunjuk Teknis Penyelenggaraan Pilot Project Penanggulangan Dengue dengan Metode Wolbachia*.

Kemenkes RI. (2023b). *Teknologi Wolbachia dalam Pengendalian*

Demam Berdarah di Indonesia. https://ayosehat.kemkes.go.id/teknologi-wolbachia-dalam-pengendalian-demam-berdarah-di-indonesia

Kemenkes RI. (2024). *Info DBD terkini hingga minggu ke 12*. https://p2pm.kemkes.go.id/publikasi/infografis/info-dbd-terkini-hingga-minggu-ke-12

Kemenko PMK. (2023). *Pemerintah Soroti Penularan Penyakit Demam Berdarah Dengue*. https://www.kemenkopmk.go.id/pemerintah-soroti-penularan-penyakit-demam-berdarah-dengue#:~:text=Kasus DBD di Indonesia terus,DBD dan 317 orang meninggal.

Menkes RI. (2020). Keputusan Menteri Kesehatan Republik Indonesia Nomor HK.01.07/Menkes/9845/2020 Tentang Pedoman Pelayanan Kedokteran Tata Laksana Onfeksi Dengue Pada Dewasa. In *Menkes RI*. https://talenta.usu.ac.id/politeia/article/view/3955

PT Geosriwijaya Nusantara. (2019). *Modul Sistem Informasi Geografis (SIG) Tingkat Dasar*. http://geosriwijaya.com

Utarini, A., Indriani, C., Ahmad, R. A., Tantowijoyo, W., Arguni, E., Ansari, M. R., Supriyati, E., Wardana, D. S., Meitika, Y., Ernesia, I., Nurhayati, I., Prabowo, E., Andari, B., Green, B. R., Hodgson, L., Cutcher, Z., Rancès, E., Ryan, P. A., O'Neill, S. L., … Simmons, C. P. (2021). Efficacy of Wolbachia-Infected Mosquito Deployments for the Control of Dengue. *New England Journal of Medicine*, *384*(23), 2177–2186. https://doi.org/10.1056/nejmoa2030243

WHO. (2024). *Dengue and severe dengue*. https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue

World Mosquito Program. (2022). *Buku Saku Program BAWIS Bontang*.

World Mosquito Program. (2024). *Wolbachia Technology and Virus Blocking Mechanisms: Annual Global Report*.