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Survey of Malaria Vectors in the Rainy Season in Inalipue Village, Wajo District, South Sulawesi

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ABSTRACT
Climate change will affect the physical and biological environment that supports the development of various infectious diseases, including malaria. Wajo District, particularly Inalipue Village in Tanasitolo Sub-district, faces a major challenge in controlling the malaria vector, the Anopheles mosquito. The main objective of this survey was to identify and understand the environmental factors that contribute to Anopheles mosquito population density in Inalipue Village. Data were obtained by capturing adult mosquitoes using the Human Landing Collection (HLC) method as well as surveying Anopheles mosquito larval breeding sites. Mosquito trapping was conducted inside and outside the house and around livestock pens. Anopheles barbirostris was the most dominant species, found in all capture methods with the highest Man Biting Rate (MBR) of 1.00 for outdoor capture. *Anopheles nigerrimus* and *Anopheles vagus* were also found, although in smaller numbers. Of the 17 breeding habitat sites, 5 showed positive larval results. Water temperature, pH, and the presence of flora and fauna in these habitats varied, but most had ideal conditions for mosquito breeding. *Anopheles barbirostris* shows high adaptation to a wide range of habitats, making it the main vector. These findings provide a strong basis for local governments and health agencies to plan and implement more effective and integrated malaria control programs.

Keywords : anopheles; larva; malaria; mosquito vector; temperature

ABSTRAK
Perubahan iklim akan mempengaruhi lingkungan fisik dan biologis yang mendukung berkembangnya berbagai penyakit menular, termasuk malaria. Kabupaten Wajo, khususnya Desa Inalipue di Kecamatan Tanasitolo, menghadapi tantangan besar dalam mengendalikan vektor malaria, yaitu nyamuk Anopheles. Tujuan utama dari survey ini adalah untuk mengidentifikasi dan memahami faktor-faktor lingkungan yang berkontribusi terhadap kepadatan populasi nyamuk Anopheles di Desa Inalipue. Data diperoleh melalui penangkapan nyamuk dewasa menggunakan metode Human Landing Collection (HLC) serta survei tempat perkembangbiakan larva nyamuk Anopheles. Penangkapan nyamuk dilakukan di dalam dan luar rumah serta di sekitar kandang ternak. Anopheles barbirostris adalah spesies yang paling dominan, ditemukan di semua metode penangkapan dengan Man Biting Rate (MBR) tertinggi sebesar 1,00 untuk penangkapan di luar rumah. Anopheles nigerrimus dan Anopheles vagus juga ditemukan, meskipun dalam jumlah yang lebih sedikit. Dari 17 lokasi habitat perkembangbiakan, 5 menunjukkan hasil positif larva. Kondisi suhu air, pH, dan keberadaan flora serta fauna di habitat ini bervariasi, namun sebagian besar memiliki kondisi ideal untuk perkembangbiakan nyamuk. Temuan ini memberikan dasar yang kuat bagi pemerintah daerah dan lembaga kesehatan untuk merencanakan dan melaksanakan program pengendalian malaria yang lebih efektif dan terintegrasi.

Kata Kunci: *anopheles; larva; malaria; vektor nyamuk; suhu*

INTRODUCTION

Climate change has become a pressing global issue with far-reaching impacts on many aspects of life, including public health (Agache et al., 2022). One of the significant consequences of climate change is changes in rainfall patterns and air temperature. Increased concentrations of greenhouse gases such as carbon dioxide in the atmosphere have caused the greenhouse effect resulting in global warming (Kabir et al., 2023). This global warming alters ecosystem dynamics, affects weather patterns, and creates environmental conditions that favor the development of various infectious diseases. Malaria, transmitted by Anopheles mosquitoes, is one such disease that is strongly affected by climate change. Changes in rainfall and temperature patterns can expand mosquito habitats and increase the risk of malaria transmission (Chandra & Mukherjee, 2022; Ryan et al., 2020).

Various studies have shown a correlation between climate change and increased incidence of vector-borne diseases, including malaria. Previous studies have shown that climate change can increase the geographic distribution and seasonality of malaria transmission (Mardiana & Musadad, 2012; Wibowo et al., 2019). Other studies have identified that environmental factors such as rainfall, temperature, and humidity strongly influence Anopheles mosquito populations (Agyekum et al., 2021; Pinontoan et al., 2022; Villena et al., 2022). The results of this study confirm that changing climatic conditions can increase the risk of malaria transmission by expanding areas suitable for Anopheles mosquito life.

In Wajo District, especially in Inalipue Village, Tanasitolo Sub-district, the challenges in malaria control are getting bigger. The village often experiences drastic climate change, especially during the rainy season. These conditions create an ideal environment for Anopheles mosquitoes to breed and spread malaria. Wajo district has reported significant incidences of malaria in recent years, indicating the need for more effective control measures and more intensive monitoring of Anopheles mosquito populations. Although various control efforts have been made, such as the use of insecticides and the provision of bed nets, the success of these programs is highly dependent on an accurate understanding of mosquito population dynamics at the local level.

This survey was conducted to collect current data on species diversity, biting activity, and breeding habitat of Anopheles mosquitoes in Inalipue Village during the rainy season. The survey also aimed to identify mosquito distribution patterns and environmental factors that influence mosquito population density. This comprehensive field research is essential to gain a clear picture of the risk of malaria transmission and the effectiveness of existing control measures. In addition, the data collected from this survey will provide a solid basis for planning more effective and sustainable control strategies.

The main objective of this survey was to identify and understand the environmental factors that contribute to Anopheles mosquito population density during the rainy season in Inalipue Village. Specific objectives of the survey included determining the dominant mosquito species, analyzing mosquito biting activity, identifying breeding habitats, and evaluating the risk of malaria transmission. With a better understanding of the population dynamics of Anopheles mosquitoes, it is hoped that malaria control programs can be further improved, thereby reducing the incidence of malaria in Inalipue Village and surrounding areas. The results of this survey will also contribute to scientific knowledge on the impact of climate change on the spread of infectious diseases, particularly malaria.

Tabel 1. Diversity of Mosquito Species Captured

Mosquito Species	Bait Method		Resting Method	
	UOD	UOL	Wall	Cage
Anopheles barbirostris	2 (10%)	6 (30%)	3 (15%)	3 (15%)
Anopheles nigerrimus	1 (5%)	1 (5%)	0 (0%)	1 (5%)
Anopheles vagus	0 (0%)	1 (5%)	0 (0%)	2 (10%)
Total	3 (15%)	8 (40%)	3 (15%)	6 (30%)

METHODS

The survey method involved collaboration with Wajo District Health officers and volunteers from Inalipue Village, Tanasitolo Sub-district, who acted as adult mosquito collectors. The entomological survey was conducted during the rainy season, from May 17-21, 2022. This activity was designed to collect data on Anopheles mosquito populations, species types, biting activity, and breeding habitats in the environment around the village.

The initial stage was the capture of adult mosquitoes. The HLC method was used to capture adult mosquitoes by placing human collectors inside and outside houses and around livestock pens. Collectors sat in a specific place and captured mosquitoes that landed on their bodies using aspirators for a specific period. Catching is done every hour for 40 minutes, followed by 20 minutes of rest, for 12 hours starting from 6 pm to 6 am (MOH, 2017).

The second stage was mosquito species identification. Captured mosquitoes were put into paper cups, then killed using chloroform and identified to species using a microscope. Identification was based on the identification key compiled by O'Connor (O'Connor, C.T, WHO Entomologist, 1989).

The third stage is the measurement of Man Biting Rate (MBR). Man Biting Rate (MBR) was calculated as the number of mosquito bites per person per night. The MBR was analyzed for each mosquito species and compared to the quality standard value set by the Ministry of Health of the Republic of Indonesia, which is <0.025 bites per person per night (Kementerian Kesehatan RI, 2017).

The larval breeding habitat survey was the fourth stage of this activity. Surveys were conducted to observe potential breeding sites for Anopheles mosquitoes, such as rice fields, ditches, irrigation, and swamps. Each habitat was assessed based on physical (water temperature, depth, turbidity), chemical (pH), and biological (presence of flora and fauna) characteristics. Mosquito larvae are collected using larval dippers from various water bodies in breeding sites as in the survey guidelines of the Center for Research and Development of Disease Vectors and Reservoirs, Kementerian Kesehatan RI (2017).

The final stage is training and coordination. Before field activities begin, health workers and volunteers are given a brief training on mosquito trapping and habitat observation techniques. This aims to ensure that the entire team has a good understanding of the procedures to be followed and to improve the accuracy and consistency of the data collected.

RESULTS AND DISCUSSION

The diversity of Anopheles mosquito species found using the person-baiting and resting methods is depicted in Table 1. Table 1 shows that Anopheles barbirostris was the most dominant mosquito species in Inalipue Village. This species was caught in all capture methods, both inside and outside the house as well as around livestock pens. This indicates

that Anopheles barbirostris has high adaptability to various habitats and environmental conditions in Inalipue Village. This adaptability indicates that Anopheles barbirostris mosquitoes are able to survive and breed in various environmental conditions, making them the main vector of malaria transmission in this area.

This finding is consistent with previous studies. Studies in South Sulawesi, Indonesia, showed that Anopheles barbirostris is the dominant species in malaria endemic areas, with good adaptability to various environmental conditions including rice fields and swamps (Davidson et al., 2020). This study also found that Anopheles barbirostris is able to breed in varied habitats, from stagnant water to slow flowing water, demonstrating its ecological flexibility (Jastam, 2014).

The presence of Anopheles nigerrimus and Anopheles vagus in smaller numbers suggests that although these species are not dominant, they remain a potential threat to malaria transmission. Studies in South Sulawesi found that Anopheles nigerrimus and Anopheles vagus, although less dominant than Anopheles barbirostris, still have the potential to transmit malaria as they are often found in the same breeding habitat (Ishak et al., 2023). This suggests that malaria control should take into account the presence of various mosquito species, not just the most dominant ones.

Research outside Indonesia also supports these findings. A study in Thailand showed that Anopheles barbirostris is one of the main species involved in malaria transmission, with high adaptability to various habitats (Zhang et al., 2022). This study found that Anopheles barbirostris can breed in different types of water environments, including irrigation canals and ponds, demonstrating the ability of this species to adapt well to environmental changes.

The dominance of Anopheles barbirostris in multiple habitats suggests the importance of comprehensive and focused mosquito control across multiple environments in Inalipue Village. Control efforts that only focus on one type of habitat may not be effective enough given the high adaptability of this species. For example, indoor-only control may not be sufficient given that the mosquito is also commonly found outdoors and around livestock pens. Therefore, mosquito control strategies should cover a wide range of locations and environmental conditions to ensure maximum effectiveness.

In addition, the presence of Anopheles nigerrimus and Anopheles vagus as secondary vectors should not be overlooked. Although they are fewer in number, their ability to adapt to certain habitats suggests that they still have the potential to transmit malaria. Control that only focuses on the dominant species may not be sufficient to eliminate the overall risk of malaria transmission. Therefore, it is important to conduct continuous surveillance and adjust control strategies based on changes in the population and distribution of mosquito species in Inalipue Village.

Table 2. Biting Activity of Anopheles Mosquitoes

Mosquito Species	Biting Time (Peak activity)	Biting location
Anopheles barbirostris	23.00-24.00, 24.00-01.00	Indoors and outdoors
Anopheles nigerrimus	24 .00-01.00, 01.00-02.00	Outdoors
Anopheles vagus	24.00-01.00, 01.00-02.00	Outdoors

From Table 2, it can be seen that Anopheles barbirostris mosquitoes have a peak biting activity in the middle of the night, both inside and outside the house. This peak activity occurs between 23:00 and 01:00. Knowledge of this mosquito biting activity pattern is very important for the local community. By knowing the peak mosquito activity times, communities can take appropriate preventive measures to reduce the risk of mosquito bites and malaria transmission. One effective preventive measure is to use mosquito nets when sleeping, especially during the hours when mosquitoes are most active.

In addition to the use of mosquito nets, other measures such as installing nets on windows and doors, and avoiding outdoor activities during peak mosquito activity times are also highly recommended. The public needs to be educated on the importance of closing doors and windows at night to prevent mosquitoes from entering the house. The use of protective clothing that covers the whole body when outdoors at night can also help reduce the risk of mosquito bites.

Anopheles nigerrimus and Anopheles vagus showed similar peak biting activity to Anopheles barbirostris, but only outdoors. The peak biting activity of both species also occurred in the middle of the night, between 24:00 and 02:00. This suggests that these mosquitoes prefer to bite outside the home, so mosquito control efforts outside the home need to be strengthened. Control measures that can be taken outside the home include spraying insecticides around the house and livestock housing areas, as well as environmental management to eliminate mosquito breeding sites such as stagnant water and garbage piles.

In addition, mosquito control efforts outside the home should also involve the community in mutual cooperation activities to clean up the surrounding environment. The local government can conduct regular environmental cleaning programs to ensure that there are no places that can become mosquito breeding habitats. Educating the community on the importance of keeping the environment clean and eliminating stagnant water is also very important to reduce the mosquito population outside the home.

The MBR calculation results shown in Table 3 indicate that all Anopheles mosquito species caught in Inalipue Village exceeded the quality standard value set by the Ministry of Health of the Republic of Indonesia, which sets the MBR threshold at <0.025 bites per person per night. Anopheles barbirostris species showed the highest MBR of 1.00 for outdoor capture. This is well above the safe limit, indicating that the risk of malaria transmission is very high in this area. High MBR values reflect intense mosquito biting rates, meaning there is great potential for malaria transmission if the mosquitoes are carrying Plasmodium parasites.

Table 3. Man Biting Rate (MBR) of Anopheles Mosquitoes

Mosquito Species	Method	Number of Mosquitoes	MBR	Quality Standard Value
Anopheles barbirostris	UOD	2	0.33	> 0.025
Anopheles barbirostris	UOL	6	1	> 0.025
Anopheles nigerrimus	UOL	2	0.33	> 0.025
Anopheles vagus	UOL	1	0.17	> 0.025

This finding is in line with previous studies showing that areas with high MBR have a greater risk of malaria transmission. A study in Papua, Indonesia, for example, found that areas with high MBR had a higher incidence of malaria. This study also found that physical environmental factors such as the presence of stagnant water, humidity, and air temperature > 30°C influenced malaria incidence. In addition, another study found that the presence of livestock pens near the house, not installing wire mesh on ventilation, and house walls made of boards also increased the risk of malaria (Babba, 2007).

Besides Anopheles barbirostris, Anopheles nigerrimus and Anopheles vagus species also showed significant MBR. Anopheles nigerrimus had an MBR of 0.33 for outdoor capture, while Anopheles vagus had an MBR of 0.17 for outdoor capture. Although the MBRs of these two species are lower than Anopheles barbirostris, they still exceed the safe threshold and suggest that they also contribute to the risk of malaria transmission in Inalipue Village. Previous research in India has also shown that different mosquito species can have varying MBRs, but all still contribute to the risk of malaria transmission (Naik et al., 2023).

Overall, the high MBR values in Inalipue Village indicate the urgency for effective and sustainable vector control interventions. A combination of environmental management, insecticide use and community education would be an effective strategy to suppress mosquito populations and reduce the risk of malaria transmission in this area. The results of this survey provide a strong basis for local governments and health agencies to plan and implement more effective and integrated malaria control programs. The findings also reinforce the results of previous studies, confirming that MBR is an important indicator in malaria risk assessment and that comprehensive control strategies are needed to reduce the burden of this disease.

Table 4. Anopheles Mosquito Breeding Habitat

Location	Type of Habitat	Positive Larvae	Water (°C)	pH	Water flow	Turbidity	Fauna/Flora
Point 1	Rice Paddy	Negative	30/31	6	Flooded	Cloudy	Rice, grass
Point 2	Sewer	Negative	30/31	6	Flooded	Cloudy	Grass
Point 3	Irrigation	Positive	30/32	6	Flooded	Cloudy	Grass
Point 4	Rice Paddy	Negative	26/27	6	Not Flowing	Cloudy	Moss
Point 5	Rice Paddy	Positive	27/28	6	Not Flowing	Cloudy	Moss
Point 6	Swamp	Negative	2728	6	Not Flowing	Cloudy	Tadpoles, Moss
Point 7	Rice Paddy	Negative	26/27	6	Not Flowing	Cloudy	Tadpoles, Moss
Point 8	Pond	Negative	26/27	6	Not Flowing	Cloudy	Moss, Rice
Point 9	Rice Paddy	Negative	26/27	6	Not Flowing	Cloudy	Tadpoles, Moss
Point 10	Puddles	Negative	26/27	6	Not Flowing	Cloudy	Moss
Point 11	Rice Paddy	Positive	30/31	6	Flooded	Slightly cloudy	Rice, Grass
Point 12	Irrigation	Negative	30/31	6	Flooded	Slightly cloudy	Grass
Point 13	Rice Paddy	Negative	30/31	6	Flooded	Slightly cloudy	Grass
Point 14	Rice Paddy	Positive	26/27	6	Not Flowing	Slightly cloudy	Rice
Point 15	Rice Paddy	Positive	26/27	6	Flooded	Clear	Rice, Grass
Point 16	Rice Paddy	Negative	26/27	6	Flooded	Clear	Small fish, Grass, bush
Point 17	Irrigation	Negative	26/27	6	Slow flow	Clear	Small fish, Grass, bush

Table 4 shows that there are many potential breeding habitats for Anopheles mosquitoes in Inalipue Village, with 5 out of 17 sites showing positive larval results. These habitats include rice fields, ditches, and irrigation that have physical, chemical, and biological characteristics that favor mosquito breeding. Water temperature, pH, and the presence of flora and fauna in these habitats varied, but most had ideal conditions for mosquito breeding. This study revealed that stagnant environments with clear to slightly turbid water, and water temperatures between 26-32°C, create ideal conditions for Anopheles mosquito breeding.

This finding is in line with previous studies. Studies in West Java, Indonesia, showed that Anopheles mosquito habitats are often found in rice fields, irrigation canals, and waterlogged swamps, especially during the rainy season when standing water is abundant (Ishak et al., 2023; Jastam, 2014). This study shows that warm water temperature and neutral pH are optimal conditions for the development of Anopheles mosquito larvae. This study also emphasizes the importance of water management and environmental management in mosquito population control.

Other studies also support these findings. In Papua New Guinea, a study by (Cooper et al., 2009) found that rice paddies and stagnant water that occur during the rainy season are major breeding habitats for Anopheles mosquitoes. Water temperature and pH similar to those found in Inalipue Village were also reported to favor mosquito larval growth in Kenya. This study shows that good water management and reduction of stagnant water are effective strategies to reduce mosquito populations.

To reduce mosquito breeding habitat in Inalipue Village, better environmental management measures are needed. One effective strategy is to drain unnecessary stagnant land, improve drainage channels to prevent stagnant water, and ensure that water containers are tightly covered. Communities should also be involved in gotong royong activities to clean up their neighborhoods and eliminate potential breeding grounds for mosquitoes. Local governments can play a role by providing facilities to drain stagnant land and improve drainage systems.

Overall, the findings of this study are consistent with previous research, which suggests that environmental conditions that support the development of Anopheles mosquito larvae are a key factor in malaria transmission. Effective control strategies should include environmental management, water management and community education to reduce mosquito populations and the risk of malaria transmission.

CONCLUSIONS

A survey conducted in Inalipue Village, Tanasitolo Sub-district, Wajo District, showed that Anopheles barbirostris mosquitoes were the most dominant species. This species was found in all capture methods, both indoors and outdoors as well as around livestock pens, showing high adaptability to various habitats and environmental conditions. The high Man Biting Rate (MBR) of Anopheles barbirostris indicates that the risk of malaria transmission in this village is very high. Therefore, comprehensive and sustainable control measures are needed to reduce mosquito populations and the risk of malaria transmission.

In addition to Anopheles barbirostris, Anopheles nigerrimus and Anopheles vagus species were also found although in smaller numbers. Their presence as secondary vectors remains a potential threat to malaria transmission. The results of this survey suggest that malaria control should cover a wide range of mosquito species, not just focus on the most dominant species. Effective control strategies should include environmental management,

insecticide use and community education to reduce mosquito populations in various habitats.

Overall, this survey provided a better understanding of Anopheles mosquito population dynamics in Inalipue Village. The findings underscore the importance of a multifaceted and evidence-based approach to malaria control. Local governments and health agencies should work together to plan and implement more effective and integrated malaria control programs. Community education and active involvement are also critical to the success of mosquito control efforts and reduction of malaria transmission risk in this region.

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