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RESTING ECOLOGY AND SPATIAL HETEROGENEITY OF FILARIASIS MOSQUITO VECTORS IN TROPICAL WETLANDS: IMPLICATIONS FOR INTEGRATED VECTOR CONTROL IN BANYUASIN, INDONESIA

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ABSTRAK

Filariasis limfatik masih menjadi tantangan kesehatan di ekosistem lahan basah tropis, sementara aspek ekologi perilaku istirahat nyamuk belum banyak dikaji meski penting bagi kelangsungan hidup vektor dan efektivitas pengendalian. Penelitian ini menganalisis perilaku istirahat, komposisi spesies, dan heterogenitas spasial di empat desa endemis di Kabupaten Banyuasin. Sebanyak 2.752 nyamuk dari 26 spesies berhasil dikumpulkan, dengan dominasi Mansonia uniformis, Culex tritaeniorhynchus, Culex vishnui, dan Mansonia annulifera yang mencakup lebih dari 70% total individu. Pola spasial menunjukkan lahan basah bervegetasi padat mendukung dominasi Mansonia, sedangkan lanskap pertanian lebih mendukung Culex. Sebagian besar spesies bersifat eksofilik, sementara Culex quinquefasciatus cenderung endofilik. Aktivitas istirahat memuncak pada pukul 19.00–22.00. Meskipun tidak ditemukan larva filaria infektif, tingginya kelimpahan vektor menunjukkan potensi penularan tetap ada. Temuan ini menekankan pentingnya integrasi pendekatan ekologi perilaku dan heterogenitas lanskap dalam strategi surveilans dan pengendalian vektor secara terpadu.

ABSTRACT

Resting Ecology And Spatial Heterogeneity Of Filariasis Mosquito Vectors In Tropical Wetlands: Implications For Integrated Vector Control In Banyuasin, Indonesia. Lymphatic filariasis remains a public health challenge in tropical wetland ecosystems, where mosquito resting ecology is still poorly understood despite its importance for vector survival and control effectiveness. This study analyzed resting behavior, species composition, and spatial heterogeneity across four endemic villages in Banyuasin, Indonesia. A total of 2,752 mosquitoes representing 26 species were collected, dominated by Mansonia uniformis, Culex tritaeniorhynchus, Culex vishnui, and Mansonia annulifera, accounting for over 70% of individuals. Spatial patterns revealed that vegetation-rich wetlands favored Mansonia, while agricultural landscapes supported Culex species. Most dominant species exhibited exophilic resting behavior, whereas Culex quinquefasciatus showed more endophilic tendencies. Peak resting activity occurred between 19:00 and 22:00. Although no infective filarial larvae were detected, the high abundance of competent vectors suggests continued transmission potential. These findings highlight the importance of integrating resting ecology and landscape heterogeneity into comprehensive vector surveillance and control strategies.

INTRODUCTION

Lymphatic filariasis remains one of the most important neglected tropical diseases, affecting more than 850 million people worldwide who remain at risk of infection, particularly in tropical and subtropical regions. Despite significant progress achieved through the Global Programme to Eliminate Lymphatic Filariasis (GPELF), transmission persists in many endemic areas where ecological conditions support the survival and reproduction of mosquito vectors.[1,2,3] In Southeast Asia, lymphatic filariasis is primarily transmitted by mosquitoes belonging to the genera Mansonia, Culex, Anopheles, and Aedes, whose ecological characteristics strongly influence transmission dynamics and local disease risk.[4,5]

Vector ecology plays a fundamental role in determining the spatial distribution and persistence of mosquito-borne diseases. Environmental factors such as land-use change, hydrological systems, vegetation structure, and climate variability strongly influence mosquito breeding habitats, population dynamics, and host–vector interactions.[6,7,8,9] Recent global analyses demonstrate that landscape characteristics shape mosquito community composition, population connectivity, and vectorial capacity, thereby influencing spatial patterns of disease transmission risk.[1,7,9]

Although many entomological studies have examined mosquito abundance, larval habitats, and host-seeking behavior, relatively few have focused on mosquito resting ecology, a critical yet often overlooked component of vector biology. Resting behavior determines mosquito survival, digestion of blood meals, completion of the gonotrophic cycle, and exposure to insecticides, thereby influencing vectorial capacity and the effectiveness of vector control interventions.[10,11,12] Consequently, understanding mosquito resting ecology is essential for identifying key resting habitats and optimizing vector surveillance and control strategies.

Recent studies also indicate that mosquito populations may exhibit behavioral plasticity in response to vector control interventions. In several endemic regions, mosquito populations have shifted toward more exophilic and exophagic behavior, potentially reducing the effectiveness of indoor-based interventions such as insecticide-treated nets and indoor residual spraying.[11,13] Such behavioral adaptations may contribute to residual transmission, particularly in ecological landscapes where mosquito populations exploit outdoor habitats.

Wetland ecosystems are highly productive ecological landscapes that can sustain diverse mosquito communities. These environments are characterized by permanent water bodies, dense aquatic vegetation, and complex hydrological networks that provide suitable breeding habitats for many mosquito species. In Southeast Asia, Mansonia mosquitoes are strongly associated with swamp ecosystems because their larvae attach to submerged aquatic macrophytes to obtain oxygen, allowing them to thrive in vegetation-rich wetlands and act as vectors of Brugia malayi.[2,5]

Indonesia contains extensive wetland ecosystems that support diverse mosquito communities. Banyuasin Regency in South Sumatra represents one of the largest wetland landscapes in Indonesia, characterized by swamp forests, irrigation canals, rice-field ecosystems, and abundant aquatic vegetation. These environmental conditions create highly suitable habitats for wetland-associated mosquito genera such as Mansonia and Culex, which have been reported as potential vectors of lymphatic filariasis in several Indonesian regions.[5,14,15,16,17]

However, despite the ecological importance of wetland ecosystems, mosquito resting ecology across heterogeneous wetland landscapes remains poorly understood, particularly in Indonesia. Most entomological studies conducted in the region have focused primarily on mosquito abundance and larval habitats, while spatial variation in mosquito resting behavior has received limited attention. This knowledge gap limits understanding of how landscape heterogeneity influences mosquito behavior, vector survival, and the effectiveness of vector control interventions.

Therefore, this study aimed to investigate mosquito resting ecology, community structure, and spatial heterogeneity across four wetland villages in Banyuasin Regency, South Sumatra, Indonesia. Specifically, this research examined mosquito species composition, spatial dominance patterns, and temporal resting activity in indoor and outdoor environments. By integrating mosquito community ecology with behavioral observations across heterogeneous wetland landscapes, this study provides insights into ecological drivers of mosquito resting behavior and their implications for vector surveillance and lymphatic filariasis control strategies in tropical wetland ecosystems.

METHODS

Study Area

This study was conducted in Banyuasin Regency, South Sumatra Province, Indonesia, an area characterized by extensive tropical wetland ecosystems. Four endemic villages were selected as study sites: Sedang (latitude: 2°40'44"S longitude: 104°56'24"E), Sungai Rengit Murni (latitude: 2°33'11"S longitude: 104°55'48"E), Gasing (latitude: 2°31'12"S longitude: 104°58'48"E), and Muara Sugih (latitude: 2°37'48"S longitude; 105°04'48"E). Geographically, Banyuasin Regency is located in the eastern coastal region of South Sumatra and is dominated by swamp ecosystems, irrigation canals, rice fields, and aquatic vegetation. These environmental conditions create suitable habitats for mosquito breeding and survival, particularly for wetland-associated genera such as *Mansonia* and *Culex*. The climate of the study area is tropical humid with relatively high rainfall and temperature throughout the year, conditions that support continuous mosquito development. Mosquito collections were conducted between December 2016 and January 2017 in residential areas and surrounding vegetation within each village.

Figure 1. Study area in Banyuasin Regency, South Sumatra, Indonesia.

Sedang Sungai Rengit Murni Gasing Village Muara Sugih

Figure 2. Aquatic Plants of Four Villages

Mosquito Sampling

Mosquito collections were conducted using a combination of Human Landing Collection (HLC) and resting collection methods targeting both indoor and outdoor habitats. In each study village, mosquito sampling was conducted for one night over a 12-hour period (18:00–06:00 WIB). A total of six trained mosquito collectors participated in each sampling event, consisting of three collectors positioned indoors and three collectors outdoors in six selected houses. All collectors received prior training on standardized mosquito collection techniques to ensure methodological consistency.

To ensure comparability among study sites, the same sampling protocol, number of collectors, and collection duration were applied across all four villages, thereby maintaining equal sampling effort. Within each hour of sampling, 40 minutes were allocated for human landing collection, followed by 10 minutes for resting mosquito collection, and 10 minutes for collector rest. Captured mosquitoes were collected using aspirators, placed in labeled collection cups, and transported to the laboratory for morphological identification. Female mosquitoes were dissected to determine the presence of infective third-stage larvae (L3) following standard dissection procedures used in lymphatic filariasis vector surveillance.[4,5,10]

Mosquito Identification

Mosquito specimens were morphologically identified to species level using standard taxonomic keys based on diagnostic morphological characteristics including wing venation, leg banding, proboscis morphology, and abdominal scaling under a stereomicroscope following established mosquito identification keys.[18,19]

Data Analysis

The relative abundance of each mosquito species was calculated using the following formula:

$$\text{Relative Abundance (\%)} = (ni / N) \times 100$$

where:

ni = number of individuals of species i

N = total number of mosquitoes collected

Species dominance was calculated to determine the dominant mosquito species in each study village using the formula:

$$\text{Dominance Rate} = \frac{\text{Number of individuals of species}}{\text{total mosquitoes collected}} \text{ x } 100\%$$

Species with the highest dominance values were considered dominant within the mosquito community.

Diversity Analysis

Mosquito diversity was calculated using the Shannon–Wiener diversity index:

$H' = -\sum(pi \ln pi)$ where $pi = ni/N$

H' = Shannon–Wiener diversity index
(p_i) = Proportion of individuals belonging to species i
(n_i) = Number of individuals of species i
(N) = Total number of individuals of all species
(ln) = Natural logarithm

Spatial Analysis

Spatial comparisons were conducted to evaluate differences in mosquito species composition among the four villages with different ecological characteristics.

Temporal Analysis

Temporal analysis was performed to evaluate hourly resting activity patterns of mosquitoes between 18:00 and 06:00. Hourly mosquito densities were analyzed to identify peak resting periods.

Ethical Approval

This study was approved by the Ethics Committee of the Faculty of Medicine, Universitas Sriwijaya (Approval No. 522/kepkrsmhfkunsri/2016).

RESULTS

Mosquito Community Structure

A total of 2,752 mosquitoes representing 26 species were collected from four villages in Banyuasin Regency (Table 1). Mosquito abundance varied among villages, with the highest number recorded in Sungai Rengit Murni (1,155), followed by Sedang (735), Gasing (658), and Muara Sugih (204). The mosquito community was dominated by *Mansonia uniformis* (655), *Culex tritaeniorhynchus* (482), *Culex vishnui* (456), and *Mansonia annulifera* (432). Clear spatial variation was observed among villages, with *Mansonia* species predominating in wetland areas, whereas *Culex* species were more abundant in agricultural landscapes.

Table 1. Mosquito Species Composition in Four Study Villages, Banyuasin Regency by Resting Method

Species	Sedang	Sungai Rengit Murni	Gasing	Muara Sugih	Total
Mansonia indiana	176	4	5	1	186
Mansonia uniformis	117	515	6	17	655
Mansonia annulifera	396	36	0	0	432
Mansonia annulata	1	1	0	0	2
Mansonia dives	0	4	0	21	25
Mansonia bonneae	0	0	5	0	5
Culex gelidus	18	27	33	0	78
Culex quinquefasciatus	13	14	103	34	164
Culex vishnui	5	84	333	34	456
Culex tritaeniorhynchus	0	420	62	0	482
Culex fuscocephalus	0	0	75	0	75
Culex sitiens	0	0	1	0	1
Culex tripteroides	4	0	0	0	4
Culex solitarius	1	0	0	0	1

Species	Sedang	Sungai Rengit Murni	Gasing	Muara Sugih	Total
Anopheles barbirostris	1	0	0	0	1
Anopheles letifer	0	13	0	0	13
Anopheles sinensis	0	9	0	0	9
Anopheles umbrosus	0	23	20	6	49
Aedes aegypti	2	0	0	3	5
Aedes albopictus	0	0	0	2	2
Aedes andamanensis	0	0	10	85	95
Ochlerotatus fulvus pallens	0	4	0	0	4
Armigeres subalbatus	1	1	0	0	2
Lutzia sp.	0	0	2	0	2
Malaya sp.	0	0	3	0	3
Malaya jacobsoni	0	0	0	1	1
Total collected	735	1155	658	204	2752

Table 2 presents the distribution of dominant mosquito species between indoor and outdoor resting sites. A total of 2,189 mosquitoes were analyzed, with a higher proportion collected outdoors (57.0%) than indoors (43.0%), indicating a predominantly exophilic resting behavior. *Mansonia uniformis* was the most abundant species (29.9% of total mosquitoes) and showed nearly equal indoor and outdoor resting proportions (49.5% vs 50.5%). In contrast, *Culex* species demonstrated stronger outdoor resting tendencies, particularly *Culex quinquefasciatus*, where 71.3% of mosquitoes were collected outdoors. These results highlight the importance of vegetated outdoor environments as key resting habitats for several dominant mosquito vectors.

Table 2. Indoor and Outdoor Resting Distribution of Mosquitoes

Species	Indoor (n)	Outdoor (n)	Total	Indoor (%)	Outdoor (%)
Mansonia uniformis	324	331	655	49.5	50.5
Mansonia annulifera	210	222	432	48.6	51.4
Culex vishnui	179	277	456	39.3	60.7
Culex tritaeniorhynchus	181	301	482	37.6	62.4
Culex quinquefasciatus	47	117	164	28.7	71.3

Mosquito Diversity Across Villages

The highest diversity was recorded in Muara Sugih (H’ = 1.67), followed by Gasing (H’ = 1.59), Sungai Rengit Murni (H’ = 1.41), and Sedang (H’ = 1.24). Despite having the highest mosquito abundance, Sungai Rengit Murni showed lower diversity, with Mansonia uniformis and Culex tritaeniorhynchus dominant. Similarly, the mosquito community in Sedang was strongly dominated by *Mansonia annulifera*, resulting in lower diversity values. In contrast, Muara Sugih and Gasing exhibited more balanced species distributions. Overall, mosquito communities in the Banyuasin wetland ecosystem showed moderate diversity, with a combined Shannon–Wiener index of H’ = 2.14 across all villages, reflecting the presence of 26 mosquito species but with community structure dominated by the genera Mansonia and Culex.

Table 3. Shannon–Wiener Diversity Index (H') of Mosquito Communities in Four Villages

Village	Total mosquitoes	Number of Species	Shannon–Wiener Index (H')	Diversity Category
Sedang	735	11	1.24	Moderate
Sungai Rengit Murni	1155	13	1.41	Moderate
Gasing	658	11	1.59	Moderate
Muara Sugih	204	9	1.67	Moderate
Total (All Villages)	2752	26	2.14	Moderate–High

Spatial Heterogeneity of Mosquito Communities

Mosquito community composition varied markedly among the four study villages, reflecting differences in local environmental conditions and land-use characteristics. Villages characterized by dense aquatic vegetation and swamp ecosystems, such as Sedang and Sungai Rengit Murni, were dominated by *Mansonia* species, particularly *Mansonia uniformis* and *Mansonia annulifera*. These species are closely associated with aquatic macrophytes, where larvae attach to submerged plant tissues to obtain oxygen.

Table 4. Spatial Heterogeneity of Mosquito Communities Across Study Villages

Village	Total Mosquitoes	Dominant Species	Relative Abundance (%)	Habitat Characteristics	Ecological Pattern
Sedang	735	*Mansonia annulifera*	54.0	Swamp wetlands with dense aquatic vegetation	Wetland-dominated vector community
Sungai Rengit Murni	1155	*Mansonia uniformis*	44.6	Vegetated swamp ecosystem with floating macrophytes	Mansonia-dominated wetland habitat
Gasing	658	*Culex vishnui*	50.6	Irrigated rice-field agriculture	Agricultural mosquito assemblage
Muara Sugih	204	*Aedes andamanensis*	41.7	Peri-domestic vegetation and mixed landscape	Container-associated mosquito habitat

In contrast, Gasing Village displayed a mosquito community dominated by *Culex vishnui* and *Culex quinquefasciatus*. These species are typically associated with rice-field ecosystems and peri-domestic habitats, indicating the influence of agricultural land use and human settlements on mosquito community structure. Meanwhile, Muara Sugih Village exhibited a distinct ecological pattern characterized by the dominance of *Aedes andamanensis*. The presence of this species in relatively high abundance suggests the existence of localized ecological niches that support container-breeding or vegetation-associated mosquito species.

Overall, these findings demonstrate clear spatial heterogeneity in mosquito community composition across wetland landscapes, indicating that environmental characteristics such as aquatic vegetation, agricultural practices, and settlement patterns play a critical role in shaping mosquito assemblages.

Resting Behavior of Dominant Mosquito Species

Resting collections revealed clear differences in indoor and outdoor resting behavior among dominant mosquito species (Table 4). Overall, most species exhibited predominantly exophilic resting tendencies, with higher proportions of individuals collected in outdoor environments such as vegetation and shaded areas surrounding human dwellings. *Mansonia uniformis*, the most abundant species collected in this study, showed nearly equal indoor and outdoor resting frequencies (49.5% vs. 50.5%), indicating behavioral plasticity and the ability to utilize multiple resting habitats. A similar pattern was observed for *Mansonia annulifera*, although a slightly higher proportion of individuals were found resting outdoors.

In contrast, *Culex vishnui* and *Culex tritaeniorhynchus* were predominantly collected in outdoor environments, accounting for 60.7% and 62.4% of resting individuals, respectively. This pattern suggests a strong ecological association with vegetated and agricultural habitats, particularly rice-field ecosystems surrounding human settlements. Although *Culex quinquefasciatus* is generally described as an endophilic species, a substantial proportion of individuals in this study were collected outdoors (71.3%). This finding indicates behavioral variability in resting preferences, possibly reflecting ecological adaptation to heterogeneous wetland landscapes.

Overall, these results demonstrate considerable behavioral heterogeneity in mosquito resting ecology, which may influence the effectiveness of vector control strategies targeting indoor resting habitats.

Table 5. Resting Behavior of Dominant Mosquito Species

Species	Indoor (n)	Outdoor (n)	Total	Indoor (%)	Outdoor (%)	Resting Preference
Mansonia uniformis	324	331	655	49.5	50.5	Mixed (endophilic–exophilic)
Mansonia annulifera	210	222	432	48.6	51.4	Predominantly exophilic
Culex vishnui	179	277	456	39.3	60.7	Exophilic
Culex tritaeniorhynchus	181	301	482	37.6	62.4	Exophilic
Culex quinquefasciatus	47	117	164	28.7	71.3	Exophilic tendency

Temporal Patterns of Mosquito Resting Activity

Temporal analysis of mosquito resting activity across the four study villages revealed clear hourly patterns throughout the night (Figures 3 and 4). Both outdoor and indoor resting activity increased during the early evening, particularly between 19:00 and 22:00, indicating a consistent peak in mosquito resting density shortly after sunset. Outdoor resting activity showed rapid increases after dusk, with pronounced peaks around 21:00–22:00, especially in Sedang and Gasing villages, while Sungai Rengit Murni maintained relatively high densities throughout the night and showed a secondary increase during the early morning hours (04:00–06:00). In contrast, Muara Sugih exhibited lower overall mosquito densities with more moderate temporal fluctuations.

A similar pattern was observed for indoor resting activity, with mosquito densities increasing during the early night period, particularly between 20:00 and 23:00, and highest in Sungai Rengit Murni and Sedang. These patterns likely reflect the post-blood-feeding resting phase, during which mosquitoes seek sheltered resting sites to digest blood meals and initiate egg development within the gonotrophic cycle. Following this early-night peak, resting densities gradually declined during the late night and early morning hours, suggesting dispersal or renewed host-seeking activity. Understanding these temporal resting dynamics provides important insights for optimizing vector surveillance and targeted control strategies.

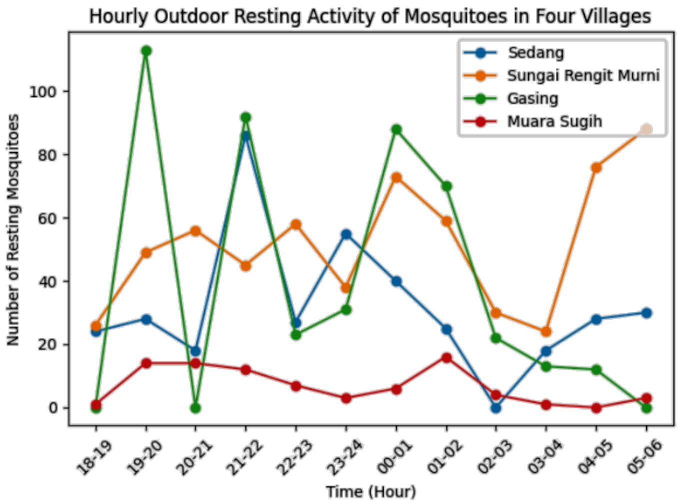

Figure 3. Hourly Outdoor Resting Activity of Mosquitoes in Four Villages

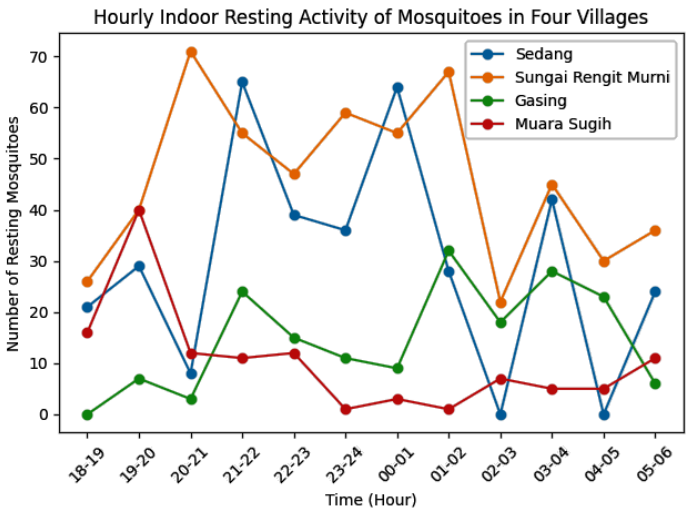

Figure 4. Hourly Indoor Resting Activity of Mosquitoes in Four Villages

Resting Behavior of Dominant Mosquito Species

The hourly resting patterns of dominant mosquito species varied among the four study villages (Figures 5–8). In Sedang Village, *Mansonia annulifera* exhibited a clear increase in resting activity during the early night period, with peak densities occurring between 21:00 and 23:00. Similarly, *Mansonia uniformis* in Sungai Rengit Murni Village showed consistently high resting densities throughout the evening hours, particularly between 19:00 and 22:00, reflecting its strong ecological association with wetland environments. In Gasing Village, *Culex vishnui* displayed a pronounced resting peak between 21:00 and 01:00, indicating a post-blood-feeding resting phase during the late evening. In contrast, *Aedes andamanensis* in Muara Sugih Village showed lower overall densities but exhibited a distinct resting concentration during the early evening (19:00–21:00). Overall, these species-specific resting patterns indicate that the early night period represents a critical phase of mosquito resting behavior when blood-fed mosquitoes concentrate in nearby resting habitats before continuing their gonotrophic cycle.

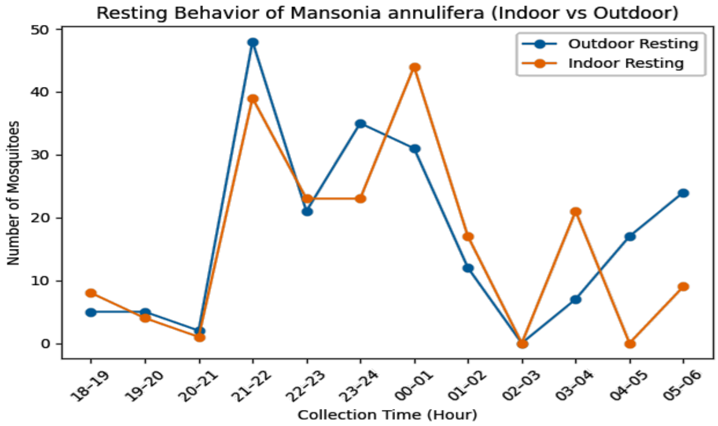

Figure 5. Resting Behavior *Mansonia annulifera* in Sedang Village

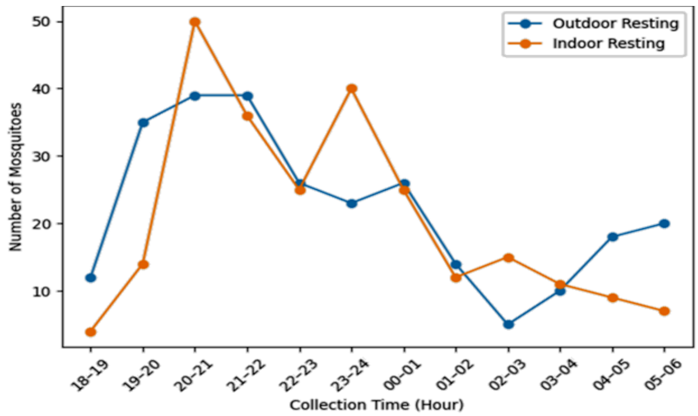

Figure 6 Resting Behavior *Mansonia uniformis* in Sungai Rengit Murni Village

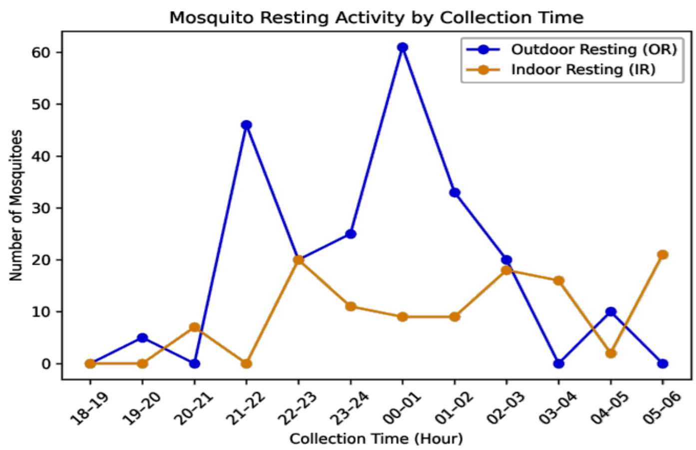

Figure 7 Resting Behavior *Culex vishnui* in Gasing Village

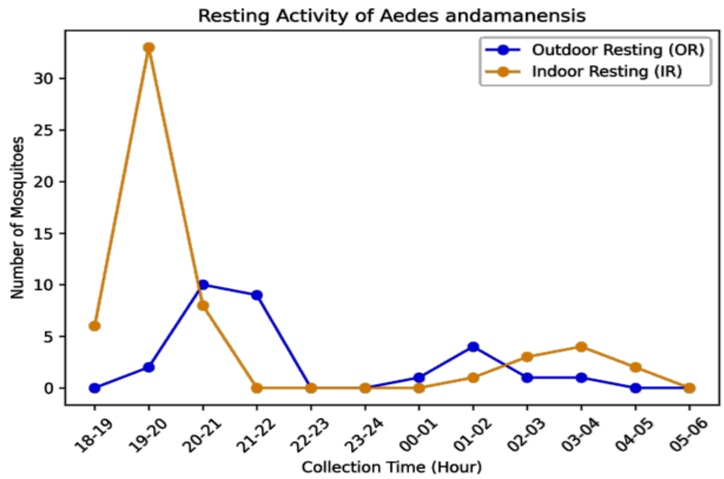

Figure 8. Resting Behavior *Aedes andamanesis* in Muara Sugih Village

Filarial Infection Status

A total of 185 mosquitoes belonging to several species were captured in Sedang and Sungai Rengit Murni villages, of which 19 individuals were dissected for the detection of infective third stage (L3) filarial larvae. All dissected specimens were negative for L3 larvae, indicating no detectable filarial infection in the examined mosquitoes.

Table 6. Dissection Results of Mosquitoes for Detection of Filarial Larvae (L3)

Species	Sedang		L3		Sungai Rengit Murni		L3		Total Captured	Total Dissected
	Captured	Dissected	Negative	Posistive	Captured	Dissected	Negative	Posiive		
Mansonia uniformis	76	17	17	0	19	1	1	0	95	18
Mansonia annulifera	25	1	1	0	0	0	0	0	25	1
Culex vishnui	0	0	0	0	55	0	0	0	55	0
Culex quinquefasciatus	0	0	0	0	0	0	0	0	0	0
Culex gelidus	1	0	0	0	6	0	0	0	7	0
Aedes andamanensis	0	0	0	0	0	0	0	0	0	0
Armigeres subalbatus	1	0	0	0	1	0	0	0	2	0
Ochlerotatus fulvus pallens	0	0	0	0	1	0	0	0	1	0
Total	103	19	19	0	83	1	1	0	185	19

The high abundance of competent vector species such as *Mansonia uniformis* and *Mansonia annulifera* suggests that the ecological conditions in the study area remain highly suitable for lymphatic filariasis transmission. The presence of large vector populations in the absence of detected infection may indicate latent or low-level transmission potential, which could persist if human reservoirs of infection are present. Therefore, continuous entomological surveillance remains essential to monitor vector populations and assess potential transmission risk in wetland ecosystems.

DISCUSSION

Environmental Drivers of Mosquito Community Structure

The results of this study demonstrate that mosquito community composition in Banyuasin wetlands is strongly structured by environmental heterogeneity and land-use patterns. The dominance of Mansonia uniformis and Mansonia annulifera in Sedang and Sungai Rengit Murni reflects their close ecological association with aquatic macrophytes and swamp vegetation, which provide both larval attachment sites and suitable resting habitats. Larvae of Mansonia species obtain oxygen by attaching their siphons to submerged plant tissues, enabling them to thrive in vegetation-rich wetlands. Similar relationships between environmental characteristics and mosquito distribution have been widely documented in vector ecology studies.[7,9,17]

In contrast, the mosquito assemblage in Gasing was dominated by Culex vishnui and Culex quinquefasciatus, species commonly associated with irrigated rice-field ecosystems and agricultural landscapes. Irrigation systems provide highly productive breeding habitats that strongly influence mosquito population dynamics in tropical regions.[14,15,16] Such spatial segregation between Mansonia-dominated wetlands and Culex-dominated agricultural environments illustrates how habitat-specific ecological niches shape mosquito assemblages. At broader spatial scales, environmental drivers such as hydrology, vegetation structure, and land-use change are recognized as key determinants of mosquito distribution and vector-borne disease risk.[6,7,8,9,10]

Mosquito Diversity and Community Structure

The Shannon–Wiener diversity index indicated moderate mosquito diversity across the four study villages, with values ranging from 1.24 to 1.67. When all sampling locations were combined, the overall diversity index increased to H' = 2.14, reflecting the presence of 26 mosquito species within the wetland landscape. Despite having the highest mosquito abundance, Sungai Rengit Murni exhibited relatively lower diversity due to the dominance of a few species, particularly Mansonia uniformis and Culex tritaeniorhynchus.

This inverse relationship between abundance and diversity is commonly observed in vector ecosystems where highly suitable habitats allow a limited number of species to dominate mosquito communities.[8,20] Similar patterns have been reported in other tropical landscapes where environmental suitability promotes the proliferation of dominant vector species, resulting in reduced community evenness.[10,21] In contrast, Muara Sugih and Gasing displayed slightly higher diversity values, suggesting more heterogeneous microhabitats that support a more balanced species composition.

Resting Behavior and Behavioral Adaptation

A key finding of this study is the predominance of outdoor resting behavior, with most mosquitoes collected in vegetation and shaded environments surrounding human dwellings. This pattern was particularly evident among Culex species, which showed strong exophilic resting tendencies. Outdoor resting behavior has increasingly been reported among mosquito populations in tropical environments, particularly in landscapes with dense vegetation and agricultural activity.[11,12]

Interestingly, Mansonia uniformis exhibited mixed resting behavior, occurring both indoors and outdoors. This suggests a high degree of behavioral plasticity, enabling the species to exploit multiple resting habitats across heterogeneous environments. Behavioral plasticity is recognized as an important ecological trait influencing mosquito survival and vectorial capacity, particularly in ecosystems experiencing environmental change or long-term exposure to vector control interventions.[10,13]

Temporal Resting Activity and Gonotrophic Cycle

Temporal analysis revealed a consistent peak in mosquito resting activity between 19:00 and 22:00. This pattern likely corresponds to the post-blood-feeding resting phase of the gonotrophic cycle, during which blood-fed females seek sheltered sites to digest blood meals and initiate egg development. Similar temporal patterns have been widely reported in mosquito ecology studies, where host-seeking activity peaks during early evening hours followed by a resting phase shortly after feeding.[6,21]

The relatively stable resting densities observed throughout the night in Sungai Rengit Murni suggest sustained mosquito activity under favorable environmental conditions, whereas lower densities observed in Muara Sugih may reflect less suitable habitat conditions or lower mosquito abundance.

Transmission Risk and Silent Transmission Potential

The high abundance of competent vector species indicates that ecological conditions remain suitable for potential transmission of lymphatic filariasis. The absence of detectable infection does not necessarily indicate the absence of transmission risk. In endemic areas where vector populations remain abundant, but infection prevalence is low, transmission may persist at undetectable levels, often referred to as silent transmission[4,22]

Several studies have shown that vector populations may remain stable even after repeated rounds of mass drug administration when environmental conditions continue to support mosquito breeding habitats.[2,3] Therefore, the presence of abundant vector populations may serve as an early indicator of potential transmission resurgence, underscoring the importance of continuous entomological surveillance.

Implications for Vector Control

The predominance of outdoor resting mosquitoes observed in this study suggests that indoor-focused interventions alone may be insufficient in wetland ecosystems. Conventional control measures such as indoor residual spraying and insecticide-treated nets primarily target endophilic mosquitoes and may be less effective against exophilic vector populations.[11,13]

Therefore, integrated vector management strategies that combine environmental management, habitat modification, and community-based interventions are essential for controlling mosquito populations in wetland landscapes. Environmental management approaches, including controlling aquatic vegetation that supports Mansonia larval development, may significantly reduce vector populations. Continuous entomological surveillance and adaptive control strategies remain crucial for sustaining progress toward the elimination of lymphatic filariasis.[3,23]

CONCLUSION

This study demonstrates that mosquito community composition and resting behavior in the tropical wetlands of Banyuasin Regency are strongly influenced by landscape characteristics. Wetland habitats with dense aquatic vegetation supported high abundances of Mansonia species, whereas agricultural landscapes were dominated by Culex mosquitoes. Most dominant species exhibited predominantly outdoor resting behavior, highlighting the importance of vegetation surrounding human dwellings as key resting habitats.

The high abundance of competent vector species indicates that ecological conditions remain favorable for potential transmission of lymphatic filariasis. These findings suggest that vector control strategies in wetland ecosystems should not rely solely on indoor interventions but also incorporate environmental management approaches. Targeted control measures such as management of aquatic vegetation that supports Mansonia breeding, reduction of outdoor resting habitats, and strengthened entomological surveillance may contribute to more effective and sustainable vector control in endemic wetland areas.

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