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Bionomics and Distribution of Anopheles Species in Different Ecological Types in Lampung Province, Indonesia

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ABSTRACT

Background: Malaria is still a global problem, including in Indonesia. Lampung is a low endemic area, but confirmed vector anopheles have been found in this province. In order to support the malaria elimination program in Indonesia in 2030, it is necessary to comprehend the bionomic Anopheles in Lampung Province.
Method: The capture of Anopheles mosquitoes was carried out using the human landing collection method in 3 districts in Lampung Province, namely South Lampung, Tanggamus and Pesawaran. Each district was conducted in 3 ecologies: Forest, urban and coastal, and each is carried out near and far from human dwellings.
Results: The most commonly found species is Anopheles sundaicus which is found in coastal ecosystems far from settlements with activity time almost all night. The next highest number were anopheles barbirostris in southern Lampung and An. Aconitus in Tanggamus. Another species found were *An. kochi, An. maculatus complex, An. nigerrimus, An. sundaicus complex, and An. tesselatus.*
Conclusion: Lampung Province has a receptive area with the discovery of anopheles species that have been confirmed as vectors on the island of Sumatra. The species that is widely found is Anopheles sundaicus with main ecosystems found on the coastal area-far from human dwellings.

1. Introduction

The Malaria remains a significant public health issue in Indonesia, largely due to the complex interactions among various Anopheles species that serve as vectors for the Plasmodium parasites causing the disease. The Annual Parasite Incidence (API) in Indonesia has increased from 2019 to 2023 by 0.8, 0.9, 1.1, 1.6, and 1.5, respectively (1). Understanding the biology, ecology, and behavior of Anopheles mosquitoes is crucial for grasping their vector potential and the dynamics of malaria transmission in the region. Indonesia is home to over 25 Anopheles species identified as malaria vectors, each exhibiting unique ecological preferences and behaviors that influence their contribution to malaria epidemiology (2, 3). The geographical diversity of Indonesia, characterized by varied climates and topographies, affects the distribution and prevalence of Anopheles species. For example, Anopheles sundaicus is widespread across several islands, including Sumatra and Java, while Anopheles maculatus is noted for its significant vectorial capacity in certain areas (4, 5). The host-seeking behaviors and feeding preferences of Anopheles species are essential for understanding transmission dynamics and developing effective vector management strategies (6).

Lampung Province in Indonesia experiences low levels of malaria endemicity, with an Annual Parasite Incidence (API) of 0.13 recorded in 2023. To effectively support malaria elimination efforts in the region, it is essential to understand the bionomic characteristics of its malaria vectors, especially since it was historically an endemic area. The potential for increased malaria cases exists if imported cases occur, given the region's susceptibility. Lampung's geographical and ecological features, including its coastal and forested regions, provide conducive environments for malaria vectors, such as *An. sundaicus and An. kochi*, which are found across various parts of the province. In particular areas such as Pesawaran, the API has been reported to be relatively high, highlighting ongoing challenges in controlling malaria transmission. Recent research has indicated significant genetic diversity among *Plasmodium falciparum* strains in Lampung, complicating treatment and control strategies. The presence of various genotypes in malaria infections suggests that local transmission dynamics are shaped by environmental conditions and human activities, including agriculture and fishing, which increase exposure to mosquito bites (8,10).

The study of Anopheles mosquitoes in Indonesia involves a detailed understanding of the various species, their ecological relationships, and behavior patterns. This report focuses on the bionomics of Anopheles species collected from three districts in Lampung Province: Lampung Selatan, Tanggamus, and Pesawaran. The species analyzed are recognized as malaria vectors on the island of Sumatra. This information about bionomic and species distribution is crucial for developing effective malaria control strategies tailored to the unique challenges posed by the diverse Anopheles populations in Lampung Province, Indonesia.

2. Method

This research is part of national research on vector and reservoir diseases (Rikhus Vektora) under MoH Indonesia. A descriptive cross-sectional study approach was used in this study, which was conducted in 29 of 34 provinces in Indonesia in 2015-2018. This article reports the bionomics and distribution of Anopheles in Lampung Province. In Lampung Province, the study took place in 2016 across three districts: Lampung Selatan, Pesawaran, and Tanggamus. Each district featured research in three different ecosystems: forest, coastal, and urban/rural settings. Within each ecosystem, two locations were selected for study: one close to human habitation and another farther away. This resulted in six study sites: Forest-Nearby Human Dwellings (FNH), Forest-Far from Human Dwellings (FFH), Urban-Nearby Human Dwellings (UNH), Urban-Far from Human Dwellings (UFH), Coastal-Nearby Human Dwellings (CNH), and Coastal-Far from Human Dwellings (CFH). Mosquito collections were performed over two days at each site. The study population was Anopheles mosquitoes in Lampung Province, which were previously confirmed as malaria vectors on the island of Sumatra.

2.1 Mosquitoes collections

The field collection of mosquitoes was conducted using the human landing catch (HLC) method, both indoors and outdoors, with three houses each situated near suspected mosquito breeding sites. The mosquito collections took place from 6 pm to 6 am, with each hour lasting 50 minutes over a 12-hour period. Local people, trained as mosquito collectors, were employed. Mosquitoes that landed on humans as bait were caught using an aspirator, placed in paper cups, and marked for each hour of capture.

The mosquitoes were then identified using mosquito identification keys [10, 11]. Man Hour Density (MHD) was calculated using the following equation

$$MHD = \frac{The\ Number\ of\ Mosquitoes\ of\ a\ particular\ species\ with\ human\ bait}{50\ X\ 12\text{-}hours\ X\ Number\ of\ collector\ X\ 2\ days\ collection}$$

2.2 Data Analysis

The analysis involved monitoring mosquito bites on human bait over a 12-hour period to observe biting behavior patterns. The study focused on Anopheles mosquitoes, which are known

malaria vectors on the island of Sumatra. Data on these vectors has been documented on Sumatra since 1902, with the latest findings confirming their presence. Additionally, the study calculated the Man Hour density (MHD) for each confirmed vector species based on previous reports.

3. Result

In this study, 7 species of Anopheles were identified.: An. aconitus, An. barbirostris, An. kochi, An. maculatus complex, An. nigerrimus, An. sundaicus complex, and An. tesselatus. All of these Anopheles have previously been confirmed as malaria vectors in this area. The Anopheles collection data by ecosystem can be seen in Table 1.

Table 7. Distribution of *Anopheles sp.* by the ecosystem in Lampung Province, Indonesia, 2016

No.	Species	Ecosystem					
		FNH	***FFH***	***UNH***	***UFH***	***CNH***	***CFH***
A	Lampung Selatan District						
1	An. Aconitus	-	-	-	2	-	1
2	An. Barbirostris	-	-	-	60	-	2
3	An. Kochi	5	-	-	-	-	-
4	An. maculatus complex	-	-	-	5	-	-
5	An. Nigerrimus	-	-	-	-	-	-
6	An. sundaicus complex	-	-	-	-	26	425
7	An. Tesselatus	-	-	-	-	-	-
B	Tanggamus District						
1	An. Aconitus	-	-	25	-	-	-
2	An. Barbirostris	-	-	-	-	-	9
3	An. Kochi	-	-	-	-	-	-
4	An. Maculatus complex	-	-	-	-	-	1
5	An. Nigerrimus	-	-	-	-	-	-
6	An. Sundaicus complex	-	-	-	-	-	69
7	An. Tesselatus						
C	Pesawaran District						
1	An. Aconitus	-	-	-	-	-	-
2	An. Barbirostris	-	-	-	8	-	-
3	An. Kochi	-	-	-	-	-	-
4	An. Maculatus complex	-	-	4	-	-	-
5	An. Nigerrimus	-	-	-	2	-	-
6	An. Sundaicus complex	-	-	-	-	2	28
7	An. Tesselatus	-	-	-	4	-	-

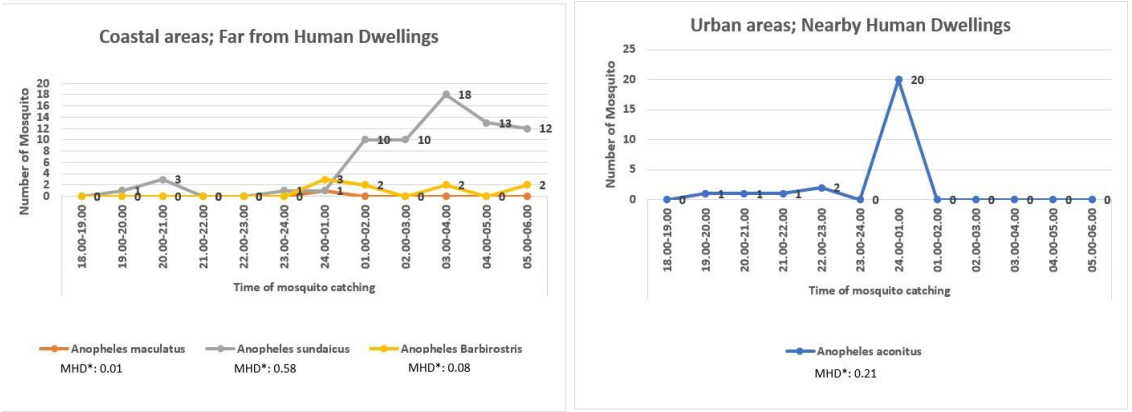
Note: FNH: Forest-near human dwellings; FFH: Forest-far from human dwellings; UNH: Urban-near human dwellings; UFH: Urban-far from human dwellings; CNH: Coastal-near human dwellings; CFH: Coastal-Far from human dwellings.

The data from Table 1 indicates that *Anopheles* mosquito vectors were not present in all Ecosystems across three districts in Lampung Province. Specifically, no Anopheles vectors were found in the FFH and UNH ecosystems in South Lampung District, in the FNH, FFH, UFH, and CNH ecosystems in Tanggamus District, and the FNH and FFH ecosystems in Pesawaran District. The detailed pattern of *Anopheles* mosquito activity at the research location, both indoor and outdoor collection, based on the time of collection and ecosystem, is illustrated in Figures 1-3.

* MHD: Man Hour Density: Average of mosquitoes number per hour per catcher

Figure 2. Human landing collection per hour in Lampung Selatan District, Indonesia

In the FNH ecosystem of South Lampung Regency, *An. kochi* was collected between 20:00 and 21:00 with a man-hour density (MHD) of 0.04. In contrast, the CNH ecosystem only recorded *An. sundaicus*, with the highest collection time between 01:00 and 02:00 and an MHD of 0.22. The UFH ecosystem revealed three species: *An. barbirostris*, *An. aconitus*, and *An. maculatus*, with respective MHDs of 0.5, 0.02, and 0.04. The most active species in this ecosystem was *An. barbirostris*, collected between 18:00 and 19:00. In the CFH ecosystem, three species were found: *An. aconitus*, *An. sundaicus*, and *An. barbirostris*, with MHDs of 0.01, 3.54, and 0.02 respectively. *An. sundaicus* was most active throughout the night, with peak biting times at 22:00–23:00 and 03:00–04:00.



* MHD: Man Hour Density: Average of mosquitoes number per hour per catcher

Figure 3. Human landing collection per hour in Tanggamus District, Indonesia

In Tanggamus Regency, Anopheles mosquitoes, which are known to transmit malaria, are found in two specific ecosystems: CFH and UNH. In the CFH ecosystem, three species were identified: An. maculatus, An. sundaicus, and An. barbirostris. The highest density of An. sundaicus was

observed, with a peak activity period from 1:00 AM to morning. In contrast, the UNH ecosystem only contained Anopheles aconitus, with a peak activity time between 12:00 AM and 1:00 AM.

* MHD: Man Hour Density: Average of mosquitoes number per hour per catcher

Figure 4. Human landing collection per hour in Pesawaran District, Indonesia

In Pesawaran Regency, *An. maculatus* was collected between 7:00 PM and 8:00 PM with a mean hourly density (MHD) of 0.03 in the UNH ecosystem, In the CNH and CFH ecosystems, only *An. sundaicus* was found, with MHDs of 0.03 and 0.32, respectively. In the UFH ecosystem, *An. barbirostris*, *An. tessellatus*, and *An. nigerrimus* were captured between 6:00 PM and 7:00 PM, with MHDs of 0.07, 0.03, and 0.02, respectively. *An. barbirostris* showed an increase in biting rates between 1:00 AM and 2:00 AM.

4. Discussion

The collection and identification of Anopheles mosquitoes as malaria vectors is critical for understanding and controlling malaria transmission In Lampung Province. The diversity of Anopheles species in this region is significant, with 13 species were confirmed as potential malaria vectors from previous study. These species have been implicated in malaria transmission due to their abundance in various habitats, including human dwellings, coastal and forested areas, where they engage in human landing collection (HLC) for blood meals (5). Human landing collections are a standard method for assessing the behavior and distribution of malaria vectors. This technique allows researchers to capture mosquitoes directly from human hosts, providing insights into their feeding preferences and activity patterns.

The results of this study showed that of the 13 species of anopheles that had been confirmed as malaria vectors on the island of Sumatra, 7 species were successfully captured in 5 ecosystems in 3 districts where the study was located. This study revealed that dominant potential vector in three district is An. Sundaicus complex, in coastal far from human dwellings ecosystem. The sundaicus caught varied, in southern Lampung and Pesawaran were found almost all night, in Tanggamus they were arrested from 01.00am until morning.

The ideal ecosystem for this sundaicus is a coastal area far from human dwellings. This species complex has been identified as a primary vector of malaria, contributing to the transmission dynamics of Plasmodium species in various ecological settings across the archipelago (4,13,14). The distribution of An. sundaicus is notably prevalent along coastal areas, where it thrives in brackish water habitats,

making it a critical focus for malaria control efforts in Lampung and similar regions (13,15). Recent studies have highlighted the genetic diversity within the An. sundaicus complex, which includes several sibling species that exhibit varying degrees of vector competence and ecological preferences (16,17). For instance, molecular analyses have shown that An. sundaicus can be differentiated from its sibling species based on mitochondrial and ribosomal markers, which is crucial for accurate species identification and understanding their respective roles in malaria transmission (18). This genetic complexity underscores the importance of employing molecular techniques in vector surveillance to inform targeted control strategies. It should be a major concern that An. The Sundaicus complex, which is found far from human dwellings, has the potential to become closer to the development of intensive residential areas. The closer this settlement will cause contact between humans and An. The Sundaicus complex is getting more intense and increases the potential risk of malaria transmission. The relationship between human activities and mosquito breeding sites is critical, as alterations in land use can impact vector populations and, consequently, malaria transmission dynamics (15)

Another species of anopheles that is widely found, is An. Barbirostris in Lampung Selatan District and An. Aconitus in Tanggamus district . There are 60 barbrostris in the South Lampung district, in the UFH ecosystem with an MHD of 0.5. In the Tanggamus district is An. Aconitus in the UNH ecosystem are 25 with an MHD of 0.21. An. Barbirostris in Lampung Selatan District were caught at 06.00 pm-07.00 pm, indicating that the activity of these anopheles is concentrated in the early twilight. The location of the catch is in urban areas far from human dwelling, such as gardens, fields and rice fields. Although the UFH ecosystem is far from human dwellings, it is an area that is often visited by humans in their daily activities. This ecosystem needs attention because it has the potential to become a transmission spot if there is an introduction of malaria cases in the area. The time of barbirostrical activity at the beginning of dusk also has the potential to cause contact if there are humans who are active at that hour. Anopheles barbirostris is recognized as an important malaria vector in various parts of Indonesia, including Lampung. This species is part of a complex that includes several sibling species, complicating its identification and the assessment of its vectorial capacity (16,19). An. barbirostris has been found in diverse habitats, including forested areas and human settlements,

where it exhibits both endophagic and exophagic feeding behaviors (Sumanto, 2022; Davidson et al., 2019). The species is particularly active during the night, with peak biting times reported between 9 PM and 4 AM (20). This nocturnal activity pattern poses challenges for malaria prevention, as it coincides with the times when individuals are most likely to be unprotected.

Anopheles aconitus, on the other hand, is another significant malaria vector in Indonesia, including Lampung. This species is known for its adaptability to various ecological conditions, often found in areas with abundant vegetation and standing water, which are conducive to its breeding (14,18). An. aconitus has been implicated in malaria transmission in both rural and peri-urban areas, highlighting its importance in the epidemiology of malaria in Indonesia (18). The species exhibits a preference for feeding on humans, which increases its vectorial capacity for transmitting malaria parasites (16).

Another species is An. Kochi, An. Maculatus, An. Nigerrimus and An. Tesselatus is found in 3 districts, although there are not many of them. This species has been confirmed as a vector on the island of Sumatra, so it must also be of concern because it has the potential to become a vector of malaria transmission in Lampung Province. Reported by previous study, An. Maculatus active during the evening and night, with peak biting times reported between 18:00 and 21:00 hours (16). Anopheles nigerrimus and Anopheles tessellatus are also noteworthy vectors in Indonesia. An. nigerrimus has been documented in various ecological settings, including urban and rural areas, where it contributes to malaria transmission dynamics (22). Its feeding behavior and habitat preferences make it a relevant species for vector control strategies. An. tessellatus, on the other hand, is often found in association with other Anopheles species, and its role as a malaria vector is increasingly recognized(22).

In conclusion, Anopheles maculatus, Anopheles nigerrimus, Anopheles tessellatus, and Anopheles kochi are critical malaria vectors in Lampung Province, Indonesia. Their ecological adaptability, feeding behaviors, and potential for insecticide resistance underscore the complexity of malaria transmission dynamics in the region. Continued research and surveillance are essential to inform

targeted vector control strategies and mitigate the impact of malaria in Lampung and other endemic areas.

5. Conclusion

As a low endemic area of malaria, Lampung Province has a receptive area with the discovery of anopheles species that have been confirmed as vectors on the island of Sumatra. The most abundant species found in Lampung province is An. Sundaicus, with the main ecosystem being coastal areas far from human dwellings which has activities almost all night. Another species found is An. Aconitus, An. barbirostris, An. kochi, An. maculatus complex, An. nigerrimus, An. Sundaicus complex, and An. Tesselatus with ecosystems in the ecosystems of UNH, FNH, UNH, CNH and CFH.

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