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ROLE OF MANGROVE FOREST IN SUPPORTING FIREFLIES HABITAT AT KG SUNGAI TIMUN, REMBAU ,NEGERI SEMBILAN

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ABSTRACT

Mangroves are among the world's most biologically significant and diversified natural systems. They are important in the ecosystem as they serve a variety of purposes in preserving the well-being and productivity of coastal ecosystems, as well as home for fireflies. Pteroptyx tener small insects known as family of Lampyridae has been found congregating on mangroves forests. Mangrove species like Sonneratia caseolaris and associated trees such as Nypa fruticans supports fireflies' population. However, mangrove degradation due to land use changes may endanger their number and the possible financial gains from firefly ecotourism. Using GIS heat mapping, the study identified three ecological zones based on mangrove density, with high-density zones requiring immediate conservation, low-density zones needing restoration, and moderate-density zones serving as environmental buffers. A comparison with Kampung Kuantan Firefly Park highlighted the benefits of dense mangrove coverage for biodiversity and ecotourism. The findings emphasize the importance of mangrove restoration and sustainable ecotourism to preserve firefly habitats and promote ecological stability. These insights can guide future conservation strategies to ensure mangrove ecosystems' lasting biodiversity and sustainability.

Keyword: Mangroves, Fireflies, Mangrove Degradation

INTRODUCTION

A unique ecosystem, mangrove forests are found in the intertidal forest throughout tropical and subtropical coastal (figure 1) of the world and are home to a variety of flora and wildlife (Anderson & Senior, 2014; Kanniah et al., 2015). They provide food, medicine, fuel, and building materials to the local inhabitants, as well as habitat for hundreds of marine and pelagic species. Being among the most carbon-rich forests in the tropics, they also play a significant role in reducing the effects of climate change by removing CO₂ which the primary greenhouse gas, aside from water vapor from the atmosphere (Dahdouh-Guebas, 2011; Donato et al., 2011). Because of their biological diversity, mangrove forests are referred to as the "rainforests of the seas"(Akram et al., 2023). One of the nations with the greatest mangrove expanses in South East Asia is Malaysia.

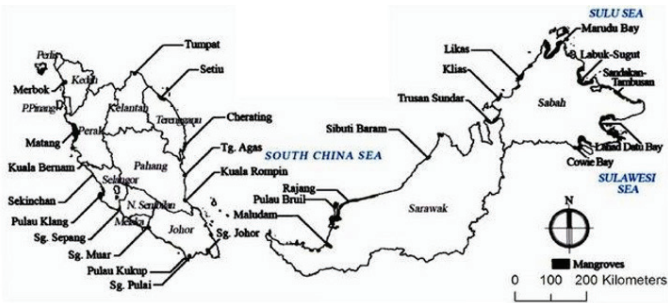


Figure 1. Mangrove forest distribution in Malaysia

Source: Kanniah et al. (2015)

In Malaysia, a number of mangrove species, such as *Sonneratia caseolaris*, and related trees, such *Nypa fruticans*, sustain the population of fireflies (Idris et al., 2022). Fireflies are a developing ecotourism attraction, making them commercially significant in many nations (Lewis et al., 2020). In Peninsular Malaysia, these rare insects perform their nightly flashing panorama in groups on riverside trees in places like Kuala Selangor, Rembau-Linggi, Kuala Sepetang, and Kerteh River. In Sabah, fireflies congregate in a number of places, including the Garama River, Teratak River, Paitan, Tuaran, Sepilok, Sakar Island off the coast of Lahad Datu, and Kawang River (Ahmad Fuzi et al., 2022). The small insect *Pteroptyx tener*, belonging to the Lampyridae family, is commonly found congregating in mangrove forests. The sight of fireflies glistening along the river at

night is breathtaking and draws tourists. One of the most popular tourist attractions in Malaysia today is ecotourism. Through these firefly ecotourism endeavours, locals can work as tour guides and food vendors (Idris et al., 2022). For example, Kampung Kuantan is a well-known CBE destination for travellers from all over the world because of its firefly attractiveness. Kampung Kuantan Firefly Park (FP) has implemented community-based ecotourism (CBE), a distinctive form of ecotourism with characteristics totally different from mass tourism. The mass plantation of mangrove leads to mass fireflies habitat.

However, mangroves forest has inevitably face risks from a variety of land use activities such as urbanisation and resettlement. In the 1990s, Malaysia's entire land area was made up of about 2% (650,000 hectares) mangrove forest. Nevertheless, in 2020 Malaysia's mangroves have been steadily declining over the past ten years, the country's entire mangrove forest area decreased to about 580,000 ha (Hu & Kong, 2020). The declining of mangroves forests affect the fireflies population (Ahmad Fuzi et al., 2022). In Negeri Sembilan, the *Pteroptyx tener* colonies were found in the Rembau River, compared to two colonies in Linggi river. *P. tener* has been observed gathering on a number of tree species, including *Sonneratia caseolaris* and *Talipariti tiliaceum*, which occur along a 9 km stretch of the brackish river in the Rembau-Linggi estuary. Sungai Timun connected with Rembau-Linggi River as fireflies tourism are nearly gone as a result of urbanisation and resettlement (Jusoh, 2014; Seri & Rahman, 2022). The reduction in the firefly population connected to local land use changes.

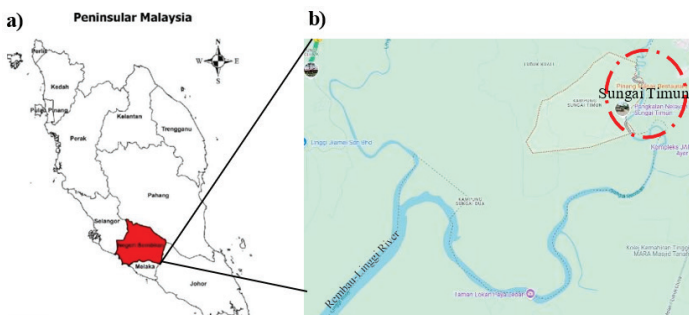


Figure 2. Rembau-Linggi River, Rembau, Negeri Sembilan

Source: (a) (Hazir & Muda, 2020) (b) Google Earth Version 10.71.0.2 (2023)

According to (Idris et al., 2022) the geographically referenced data is called a GIS as tool used to mapping the mangrove vegetation species. The findings of this study will contribute significantly to the monitoring of firefly populations and the conservation of mangrove ecosystems, both of which play a crucial role in maintaining ecological landscape. However, the formulation and implementation of effective management strategies require further in-depth research, particularly to refine and validate proposed management frameworks. Enhancing mangrove density is crucial, as these ecosystems provide essential habitats that support the lifecycle and sustainability of firefly populations. The objectives of the study are to assess how the decline in mangrove vegetation affects the ecological balance and firefly habitat in the area, to propose conservation strategies for mangrove restoration aimed at preserving firefly habitats and supporting local ecotourism sustainability and to investigate the connection between Kampung Sungai Timun's firefly populations' health and the density of mangroves of *Sonneratia caseolaris* and *Nypa fruticans*.

LITERATURE REVIEW

Relationship between Mangroves and Fireflies

Anthropogenic activities are causing the most changes in the mangrove habitat that are affecting firefly populations. The study by Ahmad Fuzi et al. (2022) examines the critical relationship between fireflies and their mangrove habitats, emphasizing the adverse effects of anthropogenic activities such as urbanization, agriculture, and logging on firefly populations. Berembang trees are a major factor in firefly habitat selection. as well as the kind of mangrove tree that thrives throughout Peninsular Malaysia's coastline. Additionally, the Berembang trees offer a place to breed and a source of food. It highlights the decrease of *Pteroptyx tener* due to habitat degradation when the loss of Berembang trees, which serve as important mating display sites. Additionally, according to Seri & Rahman (2022) the fireflies usually found close to bodies of water especially in mangroves as this allows fireflies to communicate more easily. They lay their eggs on the riverbanks close to the mangroves tree. Fireflies also rely heavily on specific tree species for mating displays and feeding. Trees such as *Sonneratia caseolaris* known

as Berembang are preferred due to their position along water edges, nectar production, and arrangements of conducive leaf. Other trees, including *Hibiscus tiliaceus* and *Rhizophora apiculata*, also support firefly populations as well as the presence of it and proximity to larval food sources, such as river snails, are crucial for sustaining firefly colonies.

The Importance of Vegetation Landscape in Firefly Habitats

The study of fireflies by Seri & Rahman (2024), especially the *Pteroptyx* species, has gained attention due to their unique ecological significance and bioluminescent behaviour. Vegetation plays a important role in shaping the habitats of these insects based on previous research established. It shows in various studies that indicated firefly behaviour, mating patterns, and survival strategies influenced by plant life's composition, function and structure. For example, specific tree species and their characteristics can provide essential resources such as food and shelter, important for the sustenance of firefly populations. Additionally, the volatile organic compounds (VOCs) emitted by certain plants have been suggested to play a role in attracting fireflies, potentially aiding in mate recognition and location. According to Lewis et al. (2024) These larvae feed on freshwater snails in clear, well-oxygenated streams, while the adult males fly among the thick riparian foliage while flashing simultaneously.

Comparative Study of Kampung Kuantan Firefly Park and Kampung Sungai Timun

The firefly colonies in Malaysia are one of the country's natural wonders, attracting tourists and researchers alike due to their remarkable bioluminescent displays. Two of the most famous firefly habitats in Malaysia are located in Kampung Kuantan located in Selangor and Kampung Sungai Timun located in Negeri Sembilan. These areas are home to large populations of *Pteroptyx tener*, a species of firefly known for its synchronized flashing behavior study by Ahmad Fuzi et al. (2022). While both Kampung Kuantan and Kampung Sungai Timun share similar ecological characteristics, their firefly colonies are subject to different environmental pressures, conservation strategies, and management practices.

A comparative study of these two locations can provide valuable

insights into firefly ecology, conservation challenges, and the effectiveness of eco-tourism as a tool for environmental protection. The firefly colonies in Kampung Sungai Timun are also found in mangrove ecosystems along the riverbanks area. However, the area is characterized by a less developed river system compared to Kampung Kuantan. The firefly population in Sungai Timun has been studied by Chong et al. (2013), who identified that the fireflies in this area are sensitive to river water quality, including pollutants from nearby agricultural activities and urbanization at the site. Unlike Kampung Kuantan, which has a relatively pristine environment, Kampung Sungai Timun has experienced more pressure from development activities, including land reclamation and agricultural runoff. While Kampung Sungai Timun has not been developed to the same extent as Kampung Kuantan, it has the potential to become a key eco-tourism site. Rashid et al. (2016) highlighted the importance of sustainable tourism development. However, they also identified that the lack of infrastructure and limited support by the government for eco-tourism could constrain the industry's growth in Kampung Sungai Timun.

Applications of Heat Mapping for Mangroves

Heat mapping is a data visualization technique used to represent the intensity or density of phenomena within a geographical area. In the context of mangrove forests, heat maps can represent the concentration of mangrove coverage, species diversity, biomass, or the impact of environmental variables such as temperature, salinity, and tidal patterns. Heat maps use colour gradients typically from more astonishing to warmer colours to highlight areas with higher or lower concentrations of the studied phenomena, allowing for easy identification of spatial patterns and trends. In particular, the Kernel Density tool and the Spatial Analyst extension provide powerful methods for creating heat maps based on point data, such as mangrove distribution locations or raster data like land cover classification from satellite imagery. For example, Zhang et al. (2014) used ArcGIS to analyze the spatial distribution and density of mangrove forests in the Guangxi Zhuang Autonomous in China. They applied the Kernel Density tool to identify high-density mangrove areas, which were then linked to environmental factors such as tidal patterns and salinity. Heat maps generated in ArcGIS was used to prioritize conservation efforts as it provided a clear visual representation of mangrove density. Kuenzer

et al. (2011) mapped the distribution of mangrove species richness in Southeast Asia using ArcGIS. By combining species occurrence data with environmental variables, they generated heat maps that indicated areas with high biodiversity potential.

Technique and Tools in ArcGIS for Heat Mapping Mangroves

The Kernel Density tool is widely employed in creating heat maps from point data by estimating the density of occurrences within a defined search radius. This method has been utilized effectively in various studies, such as Patterson et al. (2016), who applied it to map the concentration of mangrove species along the Florida coastline. The resulting heat maps provided critical insights into areas of high biodiversity, which were subsequently prioritized for conservation efforts. For raster-based datasets, such as satellite-derived vegetation indices or land cover classifications, ArcGIS provides robust spatial analysis tools. The Spatial Analyst extension, for example, enables researchers to perform advanced analyses. Tools such as Reclassify can categorize mangrove coverage based on indices like NDVI, while Map Algebra allows for the integration of multiple environmental variables, including salinity, temperature, and tidal zones. These composite heat maps offer a nuanced understanding of the relationship between mangrove distribution and environmental factors, supporting data-driven decision-making in mangrove management and conservation.

RESEARCH METHODOLOGY

Study Area

This study conducts qualitative research, a document analysis, driven by literature review. The study area is at Sungai Timun, Rembau, Negeri Sembilan. The site is a rural area and known as Eco tourism and Agro Based Tourism Destinations covers about 32 Acres of land located at Raja Melewar Route: Sumatra-Sg Timun-Kuala Linggi (Astana Palace king) . This river will flow to the mouth of Kuala Linggi and join the Sungai Linggi from Negeri Sembilan. Sungai Linggi becomes the border for Negeri Sembilan and Melaka which starts at of Sungai Rembau and Sungai Linggi with 83.5 km in length.

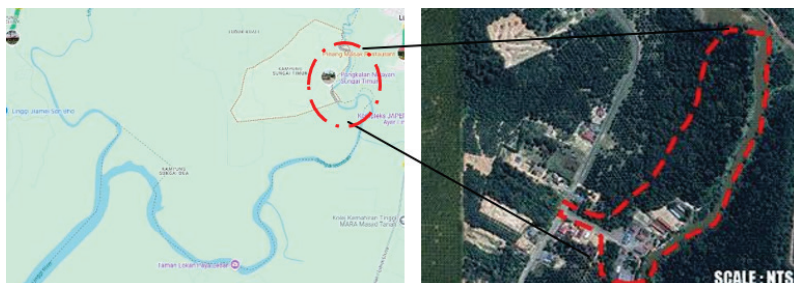


Figure 3. Key Plan (left) and Location Plan (right) of Sungai Timun, Rembau, Negeri Sembilan

Source: Google Earth Version (2023)

DATA COLLECTION

This study uses direct observation. Direct observation is a robust data collection method, enabling researchers to capture complex social phenomena in real-time. By systematically documenting observations, researchers can enhance the validity of their findings and contribute to a more comprehensive understanding of the subject matter according to Taylor-powell & Steele, n.d. (1996) and ArcGIS Pro Version 3.4 (GIS Software | Mapping Analytics | ArcGIS Pro (2024) to investigate the relationship between mangrove species diversity and their role in supporting firefly populations in Kampung Sungai Timun. Point data, representing scattered mangrove distribution across the site, were incorporated into the GIS environment. Google Earth Version 10.71.0.2 (2023) was utilized as the base map to precisely define the boundaries of Kampung Sungai Timun and enhance the spatial accuracy of the data has been collected.



Figure 4. The camera from Iphone 15 128GB Blue (left) and photographs taken by the distance mode 1.0x quality zooming Iphone camera (right)

Source : Iphone 15 Blue Model - Google Search (n.d.) (left)

In addition, field observations were conducted to document species diversity and site conditions, supported by photographic evidence that was systematically captured using a camera Iphone 15 128GB Blue with distance mode 1.0x quality zooming to document mangrove conditions for firefly activity. A checklist table to record mangrove species and it's numbers of species. This methodology provides a strong framework for analyzing the environmental connection between mangroves and firefly populations, as well as guiding practical conservation efforts. This methodology validates the role of mangroves in supporting firefly populations and emphasize the importance of preserving this unique habitat.

Table 1.0. Collection Mangrove Species Data

Distribution of Mangrove Forest Role in mapping				
Mangrove role	Botanical Name Species	Qty	Location	ArcGIS for Heat Mapping Mangroves
Breeding, Mating Platforms and food sources	<i>Sonneratia caseolaris</i> <i>Nypa fruticans</i>	30 23	Zone A	
	<i>Nypa fruticans</i>	4	Zone B	
	<i>Sonneratia caseolaris</i> <i>Nypa fruticans</i>	33 7	Zone C	

Source: Author

A checklist table to record mangrove species and it's numbers of species. This methodology provides a strong framework for analyzing the environmental connection between mangroves and firefly populations, as well as guiding practical conservation efforts. This methodology validates the role of mangroves in supporting firefly populations and emphasize the importance of preserving this unique habitat. The findings aim to support targeted conservation strategies and inform sustainable ecotourism practices which ensuring the long-term potentiality of Kampung Sungai Timun's mangrove-firefly ecosystem.

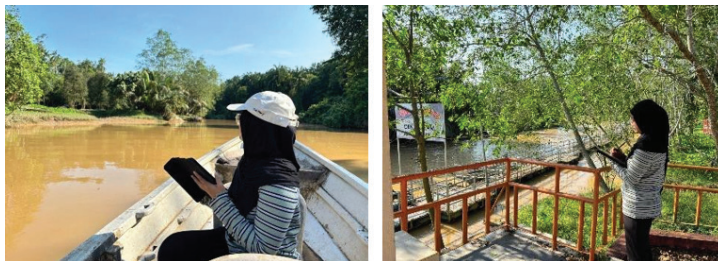


Figure 5. Identifying the Mangrove Species and its Location

Source: Author

ANALYSIS AND DISCUSSION

The Environmental Systems Research Institute (ESRI) in California created the software ArcGIS Pro, which is used in this data analysis. Geographic information systems, or GIS, are a tool for user decision-making. All of the data entered into a mapping concept can be digitised by this software. Kennedy, Michael (2006). The collected data were analyzed using a combination of GIS heat mapping to assess the relationship between mangrove species diversity and firefly populations in Kampung Sungai Timun.

In the GIS analysis, ArcGIS was worked to generate heat maps based on point data according to Patterson et al. (2016), representing mangrove distribution. The heat maps provided a visual representation of mangrove density across the study area, highlighting high-density zones that serve as critical habitats for fireflies. The classification of the study area into three distinct zones based on z-scores reflects varying ecological priorities for mangrove conservation and firefly habitat support. Areas with a high z-score, represented by red on the heat map, are identified as critical hotspots where additional mangrove coverage is required. These zones exhibit high firefly activity, suggesting a strong dependence on dense mangrove vegetation for sustaining their populations. In contrast, areas with a low z-score, shown in blue on the heat map, are classified as cold spots.

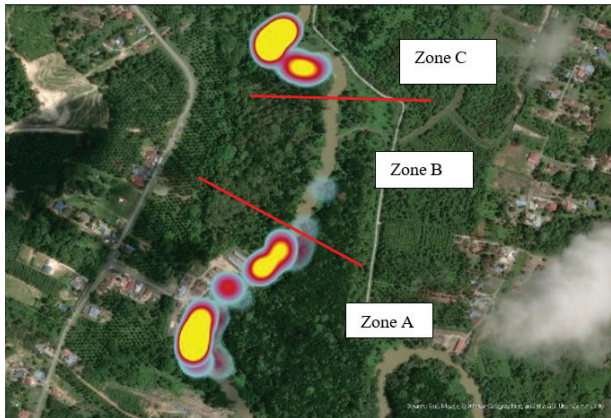


Figure 6. ArcGIS for Heat Mapping Mangroves

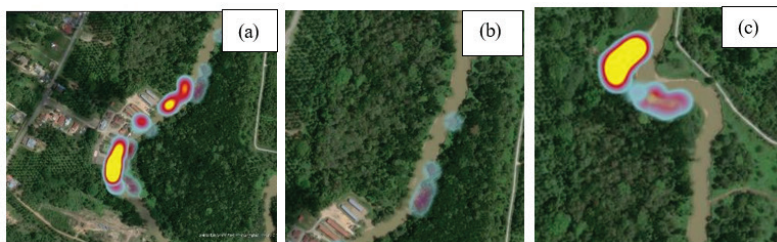


Figure 7. Location of Tree Hotspots and Coldspots in the Three Zone at Kampung Sungai Timun : (a) Zone A (b) Zone B (c) Zone C

Mangrove Distribution in Zone A (High Density)

Heat Map Interpretation: The heat map for Zone A clearly showed a high concentration of mangrove trees, with bright red and yellow areas representing high-density mangrove clusters. These areas corresponded with the most extensive mangrove habitats along the riverbank, where environmental conditions like salinity and water quality are more suitable for mangrove growth. The presence of healthy, mature mangrove trees in Zone A indicates that this area is ecologically significant, supporting a strong mangrove ecosystem.

Spatial Analysis: The dense mangrove forests in Zone A cover approximately 50% of the surveyed area. These areas are typically characterized by a high percentage of *Sonneratia* and *Nypa* species, which

are the dominant mangrove species in the area. The proximity to tidal water flow and protected riverbanks likely contributes to the high density of mangroves.

Mangrove Distribution in Zone B (Low Density)

Heat Map Interpretation: In contrast to Zone A, the heat map for Zone B showed a sparse distribution of mangrove points, with most areas marked in cooler colors such as green and blue. These cooler colors indicate low mangrove density areas where mangrove trees are absent or occur only in isolated patches.

Spatial Analysis: Zone B, accounting for 15% of the surveyed area, is likely impacted by human factors, including disturbances such as developmental activities ,agricultural activities, poor soil conditions, and water pollution. The scarcity of mangroves in Zone B underscores its ecological vulnerability the implementation of focused restoration strategies with conservation. These interpose with reintroducing native mangrove species, promoting mangrove regeneration, and restoring ecological functionality, enhancing the water quality, and convey soil limitations, are crucial for improving habitat conditions.

Mangrove Distribution in Zone C (Moderate Density)

Heat Map Interpretation: Zone C exhibited a more mixed distribution of mangrove trees, with areas showing moderate yellow and light orange concentrations. These areas have a moderate density of mangroves, with some patches of dense mangrove forests interspersed with regions of lower density.

Spatial Analysis: Zone C covers about 35% of the surveyed area and is characterized by a transition between Zones A and B. The moderate mangrove density in this zone could be allocate to a combination of favorable environmental conditions, such as adequate salinity, tidal influence, and some degree of human disturbance or natural stressors. Zones with moderate density are important for maintaining overall ecosystem health and may serve as transitional areas for mangrove species as they adapt to changing environmental conditions.

The transitional zone situated between the high-density and low density extremes. This moderate-density zone represents areas with balanced mangrove coverage and intermediate firefly activity. While not as critical as the high z-score zones, these areas play a significant role as buffers, connecting hotspots and cold spots. Effective management of this zone ensures its continued contribution to the overall functionality of mangroves and resilience of the ecosystem and the balanced mangrove density supports by maintaining its biodiversity.

The heat maps show the spatial distribution of mangroves in Kampung Sungai Timun, highlighting Zone A as an ecologically vital area with high-density mangroves that protect coastal regions, support biodiversity, and sequester carbon. This zone requires focused conservation efforts to prevent land conversion, pollution, and disturbances. In comparison with Zone B's sparse mangrove coverage indicates suboptimal conditions and vulnerability to degradation which necessary for restoration efforts like replanting, restoration and water quality improvement. With moderate density, Zone C acts as a resilient transitional buffer, contributing to ecosystem functionality and biodiversity. Effective management across these zones is essential to sustaining the mangrove ecosystem.

Comparison between Kampung Sungai Timun and Kampung Kuantan Firefly Park

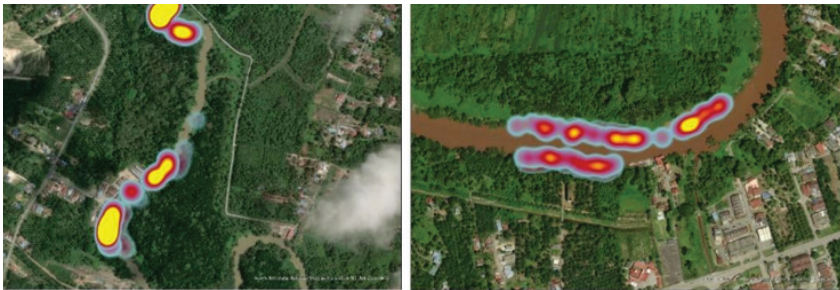


Figure 8. ArcGIS for Heat Mapping Mangroves Kampung Sungai Timun and Kampung Kuantan

The comparison of heat maps between Kampung Sungai Timun and Kampung Kuantan Firefly Park highlights key differences in mangrove distribution and firefly population density. With its dense mangrove forests, Kampung Kuantan shows concentrated areas of firefly activity, reflecting

a strong correlation between mangrove health and firefly abundance. In comparison to Kampung Sungai Timun displays more imbalance, with some zones, such as Zone B, having lower mangrove density and lower fireflies accumulate. This fragmentation in mangrove coverage suggests that Kampung Sungai Timun could benefit from validating conservation strategies similar to the method of planting in Kampung Kuantan, focusing on increasing mangrove coverage and restoring degraded areas. By prioritizing the expansion and protection of mangrove habitats, Kampung Sungai Timun can enhance its ecological functions, which support biodiversity and firefly populations while gaining from sustainable ecotourism.

The heat mapping of mangrove and firefly distribution in Kampung Sungai Timun demonstrates a positive correlation between higher mangrove density and increased firefly abundance. Dense mangrove forests provide essential habitat and ecological conditions for fireflies, and their conservation is crucial for maintaining firefly populations. The findings underscore the importance of protecting high-density mangrove areas and restoring degraded mangrove habitats to support firefly conservation efforts in the zone area. Sustainable mangrove management and restoration can preserve mangrove ecosystems and firefly populations for the next generations.

The results emphasize the importance of maintaining and implementing buffer zones to preserve the high-density mangrove habitats while implementing mitigation measures to address indirect impacts in adjacent areas. Strategies in strengthening and improving the land use practices, pollution control, and ecological connectivity between zones can ensure that resettlement and urbanization remain sustainable and uncompromise the environmental integrity of the mangrove ecosystem.

CONCLUSION

This research highlights the significant role of mangrove ecosystems in supporting biodiversity and sustaining firefly populations, especially in Kampung Sungai Timun. Mangroves provide essential ecological functions which including coastal protection and habitats for diverse species, such as fireflies, which rely on these mangrove environments for their lifecycle. The study emphasizes that the decline in mangrove vegetation , driven

by urbanization, resettlement, and other anthropogenic activities, directly impacts firefly populations and overall ecological balance.

The analysis identified three selected zones of mangrove density with high-density areas critical for biodiversity and carbon sequestration, moderate- density areas serving as ecological buffers, and low-density zones requiring restoration efforts. The findings reveal a strong correlation between mangrove health and firefly abundance that need to protect and restore these ecosystems as well.

Comparing Kampung Sungai Timun with Kampung Kuantan highlights the importance of sustainable conservation strategies with increasing mangrove coverage, improving water quality, and mitigating the impacts of development activities. Kampung Sungai Timun can enhance its ecological functions, support firefly populations, and develop sustainable ecotourism by adopting measures to protect high-density mangrove zones and restore degraded areas.

The study concludes that preserving mangrove ecosystems is essential for maintaining biodiversity, ecological stability, and local economic benefits through ecotourism. Enforcing the targeted conservation strategies and raising awareness about the importance of mangroves and fireflies and can secure the long-term sustainability of these mangroves habitats that can benefiting both the environment and new generations. Further research is recommended to refine conservation frameworks and improve the integration of ecological and socio- economic priorities.

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