

IDENTIFICATION OF FIREFLY POPULATION AREAS ALONG SEPETANG RIVER USING THE BUFFER METHOD

Pengenalpastian Kawasan Populasi Kelip-Kelip Sepanjang Sungai Sepetang Menggunakan Kaedah Buffer

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ABSTRACT *This study identifies firefly population areas along the Sepetang River using Geographic Information System (GIS) buffer analysis. The focus is on *Pteroptyx tener*, which thrives in mangrove ecosystems, especially around *Sonneratia caseolaris* (Berembang trees). Field data were collected over six months from ten stations along the river to analyze firefly abundance concerning surrounding land use and vegetation types. Buffer zones of 50, 100, and 150 meters were applied to assess the impact of environmental factors and human activities on firefly populations. The results revealed that Station 6 had the highest firefly concentration, attributed to its dense Berembang tree cover. These findings emphasize the significance of mangrove conservation for sustaining firefly habitats. This research highlights the effective use of GIS in ecological conservation and underscores the need for protective buffer zones to mitigate the impacts of urbanization on firefly populations.*

Keywords: Firefly population, GIS buffer analysis, Sepetang River, mangrove conservation, *Pteroptyx tener*

1. Introduction

Nowadays, a lot of local and private agencies prefer to use Geographic Information System (GIS) for analysis especially in mapping techniques. Some key areas for the fireflies are highlighted on maps. GIS is a technology that assists in storing, gathering, manipulating, and analyzing the necessary information. It consists of hardware, software, operators, and geographical data. In addition to help identified the firefly stations and its surrounding, GIS can help determine the land use type around the habitat as well as the location of firefly along Sepetang River. The solutions to these queries can be identified through the mapping of buffer analysis on firefly distribution. The firefly, or Lampyridae (*Pteroptyx tener*), is a member of the biggest insect order, Coleoptera. It is a common Southeast Asian firefly with

distinctly bent wings that can be found in hot, moderate areas. This species prefers to live in riversides or in mangrove swamps where it may easily access food sources. For such a little insect, the Lampyridae family has a significant impact on the local population's way of life and indirectly on the economy. Thousands of these unusual insects gather on riverbank trees throughout Peninsular Malaysia, including in Kuala Sepetang, Rembau-Linggi, Kuala Selangor, Kerteh River, and Sabah's Lahad Datu and Kawang River. These insects are renowned for their nighttime flashing rituals.

An increasing number of concerns, such as urbanization and firefly tourism, are placing pressure on environmentalists to produce *Pteroptyx* fireflies and reintroduce the species to locations where numbers are low. According to earlier research, Berembang trees (*Sonneratia caseolaris*) have a significant influence on the habitat choices made by fireflies. Mangrove trees known as Berembang trees are seen growing throughout Peninsular Malaysia's shores (Saib, Dawood, & Saikim, 2016). In addition, the Berembang trees offer a food source and a location for breeding. Research conducted on firefly colonies in Malaysia at Kuala Sepetang, Kuala Linggi, and Rembau River revealed that, in contrast to other types of mangrove trees, most fireflies were discovered at Berembang trees (Jusoh, Hashim, & Ibrahim, 2010).

The purpose of buffer analysis, a spatial analysis approach, is to locate traits or characteristics that are located within a specific radius of a centre point or feature (Longley et al., 2015). It is especially helpful for locating features that are situated within a certain radius of a focal point or feature of interest. It is frequently used to find patterns and relationships within spatial data. This method is frequently used in GIS to find possible impact areas, including those that could be impacted by a planned development or those that might be good for conservation initiatives. Numerous academic disciplines, including urban planning, environmental management, conservation of wildlife, transportation planning, crime analysis, and emergency management, frequently use buffer analysis.

2. Literature Review

2.1 Background of Fireflies along Sepetang River

The Lampyridae family of beetles is where fireflies are classified. They consist of ten subfamilies, and 2200 species have been described globally (Martin et al., 2019). As all other winged insects have two or four wings, fireflies, which belong to the Lampyridae family, are not considered to be "flies" because they only have one set of wings (Mahadimenakbar & Saikim, 2016). There are four phases of growth for fireflies: eggs, larvae, pupae, and adults. After mating, adult female fireflies lay 80–150 eggs within 24–48 hours. After ovulation, adult female fireflies die two to three hours later. The eggs will continue to hatch for a period of two to four weeks. The

mangrove snail, *Cyclotropis carinata*, provides the food source for the recently emerging larvae (Nallakumar, 2003).

The previous research also revealed that the fireflies did not utilize every *Sonneratia caseolaris* tree. Although the precise cause of the colonies' alleged affinity for mangrove species is yet unknown, it has been documented (Chey, 2004). According to Tangah et al. (2022), who discovered that fireflies exclusively ate young *Sonneratia caseolaris* trees in Kuala Selangor, this phenomenon may be partially caused by a single tree's characteristics, such as height, crown size, leaf density, and trunk diameter. Jusoff and Taha (2009) claim that there is little information available on mangrove damage. Mangroves are sensitive ecosystems that seem to fluctuate because of minute variations in the natural climate. Regional mangroves are being cleared because of fast development in response to the increasing demand for beach resorts, aquaculture ponds, and infrastructural expansion in urban areas. Factories and industries close to rivers and streams may release wastes into the water systems, causing pollution and devastation to the river system area (Jusoff & Taha, 2009). Critical genetic diversity needed for agriculture and medicine may upset their natural balance and impair their capacity to guard the shore.

Sepetang River and Kerian River in Perak, Chukai River and Setiu River in Terengganu, and Cherating in Pahang are among the few locations in Malaysia that offer firefly viewing tours along rivers, according to Khoo et al., (2012). These locations will probably have some problems with artificial light sources from neighboring townships and villages. Sepetang River also faces another difficulty because the surrounding areas have multiple aquaculture ponds that use lighting at night. Spotlights, floodlights, streetlights, and residential lighting are common sources of light that are colored white and yellow. It will be significant to investigate the effects of different colored light sources on fireflies that are flashing.

The Sepetang River's firefly habitat is primarily composed of stands of *Rhizophora* spp. mixed with *Sonneratia caseolaris* and *Nypa fructicans*. The *Rhizophora* spp. habitats are periodically flooded by river water. According to Kirton et al., (2006), areas along river estuaries where this phenomenon occurs are good for firefly aggregation because specific snails, which the larvae of fireflies eat, do well there. Jusoh et al., (2010) clarified that when considering the association between firefly populations and vegetation compositions, other factors may be taken into consideration. First, fireflies use trees as a place to mate, even though they do not mate on their wings. Five factors, according to researchers, influence whether to erect a display tree: 1. The location of the display tree along the riverbed facilitates easier communication between fireflies. 2. The leaf structure of every showcase tree needs to be suitable for mating. 3. The display tree needs to be in good health, 4. It needs to be close to a plant that larval prey eats, and 5. It needs nectarines or sap when adult fireflies feed it.

2.2 Firefly Mapping as an Initiative to Conserve the Habitat

According to Fuzi, et al., (2022) many studies have found that abundance species of fireflies in Malaysia are depending on mangroves as their breeding site to undergo breeding, growing and developing their larvae. The study of data with a spatial or geographic component falls under the purview of the Geographic Information System (GIS) branch known as "spatial analysis." It entails applying statistical and mathematical approaches to examine data and having in-depth understanding of patterns and linkages between data that are related to certain areas.

Nonetheless, Jusoh and Hashim (2012) discovered that the mangrove forest of the Rembau River had undergone significant alteration and had been converted to new land uses during the course of 20 years. These activities infringed upon the buffer zones specified by the Department of Irrigation and Drainage (DID) regulations. The conversion of wetlands to agricultural uses would inevitably put the firefly population in jeopardy because it has lost and disturbed its natural environment. Experts predict that fireflies will go extinct in the near future unless prompt and significant measures are taken to protect them. The remaining habitat should be preserved, and the number of fireflies should be tracked, in order to help maintain the sustainability of the firefly population. Breeding congregations of *Pteroptyx Tener* fireflies declined in Malaysia as a result of the conversion of riverbank mangroves to agricultural, aquaculture, and urbanization (Lewis, 2020). In Southeast Asia, large tracts of riverbank mangroves have been cleared for shrimp farms, oil palm plantations, or flood prevention; as a result, *Pteroptyx Tener* firefly larvae and their snail prey cannot survive in these places. Furthermore, many of the display trees where *Pteroptyx Tener* adults congregate for nighttime courtship displays along mangrove waterways have been destroyed.

Human endeavours such oil palm plantations, prawn farms, charcoal factories, and fishing jetty are located alongside the river. According to observations, oil palms were planted all the way up to the riverbed in some places. According to research conducted by Nada et al., (2023), the oil palm plantation is not a good habitat for fireflies. The oil palm plantation thrives in arid environments with low levels of decomposed organic matter in the soil. The habitats needed by the larvae and snails must be damp, shady, and abundant in organic materials. In addition to the need for habitat, oil palm plantations might also need to apply pesticides, which could endanger the firefly population's capacity to survive.

It is imperative to start conservation measures for the Sepetang River's firefly. Almost 60% of the life of a *Pteroptyx tener* is spent as a larva (Nada et al., 2012). Thus, maintaining the firefly population's sustainability requires protecting the breeding sites. The fireflies would suffer greatly if their habitat was lost. Since the snail population provides food for the firefly larvae, the natural riverine flora is equally essential to its survival. Since snails consume decayed organic materials, the habitat's regular flooding by river water would guarantee that there is always an abundance of this food source. Snails are important for the life-cycle of fireflies.

3. Research Area

This study was conducted in Kuala Sepetang located in Larut and Matang District as shown in Figure 1. Prior to this study, there have been few scientific articles of *Pteroptyx* fireflies in this area using different kind of GIS approach. Recent studies have shown the abundance and distribution of firefly along Sepetang River using GIS approach. Kuala Sepetang is renowned for its ecotourism activities such agricultural, aquacultural, and fisheries. Some activities that attract tourists to Kuala Sepetang are firefly watching at night, pink dolphin during daytime and eagle feeding. Along Sepetang River, there were covered by mangrove trees such as Berembang Trees that acts as a major habitat for firefly to inhabit. Then, there were other mangrove trees such as Bakau Kurap, Bakau Minyak, Nypa palms, and others.

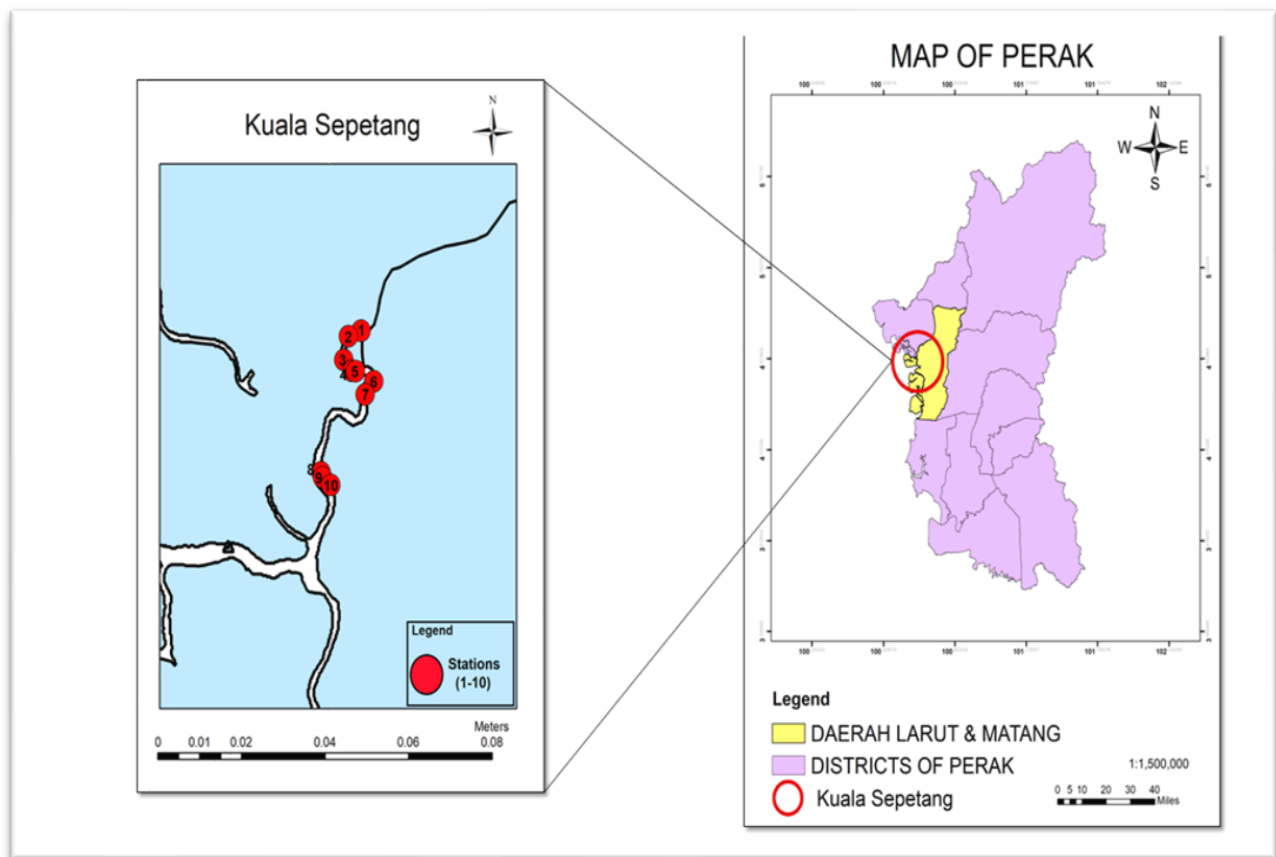


Figure 1. Map of study area
 Source: Fuzi NFA et al., 2023

4. Research Methodology

4.1 Primary Data Collection

This study aims to map ten stations along the Sepetang River and create a 150-meter buffer map around each to assess nearby geographical features that may influence firefly populations. These stations, selected for their diverse ecological characteristics, vary in proximity to fisheries activities, tourist attractions like eagle feeding sites, and river features such as banks, the river mouth, and different mangrove types. Fieldwork, conducted over six months from November 2021 to April 2022, included firefly observations over five nights per month, with consistent 10–15-minute counts at each station for reliable month-to-month comparisons.

During on-site data collection, visits focused on identifying firefly species and estimating abundance along the mangrove-lined riverbanks. Ten stations, labeled S1 to S10, were positioned sequentially along both banks, with S1 at the downstream end and S10 farthest upstream, to capture a full range of ecological diversity. For station marking, a Global Navigation Satellite System (GNSS) was used to establish precise coordinates for each sampling station, ensuring accuracy in spatial positioning along the Sepetang River. For precise firefly counts, two researchers stationed on an anchored, stationary boat used separate counters to monitor designated sections of display trees, providing comprehensive coverage on both sides. The data collection began daily at 5:30 pm, allowing preparation time before firefly activity peaked around 7:30 pm. Each night, the boat moved from S1 to S10, sequentially covering all stations.

This five-night monthly sampling routine was repeated over six months to ensure consistency across seasons. To minimize disturbances, the boat engine was turned off at each station, reducing noise, light, and movement. This method provided robust data on firefly abundance and distribution, offering valuable insights into the environmental and seasonal influences shaping firefly populations along the Sepetang River.

4.1.1 Buffer Analysis Using GIS

The GIS buffer analysis employed a 50-meter radius around each sampling station to capture relevant environmental and human-related features that could potentially influence firefly populations. This 50-meter distance was chosen based on the Coastal Zone Management Plan 2019, which recommends a 50-meter buffer zone for mangrove areas exceeding 1,000 square meters (The Leaflet, 2019). The Sepetang River mangrove areas, which are part of the Matang Mangrove Forest Reserve (MMFR) and span approximately 402,880,000 square meters, meet this criterion, justifying the selection of the 50-meter buffer. Data within these buffer zones were collected using GIS layers derived from fieldwork datasets, including vegetation type, proximity to water, and human activities, which were mapped based on

distances to nearby tourism and fishing sites. Each factor was chosen for its likely influence on firefly abundance, such as how mangrove density reflects habitat availability or how proximity to human activities could indicate disturbance levels. Within each buffer, spatial data were processed by overlaying GIS layers to quantify the variables. Vegetation type was documented within each buffer zone, while proximity metrics were computed by measuring distances from the buffer centroid to the nearest water body and nearby human activity sites, such as tourism and fishing areas.

4.2 Secondary Data Collection (PRISMA)

This study retrieved a systematic literature review; journal articles were acquired from the two major online databases, such as Elsevier (Science Direct) and Google Scholar. The literature review includes both reviews and empirical research from prominent publications, most of which were indexed by SCOPUS. The PRISMA approach (refer Figure 2) was used to identify relevant research carefully and systematically from the pool of literature prior to the in-depth review procedure. Identification, screening, and inclusion are all covered by this method's four-phase flow diagram. Computerized searches were conducted using keywords such as firefly in Malaysia, firefly conservation, firefly population and buffer analysis. Following then, for the Identification phase began with the year of the search and lasted ten (10) years, from 2014 to 2024. Although this intends to emphasize the most current findings on the issues, the year covered is quite recent.

All entries such as papers were found in the Elsevier database were 5,259 papers, whereas Google Scholar identified 4,869. Based on these two databases, a total of 10,128 papers were found. Next, all duplicate articles were carefully reviewed and eliminated. This screening is required to avoid duplicated articles out of the review process. As a result, 63 papers were kept after the duplicates were removed. Based on these 63 publications, a screening procedure based on titles and abstracts was conducted to determine the suitability and relevancy of the articles. The variables used to assess the suitability and validity of the articles were based on the study's objectives, which emphasized on firefly population, firefly conservation and buffer analysis in GIS mapping. These keywords are also important in determining the population of firefly in Malaysia, and the usefulness of GIS in preserving the habitat of firefly. Upon screening, 32 articles were eliminated, bringing the total number of papers in the next phase to 31.

The articles were then further examined based on their complete step and contents for the third step on their eligibility of the screened articles, in other words full-text articles accessed for eligibility. The total number of papers was reduced to 13 after this procedure, which determined if the articles were genuinely eligible based on the established criteria and condition such as population of firefly using GIS approach and the distribution of firefly at scattered locations. As a result, only 18 final articles were included for reviewing purposes throughout the inclusion

phase, spanning the years 2014 to 2024 where the year covered.

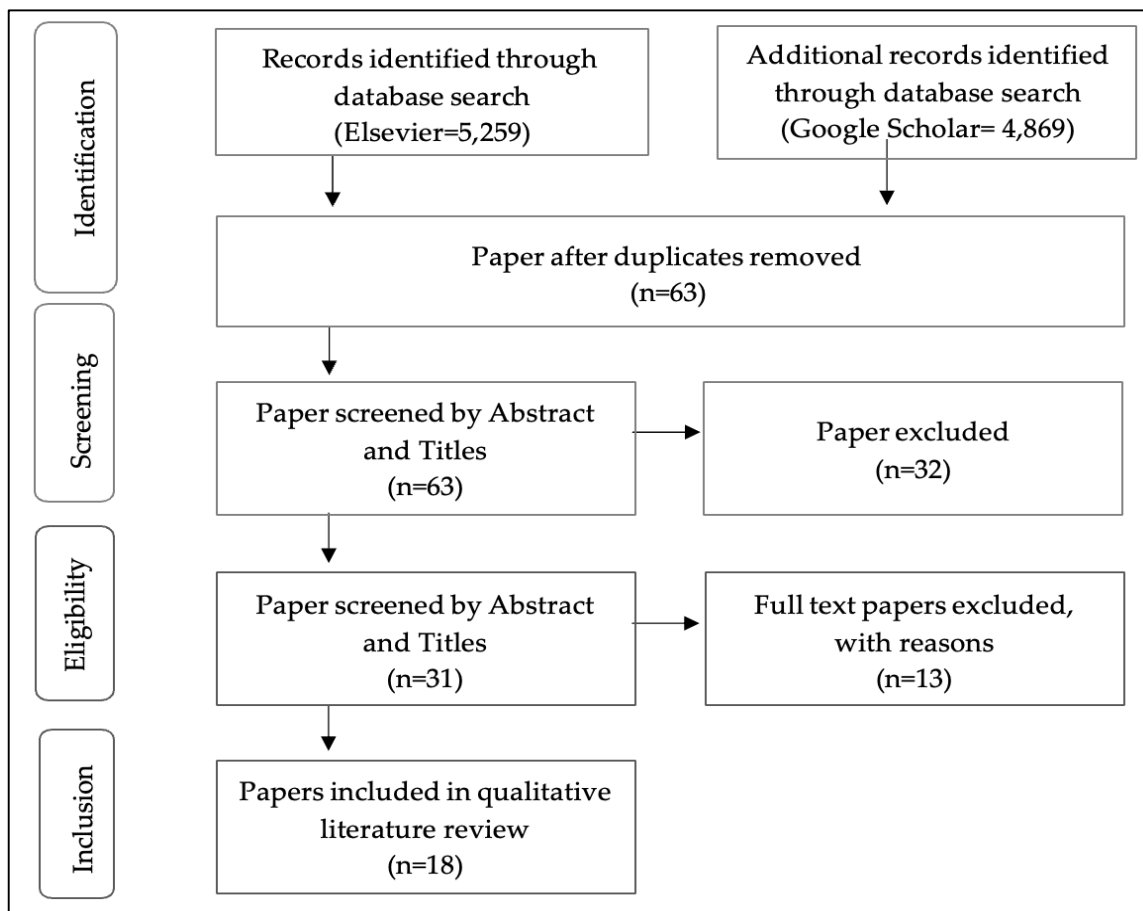


Figure 2. PRISMA methodology Flowchart

Source: UNC Health Science Library (2021). Creating a PRISMA flow diagram. Retrieved from <http://pubmed.ncbi.nlm.nih.gov/19631507/>

5. Findings and Discussion

5.1 Identification of the Area of Fireflies

The firefly stations were marked by using GNSS and then the coordinates were converted until it fit into the system to be mapped on ArcMap 10.3. Figure 3 shows the sampling stations of firefly which consists of 10 stations with different type of mangroves. Station 1 until 7 were covered by Berembang Trees (*Sonneratia caseolaris* sp.) while Station 8 and 9 were covered by Bakau Kurap (*Rhizophora apiculata*) and lastly Station 10 was covered by Bakau Minyak (*Rhizophora mucronata*).

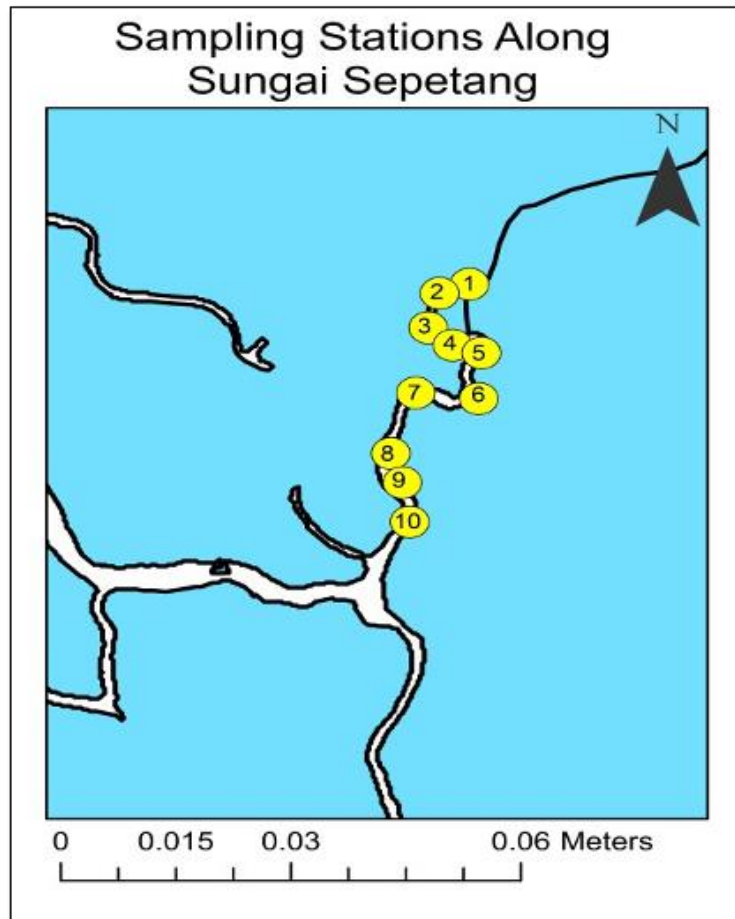


Figure 3. Sampling station along Sepetang River
 Source: Fuzi NFA, et al., 2023

5.2 Population of Firefly along Sepetang River

Figure 4 shows the scatter plot of the distribution of fireflies with the total number of fireflies. Station 6 shows the highest number among all stations as it peaks through the graph. Station 5 shows an increasing line as well as Station 6. However, the population seems to be increasing due to the parameters surrounding the mangrove habitats. Station 1,3, 8, 9 and 10 portray a steady line as the total number of fireflies are below 10,000.

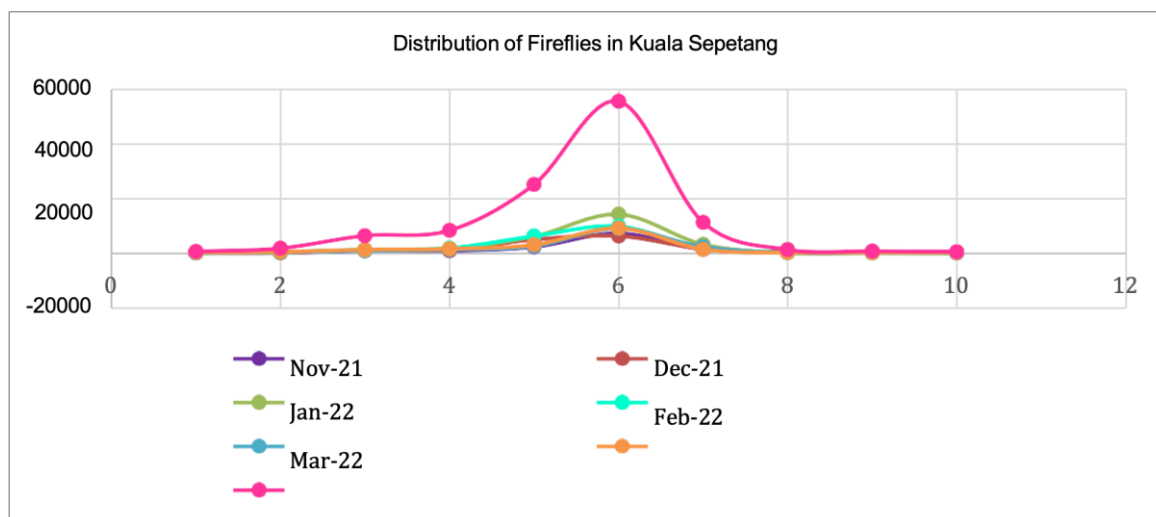


Figure 4. *Distribution of Fireflies in Kuala Sepetang*
Source: Fuzi NFA, et al., 2023

Table 1.

Distribution of Firefly Along Sepetang River

Station	STN 1	STN 2	STN 3	STN 4	STN 5	STN 6	STN 7	STN 8	STN 9	STN 10
Nov-21	72	114	799	831	2233	7250	1292	418	116	68
Dec-21	87	88	1101	1099	4952	6238	1510	319	182	55
Jan-22	118	327	1095	1642	6120	14238	3175	100	73	31
Feb-22	65	425	1244	1829	6207	9845	1666	200	121	99
Mar-22	70	336	901	1303	2573	9023	2260	109	105	113
Apr-22	190	458	1239	1574	3038	9125	1351	121	126	151
Total number of fireflies	602	1748	6379	8278	25123	55719	11254	1267	723	517

Source: Fuzi et al., 2023

The number of fireflies in Station 6 from Table 1 shows the highest number of fireflies in Sungai Sepetang with 55,719 fireflies were found altogether for the six months. Station 6 was categorized as the hotspot of the firefly by the local, tourists and the boatmen because of the density of the fireflies with the area itself because the Station 6 was surrounded by Berembang trees and located at the mouth bar and the flashing lights emitted from Station 6 was the brightest display trees due to its population of firefly. This was supported as the location of Station 6 was crowded by the amount of Berembang trees nearby.

5.3 Buffer Map for Firefly Population Along Sepetang River

Table 2.

Distance of Buffer and its land use types

Number of Buffer	Distance of Buffer (m)	Land Use Types
1	50	Land, Soil, Water, Wildlife Resources
2	100	Vegetation, Water, Land
3	150	Vegetation, Water, Land, Wildlife Resources, Soil

Source: Fuzi NFA, et al., 2023

Table 2 portray the table of buffer distance and its land use type along Sepetang River. There were 3 buffer distance which are 50m, 100m, and 150m. The buffer distance only revolves around the stations which covers around the surrounding of firefly habitats.

The "Firefly Forest Reserve" should include a buffer zone that is at least 50 meters long on both sides of the riverbank, as suggested by the earlier study by Nada et al. (2012). The buffer zone was characterized by little disturbance and was ideally composed of naturally occurring mangrove vegetation, specifically Bakau Kurap, Bakau Minyak, and Berembang trees. The preservation of firefly breeding habitats and the prevention of riverbank erosion depend heavily on these buffer zones. The Selangor River in Kuala Selangor, where oil palms are planted all the way up to the riverbank, has been shown to significantly accelerate erosion, corroborating this claim.

Figure 5 portrays the finding of this study with distance buffer of 50m, 100m, and 150m. The previous study has been recommended for the last decades and nowadays all the buffer zones along Sepetang River were still covered with the vegetations and the population of fireflies still significantly in normal distribution. As shown in the Figure 5, station 1 and 2 only situated nearby which is at 150m buffer zone. These two stations might undergo pollutions such as water pollution and light pollution. These are one of the reasons for the researchers to keep the preservation and conservation program going and GIS approach helps research to finalize it by making it into map. Station 6 was located at the mouth river, with a crowded number of mangrove trees and has been conserved for now.

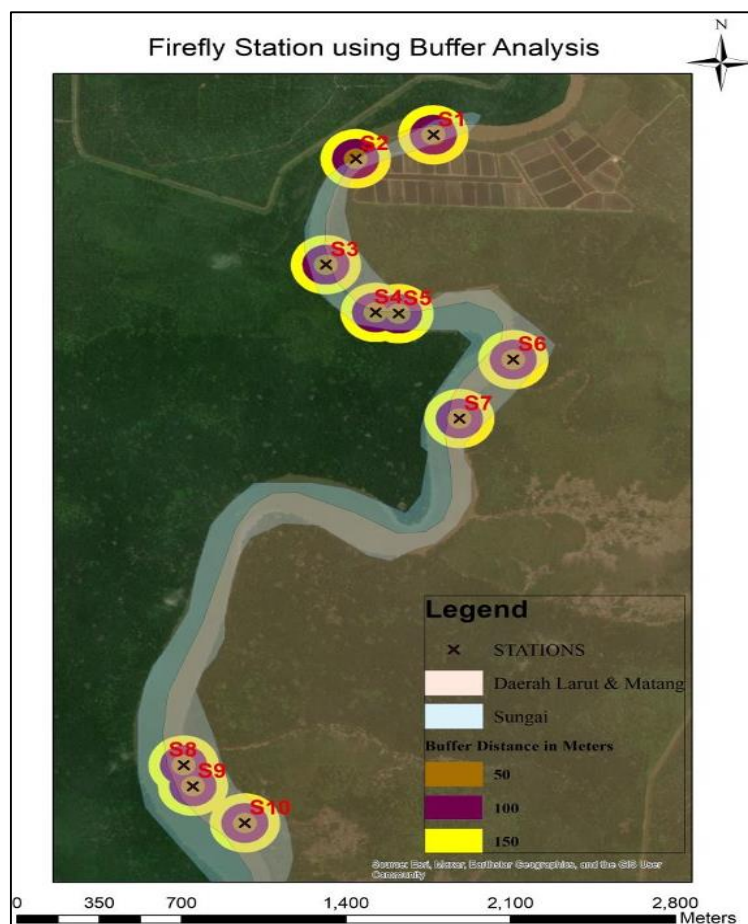


Figure 5. Firefly station using buffer analysis

Source: Fuzi NFA, et al., 2023

6. Conclusion

From this study, it has concluded that Berembang trees have become home to fireflies along Sepetang River. There has been a majority number of Berembang trees which is about 8 over 10 sampling stations. All things considered, Berembang tree is the dominant plant near Sungai Sepetang. *Pteroptyx tener's* range was concentrated around Berembang tree, a prominent species of mangrove vegetation. The largest concentration of fireflies is seen in Station 6, where their only habitat is Berembang. The most prevalent species of firefly is *Pteroptyx tener*. (Every sample returned to the lab was determined to be *Pteroptyx tener* sp.).

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