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Geographical Information System (GIS) Application Approach in the Study of Firefly Population Distribution Around the Sepetang River Area, Perak

Mohamad Alif Bin Zaidi, Azimah Abd Rahman

GeoInformatic Unit, Geography Section, School of Humanities, Universiti Sains Malaysia, 11800 USM, Pulau Pinang, Malaysia

Corresponding Author Email: azimahrahman@usm.my

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Abstract

This study investigates the relationship between environmental factors and firefly population in Sepetang River Area, Perak. Examining variables such as Relative Humidity, Air Temperature, pH levels, Conductivity, Salinity, and Total Dissolved Solids (TDS), the research sheds light on their influence on the distribution of fireflies, which is important for the development and conservation of ecotourism. In terms of methodology, Geographic Information System (GIS) techniques technology has been used to analyze data collected for six months, from November 2021 to April 2022, using Hotspot and Inverse Distance Weighted (IDW) techniques. Insights from secondary data sources and past studies, including the work of Izfa Riza & Sharifah Aliya in 2018, supplemented to the study. The investigation revealed significant variations in firefly population density across sampling stations. Station 6, situated in the river's middle, exhibited the highest density (34,070 fireflies), while Station 10 had the lowest (281 fireflies). These variations were influenced by environmental factors shaping firefly habitats. Water pH levels emerged as crucial determinants of habitat suitability, impacting population presence and abundance. Optimal environmental humidity conditions were found to support firefly reproduction and habitation. Additionally, TDS levels in water were identified as influential factors, affecting resource availability and habitat quality. Long-term studies of firefly population trends in response to environmental change and human intervention are suggested to inform effective conservation management and ecotourism in the region.

Keywords: Fireflies, Geographic Information System (GIS), Mangrove Forest, Ecotourism

Introduction

Fireflies are a small type of fauna known by their natural characteristic of emitting light from their abdomen. It is estimated that the general length of a firefly is 6mm. A firefly originates

from the larva or worm before it transforms into a firefly. Fireflies emit light before they become one, which is during the larva phase; it is also known as a light-emitting larva although it does not emit light as bright as that of a firefly. According to Barber (1951), the lighting from the firefly functions as a form of communication between gender, species, and the determination of the right location. For example, the male fireflies will fly at night while emitting their light to attract the female. This will draw some reaction from the female fireflies through the blinking of the light that produces certain patterns. With a structure similar to other winged insects, fireflies have been classified as a bug with a rather great weightage in the insect family. According to Zahradnik and Severa (1991), fireflies are a bug (Coleoptera) encompassing more than 2,000 species or about 40% of the Insecta class.

Fireflies can be found in various parts of the world, namely in Asia, Europe and America. Their habitat, located in both hot and humid areas are ideal locations for fireflies especially as a place for them to continue their life cycle. Fireflies often survive in humid areas such as at the river estuaries, lakes and swamps as they make tree branches their place of shelter. The firefly species including Pteroptyx spp., are often found gathered in a big colony on the trees or shrubs in the estuaries of the swamps, in humid tropical areas (Jusoh et al., 2010). Despite the fact that fireflies are easily located in various habitats, most of them depend on the swampy areas. The plants in swamps have leaves suitable as protection to the fireflies, and they also provide an environment that supplies ample food resources to the larvae. For instance, the swamp areas that have snails provide food resources especially to the larvae of the fireflies. Good protection and food resources play an important role to the survivability of the firefly species.

Today, Malaysia is increasingly known through its ecotourism activities due to the uniqueness of its nature. Ecotourism is a branch of tourism activities that focuses on the environment with the purpose of raising the awareness, and enjoying the natural features and characteristics including the cultural values, encouraging the conservation of the environment, and involving the locals in positive socio-economic endeavours (Ceballos-Lascurain, 1996). According to Balmford et al (2015), ecotourism is one of the economic segments that has the potential to expand in the tourism industry all over the world. The appeal, the uniqueness and the beauty of the fireflies have made several locations in Malaysia attractive to nature-loving visitors. This is evident through the firefly ecotourism activity in Sungai Sepetang, Perak; Kuala Nerus, Terengganu; Kampung Kuantan, Selangor and Sungai Rembau, Negeri Sembilan. Various activities are offered to tourists starting from the sunset to midnight, which include strolling and relaxing by getting on-board the boats to enjoy the beauty of the blinking lights of the fireflies on the mangroves by the river bank (Shahara et al., 2017). Activities like this are definitely memorable and become an unforgettable experience (Lewis, 2016). Apart from that, the activity of observing the fireflies indirectly enables one to get a sense of peace and to have a calm mind, especially among visitors coming from the city (Haugan, 2019). Other than gaining such a beautiful experience, this ecotourism activity is able to raise an awareness about the importance of conserving the sustainability of the biodiversity especially in mangrove areas. (Buckely et al., 2019).

Fireflies is one of the invaluable and highly potential sources of nature- they depend on the fauna conditions in the environment. Unfortunately, until today, the efforts to sustain the fauna around the mangrove forest are still in vain. Research related to this issue are also still very limited, especially where Malaysian studies are concerned. According to Nallakumar (2002), the habitat for the fireflies is more affected and threatened by human activities, or humans who are too greedy in planning and implementing development without concerning

about the impact to the environment. A lot of plants and damp lands suitable and important to the firefly habitat have been demolished and damaged. According to Wan Faridah et al. (2010), the firefly population is increasingly impacted due to the decreasing quality of the river water stemming from river pollution, the use of diesel by the industries and construction activities. The impact of this problem leads to the risk of extinction of the firefly species. This study is carried out to identify the distribution of the firefly population around the area of Sungai Sepetang. Immoral activities as such, that they have violated the nature's wellbeing, must be emphasised more by all the parties concerned. Thus, this study is conducted to identify if the population of fireflies in Sungai Sepetang is still well-distributed, or otherwise.

Study Methodology

Study Areas

This study is carried out around the Sepetang River area, which is a river located in the district of Taiping (Figure 1). A total of 10 study stations was used in this study to gather data related to the factors that influence the water quality in the study area (Table 1). The selection of the area is based on the information given by the firefly ecotourism entrepreneurs and the boat drivers who have the records of this fireflies' place of attraction.

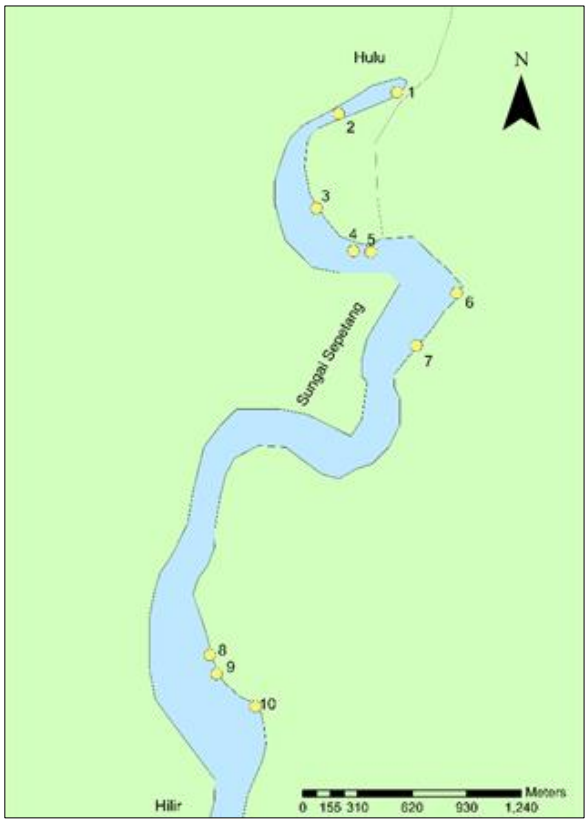

Figure 1. Study Area

Table 1
Study Station

Sampling Station	X	Y
S1	4.888062	100.6344
S2	4.886972	100.6314
S3	4.882146	100.6303
S4	4.879974	100.6322
S5	4.879918	100.633
S6	4.877828	100.6374
S7	4.875141	100.6354
S8	4.859359	100.6248
S9	4.858397	100.6252
S10	4.856724	100.6272

Conceptual Framework

This study is carried out based on the conceptual framework built, where this study adopts the GIS-system approach to display and analyse the existing data that have been gathered for the period of six months which is from November 2021 to April 2022 (Figure 2). This study identifies the difference of the firefly population distribution impacted by the factors or parameters of humidity, air temperature, water acidity level, water conductivity level, water salinity, and the Total Dissolved Solid (TDS) for ten (10) study stations. The water quality is focused in this study as the habitat of the firefly population concentrates on the mangrove forests that have a muddy environment and are close to the riverbank.

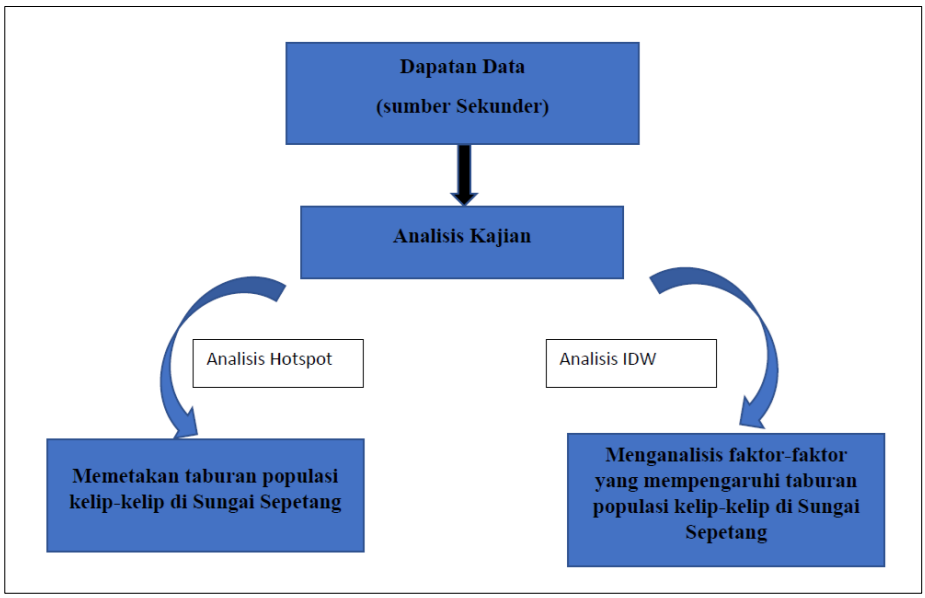

Figure 2. Conceptual framework

The Collection of Study Data

All in all, this study uses information from the secondary source. The information of the firefly population in Sungai Sepetang, Perak, Malaysia used in this study is obtained from the insights gathered from the previous scholars. The study was done in the period of six months, which

is from November 2021 to April 2022. Although the main data of the study have been obtained, researcher also made reference to a past study as the support materials to this current study, for instance by referring to the study by Izfa Riza & Sharifah Aliya in 2018 on fireflies and the aquaculture industry in Sungai Sepetang, Perak. The information obtained from these methods can be used as the basis and support in the study.

Spatial Analysis

The firefly population data will be used as data in the GIS analysis which is the Hotspot and Inverse Distance Weighted (IDW) analysis. The data analysis will be used to achieve the objectives and answer the study questions. The hotspot analysis is the spatial analysis and the mapping technique functioning to identify the clustering of the spatial phenomenon. This spatial phenomenon is depicted as a point in the map and refers to the event location or the object. This technique is used to identify the areas that have the highest firefly population density. Through this technique, the density of the fireflies can be classified according to the insights selected.

Next, the Inverse Distance Weighted (IDW) technique has been used. The function of this technique is to analyse the relationship of every factor on the distribution of the fireflies. The difference in the population distribution taking place in this area definitely has its cause, that renders the difference possible. There are several physical factors that influence the difference in the firefly population distribution in Sungai Sepetang. Among the physical factors analysed using the IDW technique are humidity, air temperature, water acidity level, water conductivity rate, water salinity, and Total Dissolved Solid (TDS). With this analysis technique, the question can be answered using the data findings and the information collected.

The Findings and Research Analysis

The Firefly Population Density Distribution

To study the firefly population distribution in Sungai Sepetang, researcher performed an analysis on the observational data (the total number of individuals found) of the fireflies along the river. The data were obtained from the notes or studies produced by previous observers. Thus, researcher used the existing data and information to analyse the distribution of the firefly population at Sungai Sepetang to determine the stations where the data would be collected. The observational value will then be divided into ten coordinates spread along Sungai Sepetang. The coordinates will be determined as the observation stations that function as the parameter in studying and analysing how the firefly population distribution takes place along Sungai Sepetang. In other words, the selection of these ten coordinates aims to represent the areas that represent all of the river and this gives a picture on the state of the firefly population in the area.

Figure 3 shows the hotspot analysis for the firefly population distribution at Sungai Sepetang using the average data throughout the entire six months gathered at the study site. For the first station, the total number of the fireflies recorded was 451. Meanwhile, the second station noted a total number of fireflies of 989, which means that the number of the fireflies in the second station exceeded that of the first station almost twice of the lower population which is 474.

However, the firefly population reached the lowest level at station 10 with only 281 fireflies. The station location, which is the closest to the upstream, is identified as the factor that gives the greatest influence to the drastic decrease in the number of the fireflies compared to the

middle of the stream. In other words, the more downstream the river, the lesser the population, and the geographical factors like the closeness to the upstream also contribute to this reduction.

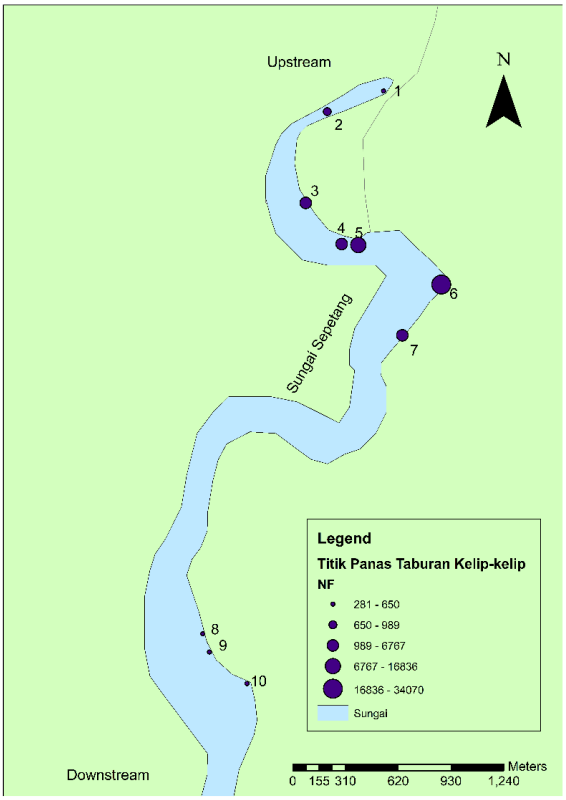

Figure 3. The Distribution of the Firefly Population for the Study Stations.

Table 2
The density of the firefly population by study station

Station	Total population
1	451
2	989
3	3908
4	4997
5	16836
6	34070
7	6767
8	650
9	474
10	281

Table 2 above shows the total population of fireflies at ten observational stations spread along Sungai Sepetang. The data was analysed from six-month worth of notes to understand the distribution and dynamics of the firefly population along the river. The total population of the fireflies at every station gives a striking difference, especially by considering the station locations in the context of the river areas- the upstream, midstream and the downstream.

The influence of the study parameter on the firefly population distribution

In the study of the firefly population distribution at Sungai Sepetang, Perak, the parameters tested have formed an important aspect in analysing the ecology of the fireflies in the area. Six major parameters namely humidity, air temperature, water acidity level, water conductivity rate, water salinity, and Total Dissolved Solid (TDS) have been considered in every observational station along the river. The use of the Inverse Distance Weighting (IDW) analysis has helped measure the influence of every parameter on the firefly population distribution.

The IDW analysis outcome shows the difference in the influence of every parameter in every study station. Humidity, as one of the parameters, gives a significant impact towards the firefly population distribution. Stations with high humidity show the tendency to be an appropriate habitat for fireflies, providing a good condition for breeding and food source. Figure 4 shows the percentage of humidity for every study station, giving the visual picture about the diversity of the environment along Sungai Sepetang. The finding outcome of this study offers an in-depth understanding about the impacts of certain parameters on the fireflies in an area. All in all, the understanding of the environmental factors has become fundamental to the firefly sustainability and preservation efforts in Sungai Sepetang.

Mantyka-Pringle et al. (2012), analysed data about the impact of the loss of the habitat on the biodiversity and the population of the species from 168 studies, gathered information on the climate for every study location, and used this information to test the interactive impact between the loss of habitat and the climate change rate and the impact of the climate on the biodiversity and species population. They discovered that the habitat loss carries a consistent negative impact on the diversity of species and the abundance of individuals for every species, and the negative impact is even more overwhelming in the hot climate. This demonstrates that the influence of the temperature on the ecology of a habitat is an issue in species population. Thus, high increase of the temperature is found to be able to give a bad impact to the fireflies. The fireflies require areas that have low and moderate temperatures as their habitats.

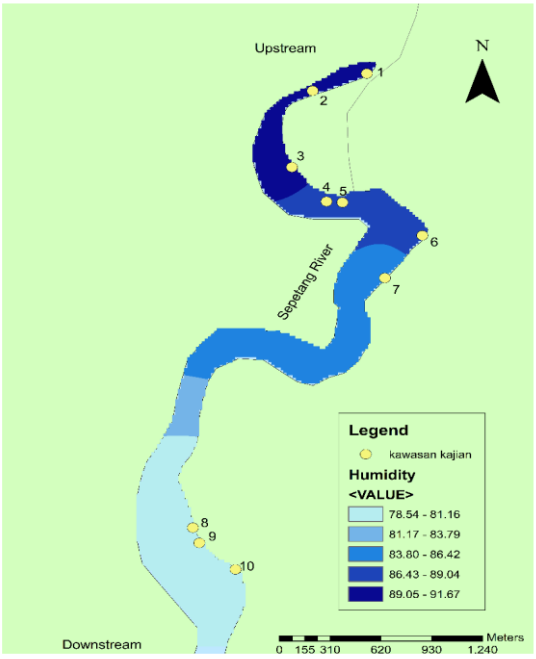

Figure 4. The impact of humidity on the firefly population

Air temperature is one of the factors that influences the selection of habitat for the fireflies. Low-significance air temperature becomes the habitat of choice for the fireflies. That said, the constantly changing temperature has proven to be an issue to the firefly habitat. This is evident from the climate change commonly taking place in not only Malaysia, but also all over the world. The climate change is the natural phenomenon that is also influenced by the anthropogenic activity especially the burning of fuels and change in land use as the major contributing factors to the greenhouse gas increase in the atmosphere. Fireflies are rather sensitive insects, vulnerable to the environment and easily exposed to threats, including polluted air as it gives an impact to the lighting. The change in the air temperature in Sungai Sepetang will indirectly influence the firefly population distribution. The IDW analysis carried out found that there were five levels of air temperature classified (Figure 5). The five levels of temperature in Sungai Sepetang were differentiated according to the different colour tones. Light tones would show a low air temperature whereas the bright tones would indicate a high temperature.

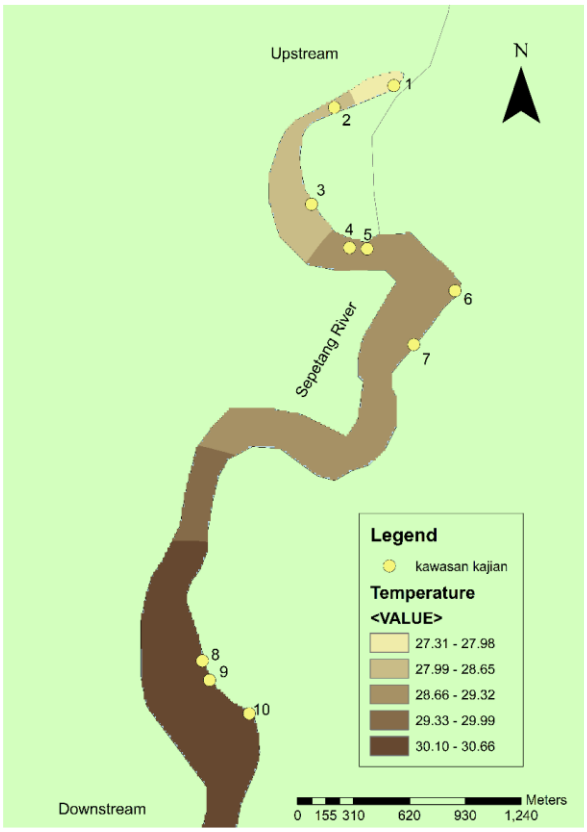

Figure 5. The impact of water temperature on the firefly distribution

Other than that, the water acidity or water pH is often the factor linked with marine life that depends on the water resource in total or serves merely as a requirement. The pH value is often measured at the scale of 0 to 14 where 7.0 is neutral. The value less than 7.0 is acidic whereas the value more than 7.0 is alkaline. Through the IDW analysis, the mapping outcome for the water acidity effect in areas in Kuala Sepetang is shown in Figure 6.

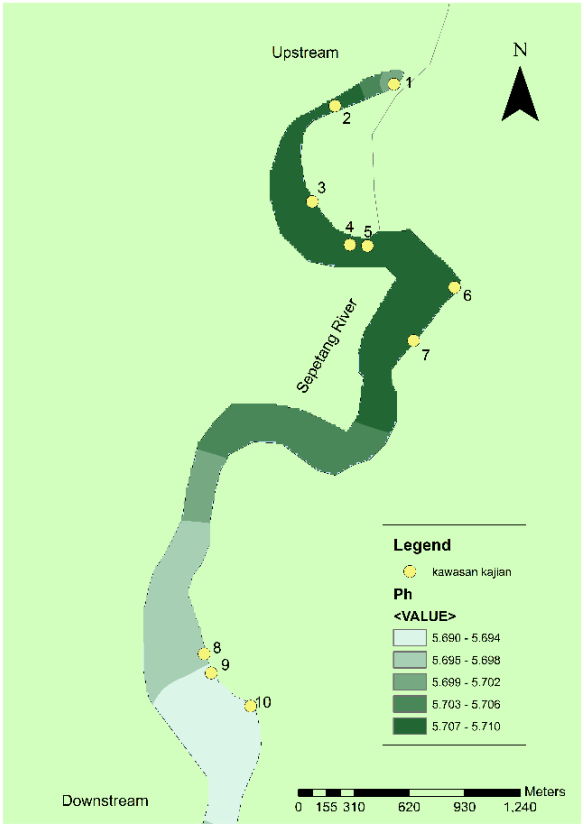

Figure 6: The Water Acidity or Water Ph of The River on The Firefly Distribution

In this study, the flow conductivity of Sungai Sepetang was also analysed. The measurement of conductivity has been used routinely in many industrial and environmental applications as it is fast, cheap and reliable in measuring the ionic content in the solution. The state of water flow conductivity in Sungai Sepetang is analysed and reported in Figure 7.

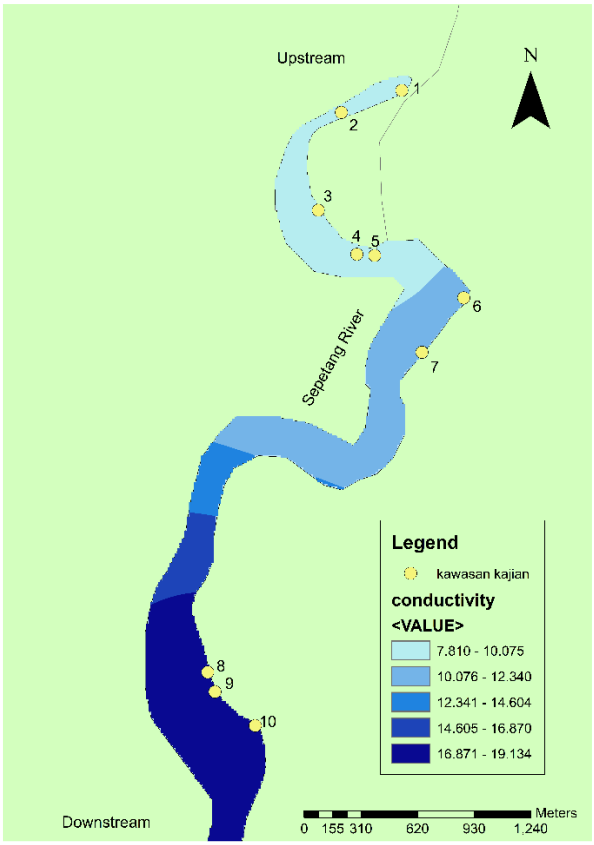

Figure 7. The State of Conductivity in Sungai Sepetang

This study also analysed the effect of the water salinity percentage which is one of the elements that influences the water quality which also affects humans and other living beings. The salinity of the river is often linked with the salt water coming in from the upstream that automatically disturbs the water's physical, chemical and biological balance. Despite the fact that Sungai Sepetang is not close to the upstream area, the percentage of water salinity needs to be considered in determining the water quality in this area. For example, Sungai Sepetang connects with Sungai Sangga Besar close to the upstream. This shows that there is a possibility of change and disturbance to the water salinity in Sungai Sepetang as the result of the change in the river close by. The analysis shows that there is a difference in the percentage of water salinity in every station of the study (Figure 8).

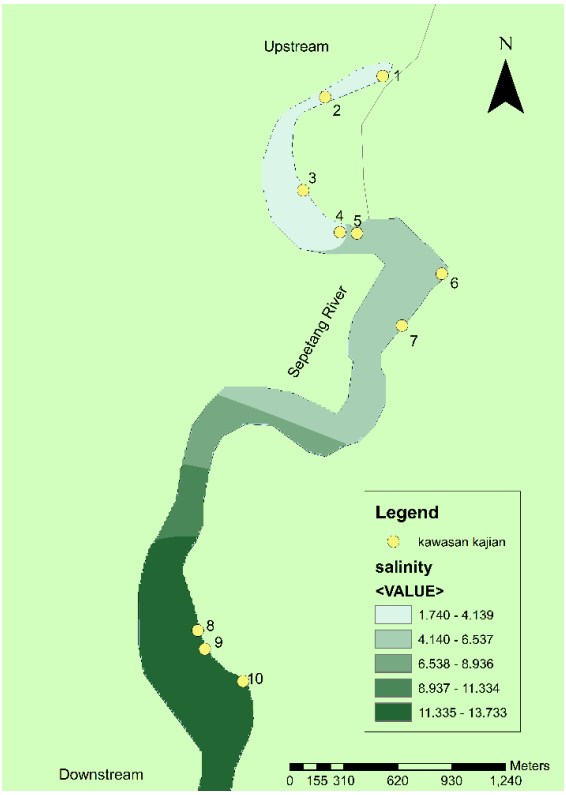

Figure 8. The Difference of The Water Salinity Along Sungai Sepetang

Total Dissolved Solids (TDS) involves finding out about the mineral dissolved in the water in the study areas. TDS combines certain mineral components such as calcium, magnesium, kalium, natrium, bicarbonate, chloride, and sulphate. This mineral content should stay balanced to ensure that the life of aquatic species is sustained. The change to the TDS will lead to the disturbance to the flora and fauna living in the mangrove areas such as the fireflies. Other than that, the level of TDS analysed can be related to the water pollution that is evident through the water's murkiness or clarity in any given area. High level of TDS will change the taste of the water such as bitter, salty or brackish. Although this is not affecting humans, the increase of the TDS will bring negative impacts to the aquatic species that fully depend on the water resource. In a body of water like the river, the higher amount of dissolved solids is often dangerous to the aquatic species. TDS alters the content of the water mineral vital to the sustainability of many animals. For instance, dissolved salt can dry up the skin of the aquatic animals, and this can even be fatal. It can increase the water temperature, causing disturbance to various species that make the water their habitat. This also indirectly affects the population rate of the fireflies, that also depend on clean and good water resource in its environment. The IDW analysis outcome done on the effect of the TDS for every station is shown in Figure 9.

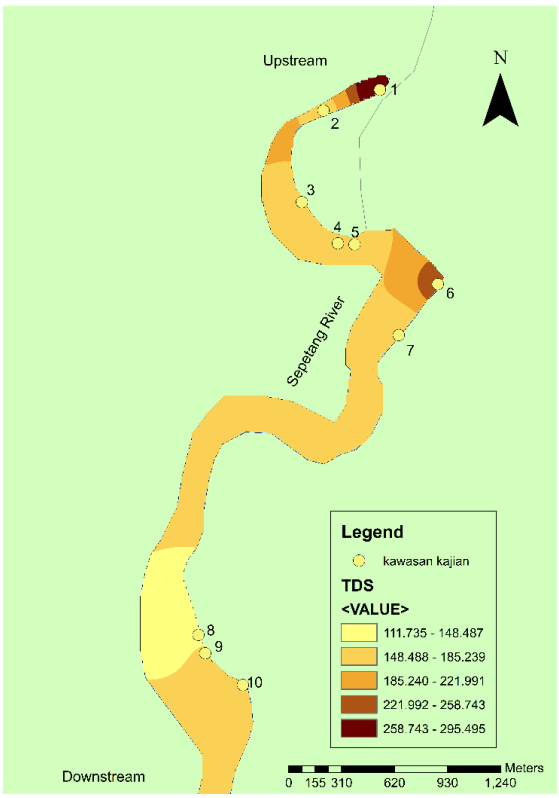

Figure 9. The effect of Total Dissolved Solids (TDS) by the study station

All in all, the analysis outcome shows the highest firefly population for areas with the humidity of 86% to 89% and the lowest population when the humidity was 78% to 81%. Also, the population density increased at the temperature of 28◦C to 29◦C and the population decreased at the temperature of 30◦C to 31◦C. The population density is also influenced by the water acidity or pH where the firefly population increased from Ph 5.702 to 5.706 and gradually decreasing from Ph 5.69 to 5.694. Other than that, conductivity also influences the condition of the population, whereby the population increased at the water conductivity from 10.074 to 12.339 and decreased from 16.869 to 19.134. The water salinity also influences the density of the population where the density increased at the salinity from 4.137 to 6.536 and decreased from the salinity from 11.334 to 13.733. The density of the population is also influenced by the TDS (Total dissolved solids) of the water in the study area. The population increased at the value of TDS 222.864 to 259.976 and decreased at 148.64 to 185.752.

Discussion

The Analysis of Factors that Influence The firefly Population Distribution in Sungai Sepetang

Air Humidity

In examining the firefly population distribution in Sungai Sepetang, the discussion about the influencing factors necessitates a clear emphasis. This analysis debates on the elements that have an important role in determining the presence and diversity of fireflies along the river. Several main factors including the humidity, air temperature, water acidity level, water conductivity rate, water salinity and the Total Dissolved Solid (TDS).

Humidity is identified as the main factor that plays a significant role in the firefly population distribution in Sungai Sepetang. The determination of the habitat is often linked with the state of the humidity in the area (Nak-Eiam, 2015). High humidity in the environment gives the

fireflies an optimal condition to spread and to find food sources. The importance of humidity in the life of the fireflies marks the fact that the environment with sufficient humidity can be regarded as the suitable habitat to ensure the sustainability of the species (Chaiwongsaen et al., 2022). This habitat provides the supporting condition for breeding activity, and prepares the food source needed by the fireflies.

The analysis about the percentage of humidity in three different stations along the river shows a remarkable difference. The following is the analysis for every station. The first area is the upstream (Station 1, 2, and 3). The high percentage of humidity, between 89.05% and 91.67%, in the upstream can be linked with the river's physical characteristics in the area. The upstream is the source of the water, making high humidity a natural characteristic here. The optimum humidity in this area creates a suitable habitat for the fireflies to breed.

The midstream is stations 4,5 and 6. The percentage of humidity in the midstream is at the second level, which was between 86.43% and 89.04%. This reduced humidity may be caused by the fact that this station is located in the middle of the river. Factors like water flow and the exposure to external elements may cause the reduction in the humidity. However, this area still offers a good condition for the firefly population.

The downstream is represented by station 7, 8, 9, and 10. The downstream shows the lowest humidity percentage, which was between 78.54% and 81.16%. The stations in this area are in the bright tone, indicating that there is lower humidity. This may be explained by the closer distance with the river mouth, and the influence from the drier surrounding areas. The downstream is prone to illustrate a less favourable condition for the firefly population. As a whole, the humidity analysis reviews the significant change in the condition of the habitat along Sungai Sepetang. Humidity is the critical factor in ascertaining the quality habitat for the fireflies, and this understanding can help in the river ecosystem's conservation and maintenance efforts.

This study is consistent with the study by Mobilim and Mahadimenakbar (2020) where their data shows that the fireflies, regardless of their life stage (male, female or larva), can be typically found in the environment with almost similar temperature and humidity levels and their change is not very striking. The male fireflies can be observed in the area with the average temperature 27.13 ± 0.32 °C and high humidity, 95.23 ± 2.11%. Similarly, the female can be found in the locations with the average temperature 26.97 ± 0.7 °C and the humidity 97.19 ± 2.34%, whereas the larva was present in the area with the average temperature 26.87 ± 0.32 °C and the humidity 98.18 ± 2.21%. The uniformity of the temperature and the humidity in all stages of their life shows that this supports the presence of the fireflies in certain habitats. During the evening, where the humidity is high and the air is cold, this creates an ideal situation for the fireflies' activity at night. This supports the many aspects of their life cycle, including breeding and the stunning light display that serve as the fireflies' special characteristic during their night activity (Goh et al., 2022).

Air Temperature

Air temperature is an important factor that influences the selection of the fireflies' habitat. Low air temperature significantly becomes the main choice for the fireflies when they find places to be their habitat. Despite this, the constantly-changing air temperature has become a challenge to the fireflies' habitat. This can be seen through the climate change phenomenon not only reported in Malaysia, but also in other countries of the world. (Tang, 2019).

The climate change causing the variation in the brings a great impact to the firefly population (Lewis et al., 2020; Fallon et al., 2021). Air pollution, or in specific, the exacerbating haze

pollution gives a significant negative effect in this context. Today, although we cannot be certain if the haze is equally detrimental to the insects, there is a high possibility that at high level, it can also cause discomfort or toxicity to the adult fireflies (Nada et al., 2012). This has affected the habitat and the breeding process of the fireflies. Fireflies are insects that are sensitive to the environment and are easily threatened by elements such as polluted air, as the elements can influence the clarity of the lighting. This is due to the fact that the mating activity of the fireflies is driven by the reduced intensity of the light (Lloyd, 2006).

From the IDW analysis, it is found that there are five stages of the air temperature classified in the analysis. The five stages of the air temperature in Sungai Sepetang are differentiated according to the different colour tones. The light tones reflect the low air temperature, whereas the bright tones show high temperature. Thus, from Figure 5 above, the difference of the air temperature in Sungai Sepetang can be identified at random through the map display.

The observation station with the lowest air temperature is the observation station 1. Only station 1 was placed in the lowest zone, which is the brightest colour tone. The air temperature recorded for this zone was between 27.31°C and 27.98°C. Additionally, this area sustains the high natural sustainability level compared to other parts of the river, like the downstream affected by human intervention. Station 2 and 3 showed an increase of temperature compared to station 1. Although both stations are also located downstream, the air temperature is slightly higher and included in the slightly brighter colour tone, with the air temperature between 27.99°C and 28.65°C.

The zone in the third colour tone represents the river area with the air temperature between 28.66°C and 29.32°C. This zone is the area with the largest number of observation stations. In this colour zone, four stations were analysed and they had air temperature within the range, namely station 4, 5, 6, and 7. The stations with the highest air temperature in this analysis were station 8, 9, and 10. Located downstream, these stations had air temperature between 30.10°C and 30.66°C. Based on the map, the temperature pattern shows that the fireflies in this study may be inclined to go to areas with low to moderate temperature, especially downstream known for its preserved natural characteristics. The study by Evan et al. (2019) provided evidence that the weather variable gives an impact to the abundance of fireflies during the early development which is more than 12 months prior to the observation. The maximum temperature before the observation produced lower abundance of fireflies.

Water Acidity Level (pH)

Water acidity or pH is the factor that is often linked with marine life that depends on the water resource, either comprehensively or only to cater for certain requirements or needs. The pH parameter measurement is a method used to determine the acidity or alkalinity of a water sample based on the hydrogen ion concentration (Metcalf & Eddy et al., 2003). The pH value is measured from the scale of 0 to 14, where the value of 7.0 is considered neutral. The value less than 7.0 shows the acidity trait, while the value more than 7.0 highlights alkaline trait.

The water pH value of Sungai Sepetang shows the acidity variation that is divided into five zones with different colour tones. The light colour tones reflect higher acidity, or low water pH, whereas darker colour tones show higher water pH value. In this study, the water acidity analysed is still in its normal level, which is in the range from pH 5 to pH 6. Observation station 1 is found to have a moderate acidity level, with the moderately dark colour tone showing the water pH to be between 5.699 and 5.702. Although this observation station is located

upstream, the water acidity for this station is slightly higher compared to other stations in this part of the river.
The majority of the stations in this study are in the darkest colour tones, which is the part of the river that shows the lowest acidity level in the analysis. Station 2 to 7 were in the pH class of 5.707 to 5.710. The acidity decreased from upstream to the midstream. Thus, most of the stations in this area highlighted high number of firefly population, including the station with the highest firefly population observed. Station 8 was in the slightly lighter colour tone, which is the second highest acidity, with the pH between 5.695 and 5.698. Downstream, the final stations, which is station 8 dan 9, had the highest acidity level, between pH 5.690 and 5.694. The two main parameters, water pH and dissolved oxygen (DO.), are emphasised as the water quality indicators and there is a potential relationship between the water quality parameters and the reduction in the firefly population. The larva of the fireflies, which is the non-mature stage of the fireflies, feeds on the river snails. If the water quality is unsuitable for the snails caused by factors such as low pH and low dissolved oxygen, it can indirectly affect the food source of the larva. Thus, the unsuitability of the water condition for aquatic life, especially the river snails, can contribute to the decreasing number of the firefly population (Mahadimenakbar et al., 2018).
The study finding shows that there is a significant difference in the water acidity between the upstream and the downstream. The upstream shows lower water acidity, whereas the downstream shows higher water acidity. This difference may be related to the level of water cleanliness or hygiene in both parts of the river. In general, human activity is more intensive in the upstream, and human actions can harm the water quality of the river. For example, the use of pesticides in agriculture close to the river can lead to the flow of toxic into the river through the surface runoff and subsurface flow. This is consistent with the past studies showing that there is a statistically significant correlation between the abundance of the fireflies and the pH level in Sungai Rembau. The correlation coefficient (r) is reported as 0.408, and the p value is less than 0.05, showing that the correlation is significant statistically. This statement also suggests that the firefly population in Sungai Rembau is sensitive to the organic compound, that may exist in the form of pollutant due to human activity close to their natural habitat. This sensitivity stresses on the ecological impact from anthropogenic factors on the firefly population, reviewing the importance of observation and the reaction on the environmental pollution that ensures the wellbeing of this sensitive insect population (Abdullah et al., 2021).

Conductivity Rate (µs/cm)

The water conductivity of Sungai Sepetang is divided into five parts based on the conductivity value for every observation station, with every section being represented by different colour tones. The lowest conductivity is represented by the lightest colour tone, and the colour tone will become increasingly darker as the water conductivity increases. Although there are five conductivity classes distinguished, only three classes of conductivity involve the observation stations for this study.
The IDW analysis outcome carried out shows that the lightest colour zone, which is the lowest water conductivity with the conductivity rate between 7.810-10.075 µs/cm, is in the upstream area and some covers the middle part of the river. Five observation stations are found in this zone, which is station 1 to 5. The outcome highlights that the lowest water conductivity rate is the zone with the most observation stations. Low water conductivity shows that the firefly population is quite well conserved in this area; as evidence, the firefly population observed in

station 5 was 16836. This total population is among the population that is the highest among all the ten observation stations.
Nonetheless, although all the five stations note an encouraging population observation on the low water conductivity factor, there are still stations reporting a higher number of firefly population. Station 6 and 7 are found to be in the second colour tone or conductivity class with the water conductivity 10.076-12.340 µs/cm. although they are in the area with slightly higher water conductivity than the first area, station 6 is the station with the highest number of firefly population which is 34070.
For the area with the highest water conductivity, which is the darkest colour tone, there are three stations found in the area. Station 8, 9, and 10 were the observation stations in the highest conductivity class, which is 16.871-19.134 µs/cm. Being downstream, the observation stations in this area generally have the lowest firefly population in the study. The study outcome shows that the water conductivity in both downstream and upstream is different. The upstream is the area with the lowest water conductivity, and vice versa.
Only one study has been found to examine the relationship between water conductivity and the firefly population. The study carried out by Shahara et al (2017) shows the relationship between conductivity and the major abiotic factors (namely temperature, relative humidity, wind speed, water salinity, fully dissolved solids, and conductivity) and fireflies PCE on both river banks, where the relationship is very weak and insignificant. As the study had concentrated on the fireflies in Sungai Bernam and not Sungai Sepetang, it is inconclusive that the relationship between the fireflies in Sungai Sepetang is similar to those in Sungai Bernam. It is important to understand that every different location may point to different adaptations or requirements for the firefly species.

Water salinity percentage (%)
The water salinity content is also analysed according to five different tones, where every colour tone represents the classes of water salinity percentage. The lowest salinity percentage class is linked with the river zone that has the lightest colour tone. The increase in the water salinity percentage is followed by the increased colour intensity of the river basin. From the upstream, four observation stations are found to be in lowest class of the water salinity percentage. This class, interpreted as the brightest colour tone, shows that the water salinity percentage centred around 1.740% to 4.139%. Station 1 to 4 were included in this category.
For the second class of the salinity percentage, the affected river area involved a wider area compared to the first class. Through the map provided, it seems that the slightly brighter colour tone involved the midstream and covered three stations which is Station 5, 6, and 7, with the water salinity percentage between 4.140% and 5.537%. The area with the highest water salinity percentage was located downstream. In this area, the colour tone used was the darkest, representing the water salinity percentage between 11.335% and 13.733%. The final three stations, Station 8, 9, and 10 were included in this category. This area shows that the station with the lowest firefly population, Station 10, with only 281 fireflies, was the station with the least number of the population. This observation shows the reverse relationship between the salinity percentage and the number of fireflies. For example, although the salinity percentage in Station 10 was the highest (13.735%), the total number of the fireflies was the lowest. Thus, it can be concluded that the water salinity percentage influences the firefly population in this context. Other than that, the water salinity (NaCl) can change the land where the fireflies lay eggs and hatch as larva (Abdullah et al., 2019). In Sungai

Rembau, Malaysia, the water salinity shows the slightly negative relationship with the abundance of fireflies in terms of the space and time. The firefly population in this area reached the optimum water salinity level, which reached its peak on January 2018 to March 2018 and from June 2018 to August 2018. In line with this occurrence, the firefly population also reached its peak in the upstream (Asri et al., 2021).

Total Dissolved Solids (ppm)

The IDW analysis carried out classifies the TDS outcome into five classes, from low to high. The map produced, as seen in Figure 9, demonstrates the TDS outcome with a variation of colour tones, from light to dark, suitable with the increase of the TDS classes. Station 1 in the observation analysis was in the area with the darkest colour tone. Thus, the TDS value for station 1 was the highest, which was in the TDS class of 258.743 – 295.295 ppm.

In the upstream, station 2 and 3 were located in the area with lighter second colour tone. The level of TDS in this station was lower compared to station 1 previously, with TDS in the class of 148.488 – 185.239 ppm. This low TDS class was not only limited to station 2 and 3, but also involving other stations. Station 4, 5, and 7 in the middle of the river, as well as station 9 and 10 downstream, also showed a lighter second colour tone in the IDW analysis. The area with the TDS class in this colour tone was also the widest area in Sungai Sepetang, with more than half of the river showing the colour tone.

Only the downstream area, involving station 8, showed the analysis outcome in the lightest colour tone. With the class of TDS 111.735 – 148.487 ppm, this station showed a better water quality compared to others in terms of the content of the of the dissolved solids. Not much is known about TDS and its relationship with the fireflies. To date, only one study was done by Shahara et al. (2017) who discovered that the Firefly Percentage Cover Estimation (PCE) on both river banks (left and right) in Sungai Bernam, Selangor, Malaysia, has a weak association and is insignificant with the TDS.

Conclusion

The analysis on the air humidity, air temperature, water acidity level (pH), conductivity rate, water salinity percentage, and total dissolved solids (TDS) in three areas of the river, (upstream, midstream, downstream) Sungai Sepetang shows a striking difference. High humidity, low temperature, and water acidity give an optimal condition for the fireflies' breeding and food hunting. The change in these factors exerts a significant impact to the habitat and the firefly population. In general, the upstream is more prone to show a better environmental condition with low water conductivity and low water salinity percentage, which is appropriate for high population of fireflies. Conversely, the downstream shows the reduced quality of the water, may be due to the human activity in the upstream area. Conclusively, a profound understanding on the environmental factors and the water quality is vital for the maintenance and conservation of the river's ecosystem, specifically for the conservation of the firefly population. This analysis offers a comprehensive outlook on the factors that influence the success and sustainability of the fireflies in Sungai Sepetang, as well as gives a platform for further maintenance and conservation actions.

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