PLANT ASSOCIATION OF FIREFLY LARVAE (COLEOPTERA: LAMPYRIDAE) IN TUMPAT MANGROVE, KELANTAN

by

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DECLARATION

I declare that this thesis entitled "Plant Association of Firefly Larvae (Coleoptera: Lampyridae) in Tumpat Mangrove, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Plant Association of Firefly Larvae (Coleoptera: Lampyridae) in Tumpat Mangrove, Kelantan

ABSTRACT

This study investigates the plant associations of firefly larvae (Coleoptera: Lampyridae) in the mangrove ecosystem of Tumpat, Kelantan. Fireflies are important bioindicators of environmental health, yet little is known about their larval ecology, especially regarding habitat and associations plant preferences. The study aimed to identify plant species associated with firefly larvae and adult display plants through field sampling using sweep nets and forceps within designated mangrove plots. Data on larval abundance relative to associations plants were analyzed along with environmental parameters such as water pH and temperature. The study found that firefly larvae predominantly associate with three mangrove plant species *Volkameria inermis*, *Acanthus ilicifolius* and *Acrostichum aureum* with *Volkameria inermis* having the highest relative larval abundance. Adult fireflies mainly utilized *Sonneratia caseolaris* as display plants. These findings highlight the ecological specificity of firefly larvae to certain low-elevation host plants, emphasizing the importance of these plants in sustaining firefly populations. The results provide valuable baseline data for conservation management of fireflies and their mangrove habitats, underlining the need to protect and restore critical plant species to maintain ecosystem health and biodiversity in Malaysian coastal regions.

Asosiasi Tumbuhan dengan Larva Kelip-Kelip (Coleoptera: Lampyridae) di Paya Bakau Tumpat, Kelantan

ABSTRAK

Kajian ini mengkaji asosiasi tumbuhan dengan larva kunang-kunang (Coleoptera: Lampyridae) dalam ekosistem paya bakau di Tumpat, Kelantan. Kunang-kunang merupakan bioindikator penting alam sekitar, namun maklumat tentang ekologi larva mereka, khususnya habitat dan tumbuhan asosiasi, masih terhad. Kajian ini bertujuan mengenal pasti spesies tumbuhan yang dikaitkan dengan larva serta tumbuhan paparan kunang-kunang dewasa melalui pensampelan menggunakan jaring sapuan dan forsep dalam plot bakau terpilih. Data kelimpahan larva mengikut tumbuhan dianalisis bersama parameter persekitaran seperti pH dan suhu air. Hasil menunjukkan larva kunang-kunang banyak dikaitkan dengan tiga spesies: *Volkameria inermis*, *Acanthus ilicifolius* dan *Acrostichum aureum*, dengan *Volkameria inermis* mencatat kelimpahan relatif tertinggi. Kunang-kunang dewasa pula menggunakan *Sonneratia caseolaris* sebagai tumbuhan paparan. Penemuan ini menunjukkan kekhususan ekologi larva terhadap tumbuhan asosiasi tertentu, menekankan peranan tumbuhan ini dalam menyokong populasi kunang-kunang. Dapatan kajian memberi asas data penting untuk pengurusan pemuliharaan kunang-kunang dan habitat bakau serta kepentingan melindungi spesies tumbuhan utama bagi menjamin kesihatan ekosistem dan biodiversiti di kawasan pantai Malaysia.

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LIST OF ABBREVIATIONS

AP	Associated Plants
DP	Display Plants
spp.	Species Plural

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Fireflies belong to the beetle family known as Lampyridae. They consist of ten subfamilies, encompassing approximately 2200 species documented globally (Martin et al., 2019), including nonluminous adults, flightless female fireflies, and lightning bugs, whose remarkable bioluminescent displays render them among the most intriguing insects on the planet (Muhammad et al., 2022). Taking into account the existing variety of firefly species, their fossil evidence is limited, with only eight taxa represented in four subfamilies: Luciolinae, Ototretinae, Lamprohizinae, and Lampyrinae (Roza et al., 2024). They are categorized into aquatic, semi-aquatic, and terrestrial lineages based on their larval habitat (Yang et al., 2024). Fireflies are commonly linked to intact land ecosystems, ranging from temperate woodlands to deserts and wetlands (Fallon et al., 2021).

Fireflies rely on various plants for different needs during their lifecycle stages. For instance, display plants (DPs) provide an appropriate setting for courtship signaling, while certain vegetation elements also serve as locations for mating, egg-laying, larval growth, and more (Ghosh et al., 2023). Larvae feed on numerous small invertebrates, including pests, and constitute the main feeding phase of the lampyrid life cycle. Consequently, firefly larvae hold ecological and economic significance due to their ability to control invertebrate prey populations in both natural and agricultural ecosystems (Mbugua et al., 2020). The newly hatched larvae will consume the

mangrove snail (*Cyclotropis carinata*) (Nallakumar, 2003). If these snails are absent in the region, the larvae will consume any snail species they can find. Finally, the larvae get ready for pupation by creating a dirty area in the soil, where they will stay for six to ten days before emerging as adult fireflies (Nallakumar, 2003)

In Malaysia, especially in mangrove ecosystems, species belonging to the genus Pteroptyx are recognized for their tendency to gather and flash in large groups (Bernard et al., 2023). These fireflies are intimately linked to particular mangrove tree species, which act as locations for adult displays and environments for larvae (Foo & M. Dawood, 2017). Fireflies are drawn to inhabit Berembang trees that grow in the muddy intertidal areas along the riverbank (Izfa Riza Hazmi & Syed, 2018). Likewise, in Sabah's Klias Peninsula, fireflies gather on different mangrove species such as *Excoecaria indica*, *Hibiscus tiliaceus*, *Nypa fruticans*, *Rhizophora apiculata*, *Avicennia alba*, and *Sonneratia alba* (Foo & M. Dawood, 2017).

This study aims to explore the associated plant relationships of firefly larvae (Coleoptera: Lampyridae) in the mangrove ecosystem of Tumpat, Kelantan, emphasizing the identification of particular plant species that provide essential microhabitats for larval growth. Firefly larvae are recognized for their habitat specificity, and their survival is deeply connected to the ecological traits of the vegetation surrounding them. Through comprehensive field observations and analysis of samples, this study seeks to reveal the connections between firefly larvae and their favored host plants, illuminating the crucial botanical elements that sustain different phases of their life cycle.

Grasping these connections is essential not only for understanding the ecological requirements of fireflies but also for directing effective conservation efforts,

especially with the rising habitat fragmentation and environmental shifts impacting Malaysia's mangrove forests. The results of this research aim to offer important insights into the habitat preferences of firefly larvae and aid in the larger initiatives of conserving firefly populations via habitat management and safeguarding vital plant species in their natural habitats.

1.2 Problem Statement

Fireflies (Coleoptera: Lampyridae) are charming bioindicators of thriving ecosystems, especially in mangrove habitats where they play a role in ecological equilibrium and draw ecotourism attention. The connection of adult fireflies with particular plant species like *Sonneratia caseolaris* mangrove trees, known for low salt tolerance, is well established (Lewis et al., 2020). Although adult fireflies have been extensively researched—particularly regarding their mating signals and habitat choices—there is notably less information available on their larval ecology, with scant literature covering the larval stages of most species in contrast to adults (Riley et al., 2021). A considerable knowledge gap still exists concerning the habitat choices and host plant relationships of firefly larvae. Fireflies (Coleoptera: Lampyridae) are well-known insects recognized for their bioluminescence and have become important as bioindicators of environmental well-being because of their sensitivity to habitat disruptions and contaminants (Lewis et al., 2020).

Therefore, this study seeks to explore the associated plant relationships of firefly larvae within the Tumpat mangrove environment. The larval stage is crucial for understanding the species' survival strategies, and habitat requirements to identify the host plants associated with firefly larvae. This lack of information hinders conservation initiatives, particularly as threats from habitat destruction, pollution, and coastal development continue to rise. Consequently, examining the associated plant connections of firefly larvae in this area is crucial for guiding conservation efforts and preserving the ecological health of the mangrove ecosystem

1.3 Objective

- To assess the plant species associated with the occurrence of firefly larvae in the Tumpat mangrove ecosystem.

1.4 Scope of Study

This study aims to explore the relationship between firefly larvae (Coleoptera: Lampyridae) and their associated plants in the mangrove ecosystem of Tumpat, Kelantan. The study aims to identify plant species associated to the occurrence of firefly larvae. Along with larval associated plants, the research further documents plant species utilized by adult fireflies as display plants, including trees or shrubs where these insects engage in bioluminescent courtship displays during the night. The research zone is limited to specific parts of the Tumpat mangrove forest where firefly populations have been noted, and data gathering occurs during the peak activity phase to capture both larval and adult stages.

The study explored the relative abundance of the total count of larvae present on each associated plant species and the elevation range (measured in meters) where these fireflies are found. This study seeks to uncover how differences in elevation within the mangrove habitat affect larval abundance and associated plant choice, offering understanding of microhabitat specialization and ecological roles filled by fireflies in this distinctive coastal ecosystem.

Taxonomically, the study concentrates on the Lampyridae family, specifically examining the larval and adult forms of fireflies while omitting other bioluminescent insects like click beetles (Elateridae).

Furthermore, this study does not include genetic analyses, captive breeding, or in-depth investigations of the entire life cycle beyond the larval and adult display phases. Rather, it aims to produce foundational ecological data that can guide upcoming conservation efforts and habitat management strategies focused on safeguarding firefly populations within Malaysian mangrove ecosystems. This study aims to provide important insights into preserving these charming insects and sustaining the ecological health of mangrove environments by recognizing the strong connection between fireflies and their associated plants.

1.5 Significance of the Study

Understanding the plant associations of firefly larvae in the Tumpat mangrove is vital for ecological insight and conservation initiatives. This study emphasizes the crucial role certain mangrove species, especially the primary associated plants, have in offering vital environments for firefly larvae. These plants provide not just physical protection but also a microhabitat that fosters larval growth and longevity. By recognizing and recording these main associated plants, the study aids in addressing current gaps in understanding the larval phase of fireflies, which is frequently less researched than the adult phase.

The importance of identifying the primary associated plant is its ability to serve as a central element for conservation management. Safeguarding and revitalizing these associated plants can significantly affect the sustainability of firefly populations, as larvae rely greatly on them for proper development and eventual transformation into adults. Furthermore, comprehending the relationship between plants and fireflies helps in identifying how mangrove ecosystems operate as linked habitats that sustain a variety of life forms

This study further carries significant implications for the conservation of biodiversity in mangrove ecosystems. Due to their sensitivity as bioindicators of environmental health, the presence and population of fireflies associated with specific plants can indicate the general state of the mangrove habitat. Conservation approaches based on this study can improve the safeguarding of both fireflies and the mangrove plant species they depend on, ultimately bolstering ecosystem resilience

CHAPTER 2

LITERATURE REVIEW

2.1 Life Cycle of Firefly

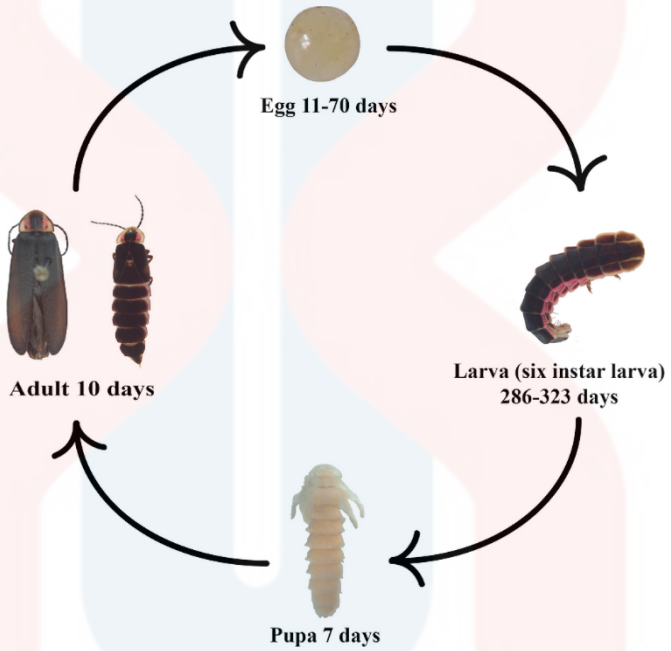

Figure 2.1: Life cycle of firefly (Source: Google Image)

Different sections of the mangrove vegetation life will influence the firefly life cycle (Figure 2.1). Adult fireflies often gather at night on a display tree, where they seek partners by flashing lights from two sections on the underside of their abdomen (Muhammad et al., 2022). Mature females deposit their eggs in the moist earth of the river's tidal area, where the eggs then hatch. Firefly larvae feed on various soft-bodied organisms, such as mangrove snails, earthworms, and insects (Lloyd, 2008). They often shed their exoskeleton. Once prepared, they transform into pupae and appear as mature fireflies (Jusoh et al., 2010a).

Female fireflies consistently lay their eggs near the food source to guarantee that the larvae will have sufficient nourishment (Muhammad et al., 2022). Female

fireflies deposit their eggs on moist or moss-covered soil. The duration for an egg to develop into a larva is approximately 15 to 20 days. The larvae will metamorphose into pupae in 23 months. The pupae will develop into mature adult fireflies in 9-12 days (Muhammad et al., 2022). The transformation of fireflies from the egg stage to adulthood requires about 6-7 months, while the typical lifespan of adult fireflies is estimated to last just 2-3 months (Nada & Kirton, 2005). Fireflies can be located in various environments, such as ponds, streams, mangroves, marshes, desert seeps, grasslands, and forests (Muhammad et al., 2022).

2.2 Display Plants in Firefly Ecology

Figure 2.2: Display plants in firefly ecology (Source: Google Image)

Based on figure 2.2, fireflies rely on various plants in different ways during the stages of their life cycle (Ghosh et al., 2023). For instance, display plants (DPs) provide an appropriate environment for courtship flashing, while various plant components also present locations for mating, oviposition, larval growth, and more (Ghosh et al., 2023). Fireflies, recognized as nectarivores or plant sap consumers, frequently obtain their nutritional sustenance from plants (Wahida et al. 2018). Certain plants harbor the prey species (especially the gastropod snails) that are targeted by the carnivorous larvae of fireflies (Jaikla et al., 2020). Research on firefly display trees by various scientists over the past few decades, especially in Southeast Asia, has demonstrated that the relationships and interactions between plants and fireflies are typically specific to species and vary notably between male and female individuals, as well as across their various life stages (Faust and Faust 2014; Jaikla et al. 2020)

2.3 Firefly Behaviour Congregating and Solitary

Firefly behavior can be classified into two types: congregational and solitary (Zainaddin & Sazali 2023). Fireflies that congregate show synchronized flashing patterns and are often seen in large clusters, whereas solitary fireflies do not exhibit synchronized flashes and are usually found alone or in smaller groups (Mobilim & Dawood 2020). In Malaysia, prevalent local *Pteroptyx spp.* have been noted in wetlands, estuaries, and brackish water settings and are frequently observed gathering on an array of riparian and mangrove trees, particularly *Sonneratia caseolaris* (Wong & Yeap 2012). The two main species of fireflies found in Malaysia are *Pteroptyx tener* Olivier and *Pteroptyx bearni* Olivier (Jusoh et al., 2018).

In contrast, solitary fireflies do not gather in large groups and do not perform synchronized flashing displays like their group-oriented counterparts (Zainaddin & Sazali 2023). While less researched and recorded than congregating fireflies, new studies indicate that multiple genera of solitary fireflies exist in Malaysia, such as Abscondita, Colophotia, Luciola, Pygoluciola, Pyrocoelia, and Medeopteryx (Jusoh et al. 2018; Mobilim & Dawood 2020; Seri & Rahman 2022).

2.4 Environmental Influences on Firefly Activity and Habitat Choice

Fireflies exhibit reduced activity in daylight and tend to settle beneath the leaves of the berembang tree (*Sonneratia caseolaris*) (Muhammad et al., 2022). This may be affected by environmental conditions like adverse weather for active fireflies, which doesn't apply at night. Numerous firefly larvae inhabit the root base of the berembang tree (Riza et al., 2017). Pteroptyx fireflies, indigenous to the coastal regions and riverbanks of Southeast Asia, showcase especially remarkable synchronized flashing among these enchanting beetles (McKenna & Farrell 2009).

2.5 Bioluminescent Mating Displays Fireflies

Adult fireflies usually demonstrate yearly activity patterns, showing greater species diversity and numbers in tropical areas during the rainy season, which aligns with the growth or harvest of local and cultivated plants, enhancing their cultural significance (Ineichen, 2016). In certain firefly species, male and female adults gather in significant amounts at the same location and navigate through plants or across open areas while showcasing their bioluminescent courtship displays (Rivera Ramírez et al., 2025).

The light or flashes they produce to convey their courtship signals differ greatly in color, brightness, and frequency, and certain species coordinate their flashes in extensive flickering clusters, yielding a significant visual effect for the viewer (e.g., *Photinus palaciosi* in Tlaxcala, Mexico, and *Pteroptyx tener* in Selangor, Malaysia; Owens et al., 2022). Consequently, it is usual for these nighttime exhibitions of fireflies to leave a memorable impact on their viewers for many years (Rivera Ramírez et al., 2025).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

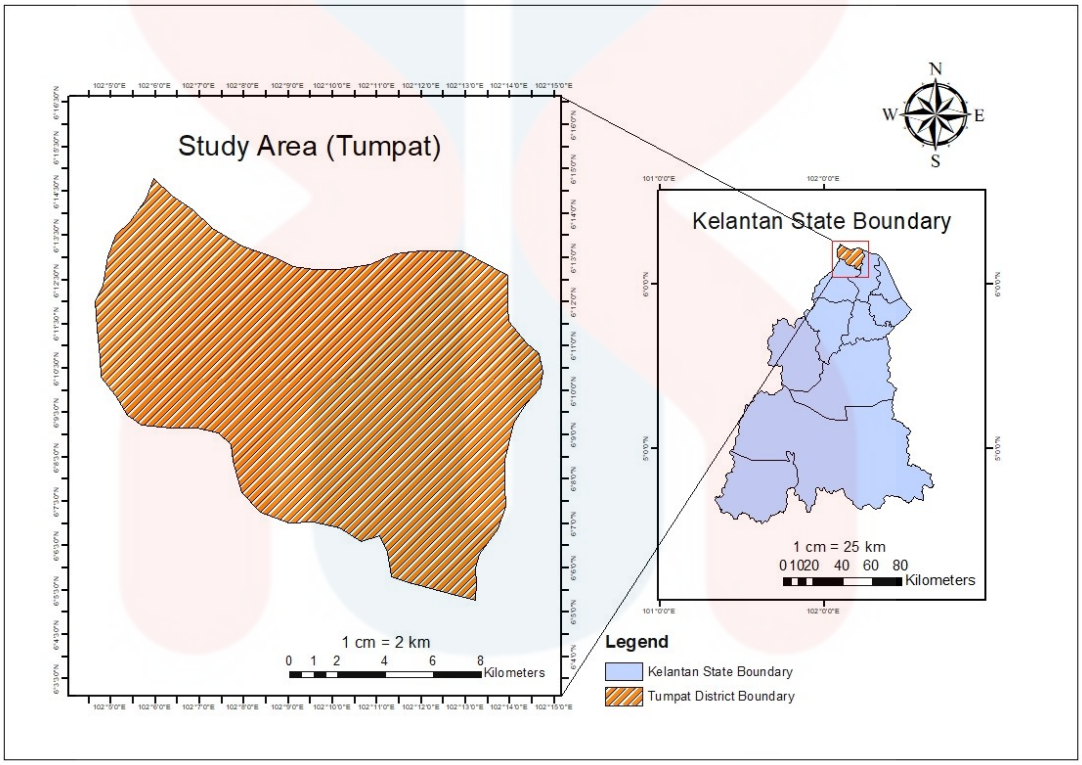

Figure 3.1a: Map of study area

The study took place in the mangrove forest region of Delta Tumpat, Kelantan, located at latitude 6.2127218N and longitude 102.2094620E (Figure 3.1a). In Delta Tumpat, there are 17 islands covering an estimated total area of 1200 ha (Ahmad et al., 2021). However, merely five (5) islands are populated with over 1,000 households. The notable geography of this region shaped the cultural, economic, and environmental health of the community. The main source of income for the community residing in the Tumpat Delta comes from fishing and coconut farming (Abas et al., 2024). This region is among the chosen areas for the Mangrove Tree Planting Program

in Kelantan, which aimed at ensuring the nation's coastline is densely populated with mangrove forests that acted as wave barriers and reduced the severe impacts of tsunami disasters. This initiatives for greening and tree planting are extensive national programs designed to guarantee that the coastal shoreline operates as a stable natural protective zone (Jemali et al., 2022). Figures 3.1b and 3.1c represent the entrance point and study location in Delta Tumpat, Kelantan. Figure 3.1b indicates the Jeti Kuala Besar, which is the primary access point to the research area via river transport. Meanwhile, Figure 3.1c highlights an observation platform located within the study location and surrounded by extensive vegetation.

Figure 3.1b: Jeti Kuala Besar

Figure 3.1c: Study site

3.2 Data Collection

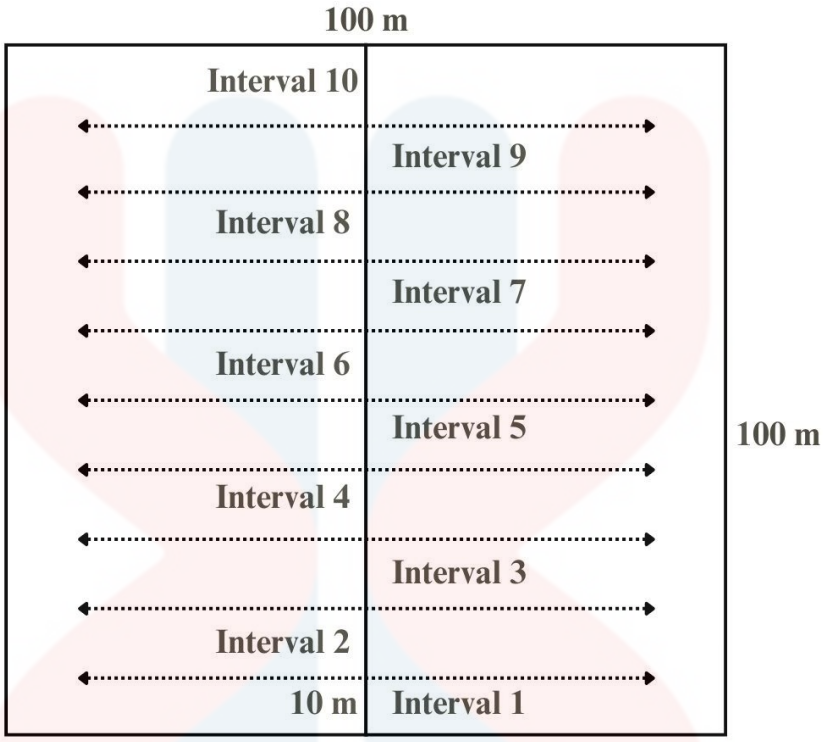

Figure 3.2: Plot and transect walk

Sampling occurred over two hours from 8 to 10 pm (Mobilim & Dawood, 2020). To reach the firefly habitat at Delta Tumpat for sampling, a boat is necessary due to challenging access on foot. Sampling was directed along the identical 100 × 100 m plot transect walk at 10 × 10 m intervals (Bernard et al., 2023) (Figure 3.2). Fireflies were gathered opportunistically with a sweep net (for adult flyers) and forceps (for larvae) (Mobilim & Dawood, 2020).

The count of larvae was determined by the associated plant discovered. Firefly species were identified, with male specimens recognized through morphological traits utilizing the key from (Ballantyne et al., 2019). Female specimens were identified to species level either when a description was accessible from the key or when observed mating with a known male (Mobilim & Dawood 2020). The primary associated plant was recognized to species level by gathering leaf and flower/fruit samples (Bernard et

al., 2023). Living fireflies and larvae were collected and preserved in 70% ethanol (Mobilim & Dawood, 2020) and stored in appropriately labeled zip-lock bags (Ghosh et al., 2023).

The GPS receiver was used to document each sampling site (Mobilim & Dawood, 2020). The assessment of abiotic parameters was conducted based on accessibility by collecting a two-liter water sample and subsequently preserving it (Amalo et al., 2025). The Eutech Instruments PCD 650 Multiparameter Meter was utilized to measure aquatic parameters including pH (Bernard et al., 2023). As shown in Table 3.2 presented the materials that were prepared and utilized throughout the sampling procedure.

Table 3.2: List and pictures of material (Source: Google Image)

Material	Picture
Forceps	
Sweep net	

70% Ethanol

Zip Lock Plastic Pouches

GPS

Eutech Instruments PCD 650

Multiparameter

3.3 Data Analysis

3.3.1 Relative Abundance

The study of firefly larvae interactions with associated plants in the Tumpat mangrove, Kelantan, involved calculating the relative abundance (%) of fireflies observed on each plant species. The relative abundance of various firefly larvae associated plants was determined using a particular formula and presented as a percentage (Routray et al., 2025). Relative Abundance (RA) as outlined by Presscot (1970), can determine the number of organisms present at an observation site/station using the following formula (Rahayu et al., 2017):

$$RA = \frac{ni}{N} \times 100\% \quad (3.1)$$

Explanation:

RA = Relative abundance
ni = number of individuals from species *i*
N = number of individuals from all observed species

The findings presented in a table that includes a description of the signs; these signs will indicate the quantity of both large and small samples collected. (Al Hidayah et al., 2025). Data gathered from field sampling were input into Microsoft Excel for initial arrangement and computation of the relative abundance figures for every plant species. The total counts of firefly larvae spotted on all associated plants served as the denominator, while the number of fireflies on each particular plant acted as the numerator

3.3.2 Water Quality Parameters

Physical water quality parameter examined in this study included temperature and pH, which serve as data on water quality that supports the habitat of firefly larvae in associated plants (Al Hidayah et al., 2025).

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Species Associated to Firefly Geographical Location Plant

Table 4.1a: Geographical location of plant species associated firefly in Tumpat, Kelantan

No.	Species	Sampling Site	Lat-Long
1	*Acanthus ilicifolius*	Delta Tumpat	N 06’12’42.0” E 102’12’35.1”
2	*Volkameria inermis*	Delta Tumpat	N 06’12’42.4” E 102’12’34.2”
3	*Acrostichum aureum*	Delta Tumpat	N 06’12’43.2” E 102’12’33.5”
4	*Sonneratia caseolaris*	Delta Tumpat	N 06’12’42.0” E 102’12’33.7”

The study revealed four different plant species associated to firefly larvae in the mangrove region of Tumpat, Kelantan. These species encompass *Acanthus ilicifolius*, *Volkameria inermis*, *Acrostichum aureum* and *Sonneratia caseolaris*, all collected specifically in the Tumpat district (Table 4.1a). The recurrent occurrence of larvae among these species indicates a possible affinity or ecological association between firefly larvae and these plants in the mangrove ecosystem.

The geographical coordinates show that all sampling locations are clustered within a relatively compact region in Tumpat, facilitating targeted ecological evaluation. The occurrence of these species nearby reinforces the notion that the larvae could depend on a particular group of mangrove plants for protection, nourishment, or

growth. Earlier research on Lampyridae larvae has demonstrated that their habitat selection is frequently associated with the presence of appropriate plants that offer essential microhabitats and food sources, including small invertebrates or detritus located on or around these plants.

Table 4.1b: Description of the acronyms and abbreviations used in the article

Terminologies (acronyms)	Description
AP	Associated Plants
DP	Display Plants

Based on Table 4.1b clarifies the acronyms used in the study, categorized as follows: AP is for Associated Plants, which are the host plants associated with firefly larvae, and DP stands for Display Plants, which are the plants used by adult fireflies for display behavior.

Table 4.1c: Length measurements of female and male species

Colophotia cf. praeusta		*Asymmetricata circumdata*	
Female	Length (cm)	Male	Length (cm)
	0.6		1.4
	0.6	N/A	N/A

	0.6	N/A	N/A
	0.8	N/A	N/A

The study identified two species, *Coleophotia cf. prausta* and *Asymmetricata circumdata*, using the morphological species identification method outlined by Ballantyne et al. (2019) for *Coleophotia cf. prausta* and Thancharoen et al. (2011) for *Asymmetricata circumdata*. Table 4.1c provides a complete assessment of the length measures of firefly from two species, *Coleophotia cf. prausta* and *Luciola bicoloripes*, discovered in Kelantan's Tumpat Mangrove. Female *Coleophotia cf. prausta* fireflies averaged 0.6 cm in length, with one specimen reaching 0.8 cm. In contrast, *Asymmetricata circumdata* is characterized only by male fireflies that measure 1.4 cm in length. The study provides invaluable insight of the physical features of fireflies within this particular mangrove habitat, stressing the need for further investigations on the ecological roles, growth, and environmental impacts impacting these species.

4.2 Associations Plant of Firefly Larvae and Adults Display Plants

Table 4.2: Plant species utilized by local firefly populations as larval Associated Plants (AP) and adult Display Plants (DP) across study sites

No.	Plants				Plants Utilisation
	Scientific Names	Local/ Common names	Range of elevation of occurrence of fireflies(m)	Families	
1	*Acanthus ilicifolius*	Jeruju	I	Acanthaceae	AP
2	*Volkameria inermis*	Bunga Pawang	I	Lamiaceae	AP
3	*Acrostichum aureum*	Piai Raya	I	Pteridaceae	AP
4	*Sonneratia caseolaris*	Berembang	III	Lythraceae	DP

[The categories of elevation of occurrences of fireflies on the AP, DPs;I-from ground level up to 0.5m; II-from ground level up to1.5m; III-from ground level up to 5m; IV-from ground level to>5m]

The results of this study emphasize the particular plant species associated various life stages of fireflies (Coleoptera: Lampyridae) in the Tumpat mangrove ecosystem of Kelantan. Determining larval associated plants (AP) and adult display plants (DP) offers important information about the ecological needs and habitat choices of nearby firefly population.

Based on Table 4.2, four essential plant species were recognized as important for the fireflies in this area. The larval host plants *Acanthus ilicifolius*, *Volkameria inermis* and *Acrostichum aureum* are mainly located at ground level, reaching heights of up to 0.5 meters. These plants are part of various botanical families, including Acanthaceae, Lamiaceae and Pteridaceae, illustrating the diverse habitat structures that firefly larvae use for protection and growth. The inclination for plants at lower elevations indicates that larvae prefer moist and sheltered microhabitats near the

ground, which could offer appropriate conditions for feeding and safeguarding from predators.

In contrast, the identified adult display plant, *Sonneratia caseolaris* (family Lythraceae), found at an elevation range of 1.5 to 5 meters above the ground. This vertical layering in plant utilization suggests a potential ecological niche distinction between larval and adult stages, with adults preferring taller plants for mating displays and communication. This conduct corresponds with the need for enhanced visibility and accessibility for attracting mates in adulthood.

4.3 Relative Abundance Associated Plant Firefly Larvae

Table 4.3: Relative abundance and count associated plants firefly larvae

No.	Associated Plants	Family	Firefly Larvae (Count)	Relative Abundance %
1	*Acanthus ilicifolius*	Acanthaceae	20	32.79
2	*Volkameria inermis*	Lamiaceae	26	42.62
3	*Acrostichum aureum*	Pteridaceae	15	24.59

The investigation of associated plant (AP) for firefly larvae (Coleoptera: Lampyridae) in the Tumpat mangrove region recognized three primary plant species that associated of the larvae: *Acanthus ilicifolius*, *Volkameria inermis* and *Acrostichum aureum*. Based on table 4.3, the counts of firefly larvae observed on these plants were 20, 26, and 15 respectively, which corresponded to relative abundances of 32.79%, 42.62%, and 24.59%.

Among these, *Volkameria inermis* recorded the highest number of larvae with 26 individuals, establishing it as the most commonly associated plant for firefly larvae in this mangrove ecosystem. This indicates that the physical or ecological traits of *Volkameria inermis* might provide more advantageous conditions for larval growth and survival in comparison to the other. *Acanthus ilicifolius* was recorded with 20 larvae, marking the second highest total and relative abundance (32.79%), suggesting it is a significant AP species in the ecosystem. In the meantime, *Acrostichum aureum* recorded the smallest number of larvae at (15 individuals), but still plays a notable role in the total firefly larvae population in the region.

Nonetheless, there are no information study about *Volkameria inermis* as AP for firefly larvae, however prior studies indicate that the display plant should be close

to the larval food plant and the tree must be in good health (Jusoh et al., 2010a). From our observation there were a presence of *Sonneratia caseolaris* (DP) in the area. In Peninsular Malaysia, fireflies are mainly located in the *Sonneratia caseolaris* mangrove (Muhammad et al., 2022), a species that has low salt tolerance (Lewis et al. 2020). This confirms the prior findings of McNae (1968), who discovered that *Sonneratia caseolaris* was the most preferred display trees relative to other mangrove species. It is likely that *Volkameria inermis* serves as the associated plant for firefly larvae, as suggested by previous studies that mention the presence of *Sonneratia caseolaris*, a plant that attracts fireflies in that region.

According to earlier research, *Acrostichum aureum* has been recognized as one of the associated plant species (AP) frequently located in firefly habitats (Asri et al., 2020). *Acrostichum aureum* is recognized as one of the mangrove species that offer suitable microclimatic conditions for mature fireflies (Fuzi et al., 2022). This species usually thrives in the rear mangrove regions, offering protection for the developing firefly larvae and serving as a breeding ground for river snails and small insects, which are the primary food source for the firefly larvae (Fuzi et al., 2022). This aligns with findings from earlier research where food sources like river snails were discovered in our study area, reinforcing the claim that *Acrostichum aureum* acts as associated plant for firefly larvae development, which act as primary food sources for them, thereby forming an appropriate feeding environment. These conditions not only aid adult fireflies but also foster a suitable setting for larvae growth by preserving the moisture and elevated humidity necessary for their survival.

Previous study indicates that *Acanthus ilicifolius* is advocated as a key species for mangrove ecosystem reforestation, acting as a crucial associated for firefly larvae (Fuzi et al., 2022). Firefly populations are significantly reliant on mangrove habitats,

which offer clean water, cool, moist microclimates, and low light pollution, all vital for their habitat preference and reproductive success (Fuzi et al., 2022). Thriving in the mangrove margins, *Acanthus ilicifolius* fulfills these ecological needs, consequently aiding the survival and growth of firefly larvae in our research area. Figure 4.3 below illustrated a bar chart depicting the distribution on firefly larvae by showing both the total count and relative abundance across the 3 identified associated plant species in the Tumpat mangroves area.

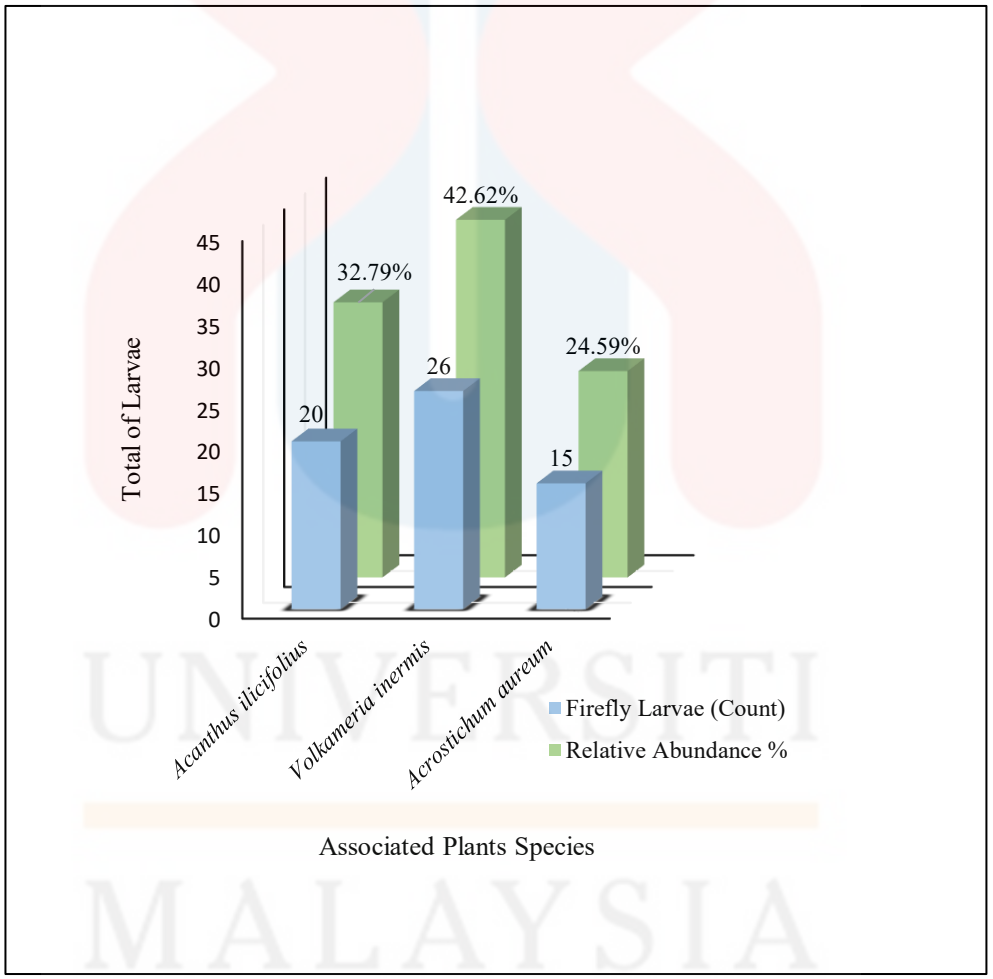

Figure 4.3: Relative abundance and count firefly larvae

4.4 Relative Abundance of Display Plant Firefly

Table 4.4: Relative abundance and count display plants firefly adult

No.	Display Plants	Family	Firefly Adult (Count)	Relative Abundance %
1	*Sonneratia caseolaris*	Lythraceae	16	61.54

The data presented in Table 4.4 highlights the relative abundance and count of firefly adults associated with the display plant *Sonneratia caseolaris*, belonging to the family Lythraceae. The count of 16 firefly adults indicates that this particular plant species plays a significant role as a display plant for fireflies in the studied ecosystem. The relative abundance of 61.54% further confirms that *S. caseolaris* is the predominant or possibly the exclusive display plant utilized by fireflies in this habitat during the observation period. The berembang tree, *Sonneratia caseolaris* is the main display tree for fireflies and is often found in mangrove swamp areas (Muhammad et al., 2022). Based on previous study found that *Sonneratia caseolaris* trees are the most preferred display trees because a preference may be owing to the availability of sugar in the sap of *Sonneratia caseolaris*, a food source for fireflies (Abu Seri et al., 2022)

According to Jusoh et al. (2010b), fireflies consider five additional criteria when selecting display trees. First, the tree should be located near the water's edge to support their communication. Second, its leaf arrangement must be suitable for mating activities. Third, if adult fireflies feed, the tree should provide nectar or sap. Fourth, it should be near the food source for larvae. Lastly, the tree must be healthy, as healthier mangrove trees have denser foliage, offering more perching space and better protection from direct sunlight (Foo & Mahadimenakbar, 2015).

This finding suggests a strong ecological association between fireflies and *Sonneratia caseolaris*, which may be attributed to specific factors such as the plant's

structural characteristics, availability, or suitability for firefly mating displays. Given the importance of display plants in firefly communication and reproduction, the presence of *S. caseolaris* likely supports the survival and reproductive success of firefly populations in the mangrove ecosystem.

Based on Figure 4.4, the pie chart illustrates the relative abundance between Associated Plants and Display Plants in the mangrove ecosystem. Associated Plants constitute the majority with 79.22%, indicating a higher presence or importance to the firefly larvae habitat. In contrast, Display Plants make up 20.78%, representing the plants primarily used by adult fireflies during their display activities. This distribution highlights the ecological significance of Associated Plants as essential habitats for firefly larvae, while Display Plants play a crucial role in adult firefly behavior.

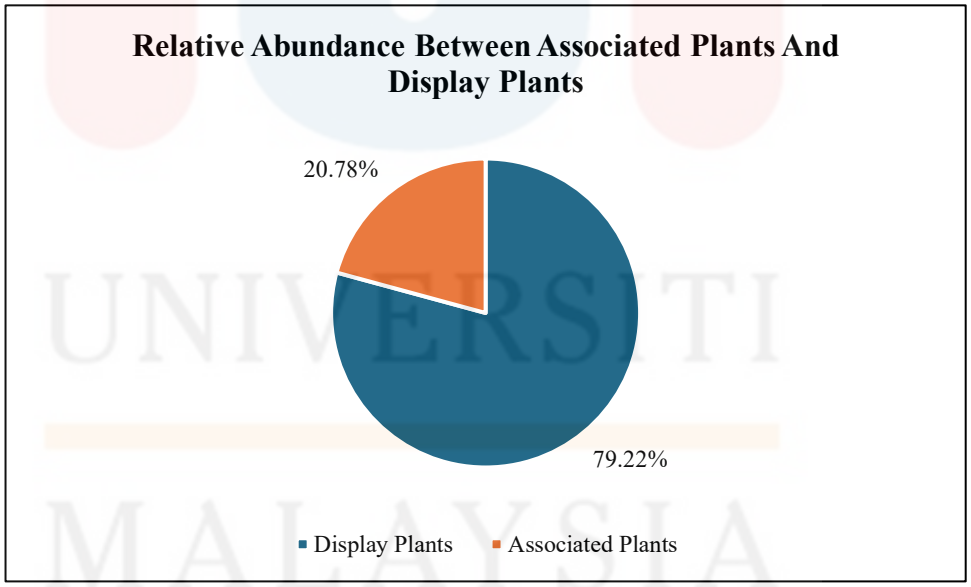

Figure 4.4: Relative abundance between associated plants and display plants

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study effectively recognized and recorded the associations plant of firefly larvae (Coleoptera: Lampyridae) within the Tumpat mangrove ecosystem in Kelantan. The findings showed that *Volkameria inermis*, *Acanthus ilicifolius* and *Acrostichum aureum* acted as major larval associated plants, whereas *Sonneratia caseolaris* was mainly used by adult fireflies as a display plant. *Volkameria inermis* showed the greatest larval abundance, suggesting its potential as a major microhabitat for firefly development, despite limited existing literature supporting its role.

These results suggest that firefly larvae show a clear preference for certain plant species found in lower areas of the mangrove zone, which offer favorable conditions such as moisture, shade, and the presence of prey like gastropod snails. The intimate spatial connection between larval associated plants and adult display plants highlights the ecological connectivity essential for the firefly life cycle.

Overall, this study provides crucial foundational ecological information for conservation initiatives, highlighting the necessity of safeguarding and rehabilitating these vital plant species within mangrove ecosystems to support firefly communities. Ongoing study on larval ecology and habitat needs is advised to enhance comprehension and aid in effective biodiversity conservation in Malaysia's coastal ecosystems.

5.2 Recommendation

The water quality assessments at the study location indicate that the pH varies from 6.83 to 6.93, suggesting conditions that are slightly acidic to almost neutral, which are favorable for mangrove habitats and the larval environment of fireflies. Low pH levels (under 6) can negatively impact aquatic organisms and hinder the development of mangroves (Amalo et al., 2025). Additional factors like temperature (29.85°C to 30.15°C), salinity (approximately 4.97 ppt), and dissolved oxygen concentrations indicate a predominantly healthy aquatic ecosystem. However, the abnormally elevated dissolved oxygen levels (exceeding 600 mg/L) could result from instrument malfunctions, and consistent monitoring is crucial to guarantee that water quality stays stable and favorable to fireflies and other aquatic organisms.

To conserve the habitat, it is important to conduct continuous water quality monitoring essential for identifying changes and preventing contamination from industrial or agricultural origins; however, the area has experienced water pollution, including garbage dumping in the river. However, the dumping of garbage by local residents is still under control because not all places experience it and the relative number is slightly concentrated in residential areas around the river. Firefly populations rely on mangroves because the essential attributes for habitat selection include clean water, a cool and clean climate, high humidity, and the absence of light pollution (Fuzi et al., 2022)

Human actions that threaten mangrove regions need to be regulated, and local communities should be informed about the significance of safeguarding these ecosystems, considering fireflies' function as bioindicators of ecological well-being. Safeguarding and rejuvenating essential mangrove species like *Sonneratia caseolaris*,

Acanthus ilicifolius, *Acrostichum aureum* and *Volkameria inermis* is crucial since these plants offer habitat and nourishment for firefly larvae. Furthermore, reducing light pollution is required to minimise disturbance to adult fireflies when their mating displays since light pollution was perceived as the greatest threat to fireflies in East Asia and South America and as either the second or third primary threat in the majority of other region (Lewis et al., 2020) considering firefly may become light sensitive and disoriented by bright light (Fuzi et al., 2022). Finally, further studies on the ecology and habitat requirements of firefly larvae, along with continuous community involvement, will enhance conservation initiatives and support the long-term preservation of these distinct mangrove ecosystems.

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APPENDIX A

Field Sampling

APPENDIX B

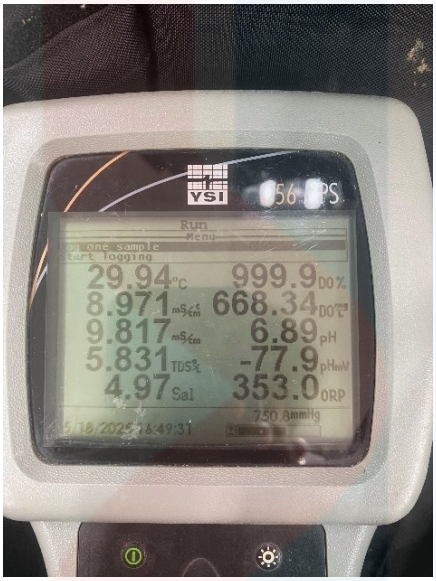
Associated Plant and Display Plants

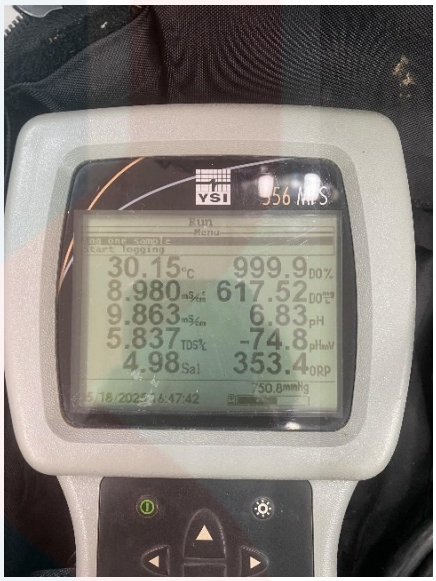
APPENDIX C

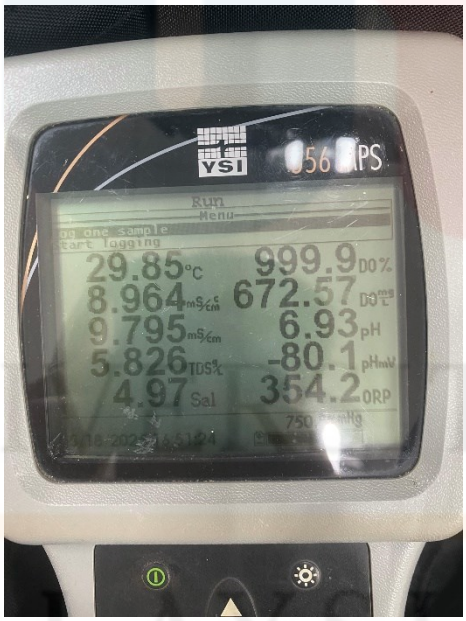
Larvae Observation

APPENDIX D

Water Parameter



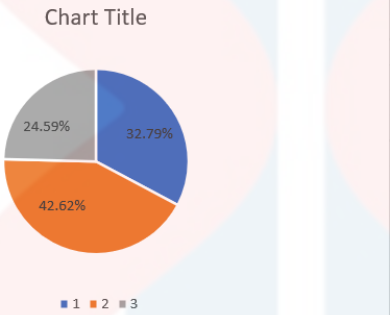




APPENDIX E

Species Data

Weeks	Date	Location	Family	*Acanthus ilicifolius*	*Volkameria inermis*	*Acrostichum aureum*
1	11/4/2025	Delta Tumpat	Lampyridae	3	4	3
	12/4/2025	Delta Tumpat	Lampyridae	0	0	0
2	17/4/2025	Delta Tumpat	Lampyridae	1	2	2
3	25/4/2025	Delta Tumpat	Lampyridae	3	5	2
	26/4/2025	Delta Tumpat	Lampyridae	3	4	3
4	1/5/2025	Delta Tumpat	Lampyridae	1	1	1
	3/5/2025	Delta Tumpat	Lampyridae	0	0	0
	5/5/2025	Delta Tumpat	Lampyridae	3	2	1
	6/5/2025	Delta Tumpat	Lampyridae	6	8	3
				20	26	15



32.79%	42.62%	24.59%