State of Nature Conservation in Malaysia 2025, 597–606
doi: 10.62613/sonc2025.v2fnc21

CHAPTER 21

Fireflies of Malaysia across 150 years (1875–2025)

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Abstract: Fireflies, known locally as *kunang-kunang* or *kelip-kelip*, have long captivated the human imagination through their bioluminescence, earning a cherished place in Malaysia's natural heritage as drivers of public engagement, ecotourism, and conservation. Yet, significant gaps in scientific understanding persist due to uneven knowledge across species, habitats, and regions. This chapter provides a brief overview of firefly research in Malaysia spanning the last 150 years, and presents its first official species checklist, documenting 78 species across three subfamilies and 21 genera. Tracing taxonomic activity from the late 1800s to the present, we identify three key phases, with surges in species naming during the 1910s – 1940s and 2000s – 2010s, while noting that nearly two-thirds of described species have received no further study since their original description. Based on current knowledge, Malaysia's fireflies can be categorised by four distinct signalling systems: roving flashers, glow-worms, dark (pheromone-based) species, and stationary synchronous flashers. They occupy diverse habitats from mangrove and riverine wetlands to montane forests and depend on distinct microhabitats at different life stages, making them sensitive indicators of ecosystem health. Primary threats include habitat loss, light pollution, pesticide contamination, and unregulated tourism, with four *Pteroptyx* species now classified as Vulnerable on the IUCN Red List. We also highlight critical gaps, including the absence of standardised survey protocols and limited data on solitary forest-dwelling species, and review ongoing conservation actions, including Malaysia's forthcoming Mangrove Firefly Conservation Action Plan.

INTRODUCTION

Fireflies are best known for their bioluminescence, a chemically produced light used for communication, warning, and courtship. The flashing fireflies inspire curiosity, advances scientific discovery and makes them powerful ambassadors for conservation (Lewis *et al.* 2024). As a "gateway bug" (Lewis as cited in Sidik, 2023), fireflies promote public engagement, generate ecotourism income and draw attention to broader declines in insect populations (Lewis *et al.* 2021). Their inclusion in educational programs motivates conservation action across all ages (Muharraran *et al.* 2024).

This paper provides a brief overview of firefly study in Malaysia, beginning with the first species described in 1875. It summarises key discoveries on their diversity, behaviour, and habitat preferences, while highlighting the main threats they face today and ongoing conservation actions. A central feature of this paper is Malaysia's first official checklist of firefly species, which we hope will deepen an understanding of fireflies and inspire continued research on taxonomy, ecology, and conservation needs.

Fireflies

Fireflies are beetles, not flies. They belong to the beetle family "shining light" (Lampyridae in Latin). The life cycle of fireflies comprises egg, larva, pupa, and adult stages. Although adult fireflies are conspicuous, much of their life cycle remains concealed. Eggs are deposited in moist, dark environments such as soil, moss, or leaf litter. Larvae may persist for months

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or even years in humid, shaded habitats, preying on snails and slugs. Pupation occurs in damp soil or decaying wood for one to three weeks. Adults are short-lived, primarily devoted to courtship and seldom feed. This strong dependence on specific microhabitats at different life stages makes fireflies highly sensitive to environmental change, and thus valuable indicators of ecosystem health (Lewis *et al.* 2024).

Fireflies are a well-known and a cherished part of Malaysia's natural landscape, commonly referred to as *kunang-kunang* or *kelip-kelip* by locals. The term *api-api* can also mean firefly (Dewan Bahasa dan Pustaka 2005), though it is rarely used for insects and is more often used to describe mangrove trees of the genus *Avicennia*. Despite their visibility, scientific understanding has developed unevenly across species, habitats, and regions, so there are still significant gaps in what we know about, where they live and how they survive.

Two common names and four signalling systems

Whether you know them as *kunang-kunang* or *kelip-kelip*, fireflies hold a special place in Malaysia's natural heritage—not because of their physical appearance, but for the way they light up the night with their unique flashes. What truly sets these insects apart are their fascinating signalling systems: roving flashers, glow-worms, dark (pheromone-based) species, and stationary synchronous flashers (Lewis 2009).



Figure 1. In Malaysia, fireflies are generally known as either *kunang-kunang* (solitary firefly) or *kelip-kelip* (congregating firefly). *Kunang-kunang* can be further divided into three signalling systems, for instance: **(a)** *Pygoluciola*, the roving flasher; **(b)** *Lamprigera*, the glow-worm firefly; and **(c)** *Lucidina*, the dark firefly. *Kelip-kelip* usually refers to the bent-winged firefly, such as **(d–e)** *Pteroptyx tener*, congregating on mangrove trees. Photo credits: (a, c) Nicholas HL Tan, (b) Tan Wei Jack / Monash University Malaysia. Photos (d-e) Forest Research Institute Malaysia.

Firefly species of Malaysia

Firefly taxonomy has progressed through many phases, each contributing to current scientific understanding. McDermott's 1966 global catalogue of Lampyridae established a foundational taxonomic framework that informed subsequent research. The launch of the Lampyridae of the World Database in 2024 (Keller 2024) signalled a modern resurgence, providing updated and expanded information on these beetles. At present, about 2,635 species are described worldwide, ~380 of them in Southeast Asia across ~46 genera (Keller 2024; Lewis *et al.* 2024).

Taxonomic activity in Malaysia shows three phases: early exploration (late 1800s – 1930s), mid-century refinement (1930s – 1950s), and a modern resurgence in the 2000s to the present, driven by ecological interest and conservation needs. Naming surged during the 1910s – 1940s and again in the 2000s – 2010s under Lesley Ballantyne and collaborators, with Peninsular Malaysia contributing most species (Ballantyne *et al.* 2019) (Figure 2).

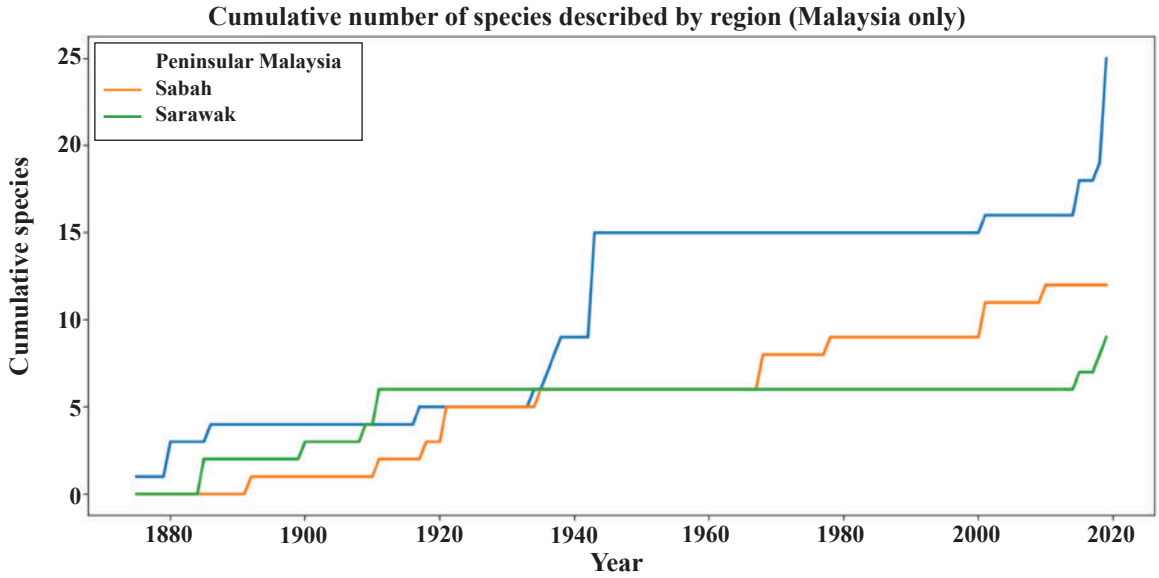

Figure 2. Cumulative number of firefly species from 1875 to 2025 based on historical and occurrence data. Peninsular Malaysia accumulates the most names overall; Sabah shows steady gains while Sarawak has a consistent but smaller trajectory.

In total, Malaysia currently has 78 firefly species distributed across three subfamilies. Two genera remain *incertae sedis* (Martin *et al.* 2017), meaning their exact classification is still uncertain (Table 1). The majority of species are found in Luciolinae (all flashing; 35 species) and Ototretinae (mostly dark; 31 species), with the remainder in Lampyrinae (Table 1). However, the true species diversity in Malaysia is likely higher than 100, as some historical records correspond to colonial-era administrative regions that do not match modern boundaries. Additionally, references to "Borneo" can include areas in Malaysia, Indonesia (Kalimantan), and Brunei.

Of these 78 species, approximately 48 were first discovered and described in Malaysia, making them the type localities for those species. The earliest, *Anadrilus indus* Kirsch, 1875, was collected in colonial Malacca and designated as the type species of *Anadrilus* by monotypy. Unfortunately, the original type specimen has been lost, leaving the taxon *incertae sedis* (Janisova and Bocakova 2013). Another genus with unresolved classification is *Lamprigera* (the so-called "giant fireflies"). Although popular and quite well known in Malaysia, the latest classifications place *Lamprigera* closer to Luciolinae, yet it shows little morphological similarity to that subfamily. This uncertainty highlights the need for broader and deeper sampling to resolve its classification.

The species list also revealed that nearly two-thirds of Malaysia's firefly species have not been studied since their original descriptions, and the original type specimens remain unlocated and are likely scattered across European museums. For many of these species, information is limited to outdated morphological descriptions and, in rare cases, brief notes on collection localities. However, not all species are lost to history. Recently, the first live sighting of *Pteroptyx gombakia* was confirmed in Kuala Lumpur, about 40 km from its original collection site in "Gombak Valley," where it was first discovered in 1921. This rediscovery not only confirms the species' continued existence but also marks the first record of a bent-winged firefly genus, *Pteroptyx*, in a non-mangrove forest, which was previously believed to be the exclusive habitat for this genus (Tan and Jusoh 2025).

Table 1. List of firefly species of Malaysia in alphabetical order by subfamily from 1875 to 2025. Type locality (T) is Malaysia, meaning it is the specific place where a newly discovered species was first found and scientifically described. Species under *incertae sedis* is indicated by an asterisk.

Subfamily	Genus	Species	Author, Year	Type locality
Lampyridae	*Anadrilus**	*indus*	Kirsch, 1875	T
incertae sedis	*Lamprigera**	*nitens*	Olivier, 1885	T
Lampyrinae	*Diaphanes*	*moultoni*	Olivier, 1909	T
	Lucidina	*angusticollis*	Pic, 1944	
	Lucidina	*flabellata*	Pic, 1944	
	Lucidina	*malaccana*	Pic, 1917	T
	Lucidina	*testaceipes*	Pic, 1944	
	Pyrocoelia	*atriventris*	Pic, 1938	T
	Pyrocoelia	*collaris*	Gorham, 1892	T
	Pyrocoelia	*consobrina*	Olivier, 1886	T
	Pyrocoelia	*fumigata*	Gorham, 1880	T
	Vesta	*pectoralis*	Pic, 1944	
Luciolinae	*Abscondita*	*berembun*	Nada, 2019	T
	Abscondita	*jerangau*	Nada, 2019	T
	Abscondita	*pallescens*	(Gorham, 1880)	
	Colophotia	*brevis*	Olivier 1903	
	Colophotia	*praeusta*	(Eschscholtz, 1822)	
	Curtos	*atripennis*	Pic, 1934	T
	Curtos	*flaviceps*	Pic, 1927	
	Kuantana	*menayah*	Ballantyne, 2019	T
	Luciola	*chapaensis*	Pic, 1923	
	Luciola	*jengai*	Nada, 2019	T
	Luciola	*maculipennis*	Olivier, 1913	
	Luciola	*niah*	Jusoh, 2019	T
	Luciola	*tiomana*	Ballantyne, 2019	T
	*Luciola**	*lata*	Olivier, 1883	
	Medeopteryx	*fraseri*	Nada, 2019	T
	Pteroptyx	*asymmetria*	Ballantyne, 2001	T
	Pteroptyx	*balingiana*	Jusoh, 2018	T
	Pteroptyx	*bearni*	Olivier, 1909	
	Pteroptyx	*decolor*	Olivier, 1911	
	Pteroptyx	*galbina*	Jusoh, 2015	T
	Pteroptyx	*gelasina*	Ballantyne, 2001	T
	Pteroptyx	*gombakia*	Ballantyne, 2015	T
	Pteroptyx	*malaccae*	(Gorham, 1880)	T
	Pteroptyx	*sayangia*	Ballantyne, 2015	T
	Pteroptyx	*tener*	Olivier, 1907	
	Pteroptyx	*testacea*	(Motschulsky, 1854)	
	Pteroptyx	*valida*	Olivier, 1909	
	Pygoluciola	*dunguna*	Nada, 2018	T

	Pygoluciola	*guigliae*	(Ballantyne, 1968)	T
	Pygoluciola	*hamulata*	(Olivier, 1885)	T
	Pygoluciola	*kinabalua*	(Ballantyne and Lambkin, 2001)	T
	Pygoluciola	*nitescens*	(Olivier, 1903)	
	Pygoluciola	*stylifer*	Wittmer, 1939	
	Pygoluciola	*wittmeri*	(Ballantyne, 1968)	T
	Pyrophanes	*semilimbata*	(Olivier, 1883)	
Ototretinae	*Brachypterodrilus*	*atricolor*	(Pic, 1943)	T
	Brachypterodrilus	*pallidipes*	Pic, 1918	T
	Drilaster (Drilaster)	*albicornis albicornis*	(Olivier, 1911)	T
	Drilaster (Drilaster)	*albicornis lateobscura*	(Pic, 1921)	T
	Drilaster (Drilaster)	*atriceps*	(Pic, 1921)	T
	Drilaster (Drilaster)	*borneensis*	(Olivier, 1907)	
	Drilaster (Drilaster)	*brevecostatus*	(Pic, 1939)	
	Drilaster (Drilaster)	*curtus*	(Pic, 1937)	T
	Drilaster (Drilaster)	*gravidus*	(Olivier, 1900)	T
	Drilaster (Drilaster)	*lateralis*	(Pic, 1921)	
	Drilaster (Drilaster)	*latipennis*	(Pic, 1943)	
	Drilaster (Drilaster)	*limbatus*	(Pic, 1925)	
	Drilaster (Drilaster)	*minutus*	(Pic, 1925)	
	Drilaster (Drilaster)	*niger*	(Pic, 1936)	T
	Drilaster (Drilaster)	*nigriceps*	(Pic, 1943)	
	Drilaster (Drilaster)	*pendleburyi*	(Pic, 1943)	T
	Drilaster (Drilaster)	*subapicalis helodiformis*	(Pic, 1921)	T
	Drilaster (Drilaster)	*subapicalis subapicalis*	(Pic, 1911)	T
	Drilaster (Drilaster)	*testaceicollis*	(Pic, 1921)	T
	Drilaster (Drilaster)	*testaceolineatus*	(Pic, 1936)	
	Drilaster (Drilaster)	*varicornis*	(Olivier, 1911)	T
	Drilaster (Loksadodrilus)	*subvittatus*	(Pic, 1943)	
	Emasia	*dentata*	Bocáková and Janišová, 2010	T
	Flabellototreta	*angustata*	Pic, 1935	T
	Flabellototreta	*inhumeralis*	Pic, 1925	
	Ototretadrilus	*maai*	Wittmer, 1978	T
	Stenocladius (Stenocladius)	*ater*	Pic, 1943	T
	Stenocladius (Stenocladius)	*basipennis*	Pic, 1943	T
	Stenocladius (Stenocladius)	*borneensis*	Pic, 1943	
	Stenocladius (Stenocladius)	*obscuripes*	Pic, 1943	T
	Stenocladius (Stenocladius)	*testaceus*	Pic, 1943	T

Habitats and ecological requirements

Fireflies in Malaysia inhabit a diverse range of environments, including mangrove and riverine wetlands, rice paddies, streams, marshes, grasslands, and forests at various elevations (Lloyd 2002; Nada *et al.* 2023). Congregating, synchronous displays are most linked to mangroves and are especially characteristic of the genus *Pteroptyx* (Jusoh *et al*. 2018; Wong 2022). However, both behaviour and habitat vary; not all *Pteroptyx* species are synchronous (e.g., *P. bearni*, *P. valida*), nor are they all limited to mangroves (e.g., *P. gombakia*) (Jusoh *et al.* 2018; Tan and Jusoh 2025). Many species occupy different habitats during different stages of their life cycle. For example, adult *Pteroptyx tener* court on mangrove trees, but females lay eggs farther up the riparian zone, and larvae develop along muddy banks where they prey on snails (Nada and Kirton, 2004). Within mangrove ecosystems, *Rhizophora* provides moist, shaded sites for oviposition; areas dominated by *Nypa fruticans* and *Metroxylon sago* support larval prey; and open-canopied *Sonneratia caseolaris* serves as a main tree for displays (Jusoh *et al*. 2010; Nada and Kirton 2004). The choice of display tree is influenced by proximity to water, leaf architecture, availability of sap or nectar, presence of larval prey, and structural stability (Jusoh *et al.* 2010).

A key ecological distinction is that only firefly larvae, not adults, exhibit aquatic or semi-aquatic behaviours. These larvae inhabit soil and leaf litter along riverbanks and pond margins and may briefly enter water while foraging. In contrast, truly aquatic fireflies have larvae that remain submerged and possess gills (Fu *et al.* 2012; Riley *et al.* 2021). For instance, the semi-aquatic *Pygoluciola dunguna* larvae crawl along sandy edges of shallow streams, indicating riparian rather than a fully aquatic lifestyle (Nada and Ballantyne 2018). Although truly aquatic firefly larvae have not yet been documented in Malaysia, they may be discovered as sampling expands.

For solitary fireflies, diversity in Peninsular Malaysia is largely shaped by habitat shifts associated with elevation, with forest type and canopy closure exerting the strongest influence (Nada *et al.* 2023). These species tend to be confined to specific elevational bands, leading to high species turnover between forest types. The cryptic nature and low density of fireflies complicate efforts to establish robust statistical links, but it is clear that habitat structure along elevation gradients is a primary driver of community composition. Worryingly, while many solitary firefly species still persist in urban areas, including Kuala Lumpur's green parks, they face ongoing threats (Mbugua *et al.* 2019; Muharraran *et al.* 2026).

THREATS TO FIREFLIES

The main threats to fireflies are habitat loss and degradation, light pollution, pesticide and insecticide exposure, water pollution, and unregulated tourism (Lewis *et al.* 2020, 2024). In Southeast Asia, habitat loss leads, closely followed by light and water pollution and pesticides. Surveys in Kuala Selangor suggest that over half of residents perceive local declines, citing insecticide use, tourism pressure, habitat loss, and water quality as leading concerns (Nadriah *et al.* 2020).

Mangrove fireflies are under pressure. On 27th of June 2024, the IUCN Firefly Specialist Group classified four congregating firefly species: *Pteroptyx bearni*, *P. malaccae*, *P. tener*, and *P. valida* as Vulnerable under the IUCN Red List (IUCN 2024). Formerly abundant in Southeast Asia's mangrove forests, these species, which can all be found in Malaysia, face severe threats from habitat loss and degradation. In fact, Malaysia has experienced substantial mangrove degradation through deforestation, reclamation, and pollution, with annual losses estimated in the thousands of hectares (Omar 2024; Islam *et al.* 2024). Such changes threaten *Pteroptyx*, which depend on specialised mangrove habitats (Nada and Kirton 2004; Jusoh and Hashim 2012). In the Rembau-Linggi estuary, land-use change coincided with nearly a 50% decline in *Pteroptyx* within two years (Jusoh and Hashim, 2012). Agricultural and industrial conversions introduce pollutant runoff that accelerates declines; oil palm and shrimp aquaculture runoff has been linked to lower *P. bearni* numbers and depressed water quality in the Cherating River (Lewis *et al.* 2020; Faudzi *et al*. 2021).

Pesticide contamination is a critical, cross-stage hazard. In the Selangor River, pesticide levels have exceeded thresholds deemed safe for freshwater biota (Leong *et al.* 2007). Such exposures can be directly lethal to eggs, larvae, pupae, and adults, and indirectly harmful by diminishing or poisoning larval prey (Pisa *et al.* 2015; Wang *et al.* 2022). Heavy motorboat traffic compounds impact by introducing oil pollution and generating waves that erode banks and dislodge display trees (Lewis *et al.* 2021).

Artificial light at night (ALAN) disrupts mate signalling by reducing contrast and detectability of flashes, curtailing activity windows, and immobilizing larvae (Gaston *et al.* 2013; Mbugua *et al.* 2019; Elgert *et al.* 2021; Owens *et al*. 2022). For *Lamprigera* sp., males have a narrow ~40-minute twilight window to locate females; bright lighting further compresses

that opportunity (Muharraran *et al.* 2024). In Bukit Kiara, larvae move away from illuminated zones, and in Cherating, reduced *P. bearni* populations have been associated with shrimp pond spotlights and nearby lights (Mbugua *et al.* 2019; Faudzi *et al.* 2021; Muharraran *et al.* 2026).

Climate change adds emerging risks. Prolonged heatwaves threaten moisture -dependent life stages, while sea-level rise can squeeze coastal wetlands, especially where human infrastructure blocks landward migration (Schuerch *et al.* 2018; Reed *et al.* 2020; Tangang 2025). Some Southeast Asian *Pteroptyx* congregate on *Sonneratia caseolaris*, a low-salinity species vulnerable to saltwater intrusion, which could in turn reshape local firefly assemblages.

EVIDENCE GAPS AND MONITORING NEEDS

Despite global renown for synchronous congregations, Malaysia still lacks comprehensive data on distribution, population dynamics, and long-term trends (Jusoh *et al.* 2010; Lewis *et al.* 2024). Most studies concentrate on a few rivers and focal sites, leaving many mangrove creeks and inland systems under-documented. Solitary and forest-dwelling species are particularly data-poor beyond select elevational transects (Nada *et al.* 2023).

A major bottleneck is the absence of standardised, habitat-specific survey protocols that enable comparisons across space and time. Establishing consistent methods for both congregating and solitary groups would strengthen trend detection and allow national-scale syntheses (Lewis *et al.* 2021). Malaysia already holds valuable datasets from long-term monitoring, elevational and recovery studies, and conservation projects; curating and integrating these across institutions would provide stronger baselines, reduce duplication, and sharpen policy planning (Nada *et al.* 2012). Taxonomic and genetic baselines are likewise needed to resolve cryptic diversity and support accurate field identifications (Jusoh *et al.* 2020).

Citizen and community science can bridge geographic and resource gaps when coupled with training and expert validation (Lewis *et al.* 2021). In urban parks such as Bukit Kiara, structured protocols allow volunteers from Friends of Bukit Kiara to monitor solitary fireflies (Friends of Bukit Kiara 2025). In riverine and mangrove systems, local communities and tour operators contribute long-term observations that track change and threats, as in the Selangor River programme (LUAS 2025). Trained volunteers and students are especially valuable for remote or high-elevation surveys (Nada *et al.* 2023). Ensuring data quality through training, photographic vouchers, and detailed metadata makes these efforts interoperable with professional datasets.

CONSERVATION ACTIONS

Over the past two decades, Malaysia has demonstrated leadership in firefly conservation, initiating the Selangor Declaration after the 2010 International Firefly Symposium (revised in 2014; Lewis *et al.* 2024), which ultimately led to the formation of the Fireflyers International Network (FIN) and the IUCN SSC Firefly Specialist Group (FSG) in 2018.

At the national level, firefly habitats are indirectly protected through legislation and policies governing permanent reserved forests, mangroves, river reserves, and environmentally sensitive areas. Research on solitary fireflies in Malaysian forests has shown that key habitat features such as canopy closure, leaf litter depth, presence of water bodies, and proximity to primary forest strongly influence firefly diversity and recovery following disturbance (Nada *et al.* 2023). These findings reinforce the importance of forest protection policies that maintain structural complexity rather than focusing solely on forest cover extent.

Local-level protection has been most explicit and operational in Selangor, where long-term research and monitoring directly informed policy outcomes. The gazettement of sections of the Selangor River as a Protection Zone under the Lembaga Urus Air Selangor (LUAS) Enactment, followed by the development of the Action Plan on Conserving the Fireflies of Selangor River 2022 – 2030 (Khoo *et al*. 2022), represents one of the clearest examples in Malaysia where sustained scientific evidence translated into enforceable conservation measures. The Action Plan integrates river basin management, land-use control, habitat rehabilitation, sustainable ecotourism, and stakeholder roles into a single implementation framework (LUAS 2025). Research along the Selangor River also demonstrates that maintaining natural riverbank vegetation behind display trees is vital for supporting larval, prey, and egg-laying populations (Nada 2011). Solely planting the *Berembang* tree, *Sonneratia caseolaris*, without broader habitat restoration, is insufficient to sustain firefly populations.

For forest-dwelling and solitary fireflies, protection in both natural and selectively logged forests is vital. Research indicates that once-logged forests can recover firefly diversity if structural complexity is preserved, whereas repeatedly logged forests exhibit poorer recovery. Moreover, numerous firefly populations persist outside protected areas and remain vulnerable (Nada 2023). Integrating firefly habitat requirements into environmental impact assessments, river and forest management, and urban planning is essential for their long-term survival (Lewis *et al.* 2024). There is also the need to integrate firefly requirements into forest management and restoration policies (Nada *et al.* 2023).

Looking ahead, Malaysia is set to achieve a conservation milestone. Wong (2022) published the Congregating Firefly Zones (CFZ) in Malaysia which established the basis for future firefly research in Malaysia. This pioneer work led to the planning of Malaysia Mangrove Firefly Conservation Action Plan, launched on the 28th of October 2025, and may result in the world's first national firefly conservation strategy. If this plan succeeds, it will help protect a key part of Malaysia's natural heritage and set an example for other countries in Southeast Asia. As Liani (2025) says, "*It takes a village to keep fireflies flashing.*" There is still a lot to do, especially in finding new species and helping populations recover, but there is a flash of hope for the future. Shine on!

Acknowledgements : We are grateful to Dr Lesley Ballantyne for her support and thoughtful feedback, which have been invaluable to this manuscript. Our sincere thanks also go to our friends at the IUCN SSC Firefly Specialist Group and Fireflyers International Network, whose continued encouragement helps illuminate our path. Most of all, we dedicate this work to Sonny Wong, in appreciation for over twenty years of friendship, trust, and for sharing the wonder of fireflies with us.

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