Special Ecology Feature

Habitat Enhancement for Fireflies

Text by Chan Su Hooi
Photography as credited

FIG. 1. *Pyrocoelia* sp. adult male emitting light (Photo: Colleen Goh).

Introduction

Fireflies are insects that belong to the order "Coleoptera". From the family "Lampyridae", which means "shining ones" in Greek, these beetles are widely regarded as fascinating and charming insects as they have the capability to emit light (Fig. 1). The precisely timed bioluminescent flashes produced by the adults of some species are actually courtship signals for species and mate recognition. The colour of the light, as well as flashing behaviour, varies according to the species of firefly. The sole purpose of the adults is to mate and reproduce, and they die soon after the reproduction process is completed. Interestingly, the larvae, pupae, and the eggs emit light. Scientists believe that the larvae use their luminescence to warn predators that they have toxic secretions or are distasteful.

Among the interesting discoveries by scientists on how the firefly's light is produced by scientists is that more than 90 percent of the energy spent to generate the light actually produces light. This is indeed very efficient, especially when compared to an incandescent light bulb that gives off about 90 percent of its energy as heat and only about 10 percent as light. This light is actually a cool chemical reaction where luciferin (an organic substrate) reacts with luciferase (an enzyme) in the presence of oxygen in the photic organs in the firefly's abdomen. The energy for this reaction comes from ATP, or adenosine triphosphate, which is an energy source that is produced during photosynthesis and respiration and used by cells for biological reactions.

The full life cycle of fireflies ranges from four months to one year. In general, adult fireflies can live for two to four weeks. The larvae take two to ten months to pupate, and the pupae take one to two weeks before emerging as adults. An example of a firefly's life cycle is shown in Fig. 2.

Fireflies can be found throughout the world, from temperate to tropical regions. Their habitats range from mountainous river valleys (e.g., Great Smoky Mountains National Park, Tennessee, USA) to agricultural plantations, forests, scrublands, and mangroves in Southeast Asia (e.g., Sungei Selangor, West Malaysia). In general, the fireflies in Singapore live in the wild and are found in rain forests, mangroves, scrublands, and grasslands.

Fireflies are highly sensitive towards the environment. They, and especially their larvae, are intolerant of pollution and chemicals. Therefore, the presence of fireflies is considered to be a good biological indicator of an unpolluted and healthy environment. In fact, in Japan, firefly larvae are used for the biological testing of treated wastewater before the water is discharged into the sea.

It is unfortunate that firefly populations are declining in many parts of the world. Habitat destruction and environmental degradation—due to activities such as logging and river modification, water pollution, and the indiscriminate spraying of pesticides and chemicals—can and do adversely affect the adult and larva firefly populations. Even light pollution, for example, in the form of streetlights or intense floodlights from buildings and highways, can affect the mating behaviour of fireflies. These factors contribute to the overall decline of firefly populations.

Singapore Fireflies and Where They Are Found

In Singapore, there are about 11 species of fireflies, with a majority of these species found only in well forested areas. Some of the more common fireflies that have the potential to be attracted to and inhabit the enhanced habitats discussed in this article are *Pteroptyx valida*, *Colophotia praeusta*, *Pyrocoelia* sp., *Stenocladius* sp., and *Diplocladon* sp.

FIG. 2. Life cycle of *Pteroptyx valida*, a firefly species found in the mangroves (Photos: Colleen Goh).

The *Pteroptyx valida* is found in Singapore mangroves. Their adults tend to favour the mangrove species *Avicennia alba*. They were also observed among other species of mangroves, such as *Rhizophora apiculata* and *Sonneratia alba*. The larvae inhabit areas with moist, wet soil, and damp leaf litters composed mainly of *Hibiscus tiliaceus* leaves and are found in the mangroves and mangrove fringes where *Acrostichum aureum*, *Acanthus ebracteatus*, and *Acanthus ilicifolius* are present.

The *Colophotia praeusta* can be found in the scrubland. The adults occur among grasses and weeds in moist areas with few trees and thick grass.

The *Pyrocoelia* sp., *Stenocladius* sp., and *Diplocladon* sp. are found in Singapore secondary forests. The adults of *Pyrocoelia* sp. tend to frequent the forest fringe in open areas, as well as forested areas. The larvae of the *Pyrocoelia* sp., *Stenocladius* sp., and *Diplocladon* sp. inhabit areas with moist, wet soil, and leaf litters at the forest fringes.

Firefly Habitat Requirements

The basic requirements of a firefly habitat are a source of clean water, a clean and cool environment, damp and high humidity, and no light pollution. If any of these conditions are not met, fireflies are unlikely to proceed with their reproductive cycle. This is why an environmental assessment of the selected site is necessary before one carries out restoration or development work.

In general, a firefly habitat can be divided into three main layers—vegetation cover for the adults, the ground surface for the eggs and larvae, and the underground for pupae. However, this applies only to terrestrial fireflies, which this article will focus on. Aquatic fireflies, which have a different breeding behaviour from terrestrial fireflies as their larvae live in water before pupation, will not be discussed here.

Habitat requirements of firefly adults

Most firefly adults do not consume food at all. They imbibe water or extrafloral nectar, which is believed to provide them with supplementary liquid. Adults depend mainly on the stored energy from their larval stage for their sustenance. This may perhaps explain the short adult lifespan. Most fireflies are inactive during the day, taking shelter on the underside of leaves or among vegetation, and emerge only during the night to find a mate. The mating habits vary according to species. In some species, the males fly around emitting light and scouting for females that are emitting light on the ground or vegetation. In other species, the males emit light on a tree, thereby attracting the female. After mating, the female looks for a suitable place to lay the eggs.

Firefly adults appear to have a preference for certain species of plants and trees that they use for mating and for shelter. Their preferred egg-laying substrates include moist or wet soils, crevices, leaves, and moss.

Habitat requirements of firefly larvae

In contrast to the adult fireflies that do not actively feed, the larvae of fireflies are vicious carnivores. They prey mainly on snails, slugs, and earthworms. Some species even prey on the larvae of other species, or their own kind! Snails are closely associated with firefly larvae, as they are the main source of food for the majority of firefly species (Fig. 3 & 4). Therefore, one needs to ensure that a conducive environment is created for the snails by providing appropriate decomposing matter, especially leaf litter and dead tree logs. Firefly larvae tend to avoid light

In Singapore, there are about 11 species of fireflies, with a majority of these species found only in well forested areas.

during the day by resting under leaf litters, soil, and stone. Below are the lists of required substrates for firefly larvae and pupae.

Required substrate for the larvae:
- Moist soil
- Leaf litter

Required substrate for the pupae:
- Moist soil
- Leaf litter
- Rock crevice

Recommendations For Firefly Habitat Development

It is not easy to develop a firefly habitat. The restoration work requires a significant investment of careful planning, time, resources, and consistent monitoring before results can be seen. The restoration of a firefly habitat could take up to three to four years, or more, before significant results can be observed. A habitat created from scratch could take many more years. It is thus recommended that firefly habitat development should be first attempted on an existing natural habitat that once hosted fireflies or that has the requirements to potentially support a viable firefly population.

Before any planning and development works are carried out, it is crucial to do an environmental assessment of the selected site to assess the suitability of the area. The previously mentioned requirements of cool ambient temperature, high humidity, and absence of light pollution should be addressed. The site should be a forested area, a scrubland, or adjacent to a water body (e.g., reservoir, pond).

Further, there should be minimal disturbances to the existing natural environment or habitat during development. The use of heavy machineries at the development site should be minimised. If night lightings are necessary (though they are discouraged), they should be dim while the throw of the light should be kept low onto the middle of the walkway. Avoid illuminating the tree canopy, vegetation fringe, and the surrounding area, as it might reduce the visibility of actual light emitted by the fireflies and interfere with any ongoing mating rituals.

The ideal firefly habitat

It is worthwhile to bear in mind that the habitat should have the capacity to support both firefly adults and their larvae. Ideally, there should be tall trees adjacent to or surrounding the habitat, which may require deliberate planting of suitable tree species. These trees provide shade and shelter for both the adults and larvae, and in some species, for mating displays. They can also help block off possible streetlights and other lighted areas to help increase the darkness that is more conducive for firefly reproductive behaviour.

The creation of small channels adjacent to, around, or within the area for a supply of water is also useful. This maintains ground moisture and a damp habitat, which are very important for egg laying and for the larvae and pupae to thrive. To ensure a sufficient food supply (i.e., snails), the provision of decomposing matter such as leaf litter and dead tree logs is necessary.

Mangrove Habitat

In mangroves, a narrow channel or channels can be created, their widths depending on site conditions, with inlets at the fringe of the mangroves from seawater and freshwater sources. This allows the flow of freshwater and seawater (Fig. 5). However, in some cases, erosion may arise as a result of the creation of channels. It is therefore advised that a trial implementation be carried out and monitored before the full implementation of this method. Firefly larvae and some of the snails they feed on tend to thrive in the intertidal zone with brackish water (seawater diluted with freshwater). Leaf litters are important for the larvae and should not be removed as part of the routine maintenance of a park (Fig. 6).

Recommended plants for planting:
- Api-api putih (*Avicennia alba*)
- Bakau minyak (*Rhizophora apiculata*)
- Perepat (*Sonneratia alba*)
- Berembang (*Sonneratia caseolaris*)
- Nipah (*Nypa fruticans*)
- Piai raya (*Acrostichum aureum*)
- Jeruju hitam (*Acanthus ebracteatus*), mangrove fringe
- Jeruju putih (*Acanthus ilicifolius*), mangrove fringe
- Sea hibiscus (*Hibiscus tiliaceus*), mangrove fringe

CLOCKWISE FROM TOP LEFT FIG. 3. *Pteroptyx valida* larva feeding on *Subulina octona*, a common terrestrial snail (Photo: Colleen Goh); Fig. 4. *Pyrocoelia* sp. larva removing faecal matter from snail before feeding on it (Photo: Colleen Goh); FIG. 5. Brackish water channel along mangrove fringe providing moist ground for larvae and snails (Photo: Chan Su Hooi); FIG. 6. Leaf litters inhabited by larvae and snails (Photo: Chan Su Hooi).

TOP FIG. 7. Scrubland with clear open space (Photo: Chan Su Hooi).
BOTTOM FIG. 8. Stream adjacent to sparse forest vegetation providing moist and damp environment for fireflies (Photo: Chan Su Hooi).

Scrubland and Grassland Habitat

While the enhancement of an existing grassland is still more realistic, it is possible to attempt creating a scrubland or grassland habitat. This type of habitat should be developed near a water body to provide constant moist ground at the grass bed.

Certain plant species are recommended, but avoid overcrowding the scrubland or grassland with trees. A characteristic of scrubland should be kept—a clear open space (Fig. 7). Allow the site to develop naturally (i.e., with the natural growth of other grasses and plants) after the planting work has been done.

Recommended plants to be planted:
- Guinea grass (*Panicum maximum*)
- Lalang (*Imperata cylindrica*)
- Acacia (*Acacia auriculiformis*)

Rain Forest Habitat

Two approaches to achieve rainforest habitats that support fireflies are possible. The first is to enhance the habitat at the fringe of an existing rainforest by making sure that leaf litters are not cleared and removed. Dead tree logs should be left in place or brought in to create a more conducive environment for snails to thrive. Where applicable, the creation of a small shallow stream, of width half a metre or less and approximately one metre away from the edge of the vegetation, is considered helpful. Within the one-metre zone, between the vegetated edge and the stream, the substrate should be composed of soil and leaf litter instead of substrates like granite chips, hardcores, and associated gravels.

The other approach is to plant a variety of forest tree species at a selected site with the potential to host firefly populations. The same concept of the former approach can be applied here. It is worthwhile to set aside an open space with sparse forest vegetation adjacent to the densely forested site and a clear open space next to the sparse forest vegetation. The males of some firefly species fly around in open space scouting for females emitting light on the ground or in vegetation. In addition, it is beneficial to create small streams within the core forest area, as well as alongside the open space adjacent to the sparse forest vegetation (Fig. 8). Streams play an important role in a firefly habitat. It is expected that this second approach would require a much longer investment of time before results can be observed.

FIG. 9. Celebrate! (Photo: Colleen Goh).

It is difficult to recommend specific plants to be introduced to this habitat as not much information is currently available on the tree species that forest firefly species are dependent on. In the absence of this information, members of the *Dipterocarpaceae* family—*Shorea*, *Hopea*, *Dipterocarpus*, and *Anisoptera*—should be planted.

Habitat Enhancement Work in Sungei Buloh Wetland Reserve

With the information obtained from a firefly survey carried out in Singapore, National Parks Board aims to enhance the firefly habitats at the Sungei Buloh Wetland Reserve (SBWR) so as to provide a more conducive and sustainable environment for the fireflies and increase the firefly population at the nature reserve.

Habitat enhancement works are being carried out at six selected sites within SBWR. The measures taken include:

- Removal of overgrown weeds to make way for leaf litters, for the benefit of the larvae and snails.
- Grass cutting (hand-held grass cutting), to provide food for the snails.
- Keeping *Hibiscus tiliaceus* leaf litters, which are important for the larvae and their prey.
- Removal of *Dillenia suffruticosa* dried leaves in the water channels to prevent blockage in water flow as these leaves decompose very slowly. The channels are also kept free from human litter to ensure the provision of clean water.
- Creation of water channels at the mangrove fringe to provide moist ground for the larvae and snails.
- Planting of *Avicennia alba*, which is used by the adults for mating displays and shelter.

The preliminary results are promising, and an increase in SBWR's firefly population has been observed. Moving forward, regular maintenance of the firefly sites at SBWR will be continued. In addition, regular monitoring of the firefly population at the SBWR will be carried out.

Recommendations for Monitoring

To see if the implementation of restoration and development works is successful, it will be important to monitor the firefly population at the restored site, by assessing whether there has been growth in the firefly population. The monitoring of the firefly population should be done in the early part of the night, starting from dusk (typically 7:30 p.m.). The date, time, ambient temperature, humidity, moon phase, soil moisture, vegetation density, and the population sighted should be recorded. These field surveys can be done once every two or three months at the initial set-up of the habitat and be increased to once a month when fireflies start to establish themselves at the site.

Conclusion

To yield a higher success rate in the restoration work, it will be necessary to monitor the restored or constructed habitat closely. Ensure that plants are growing well, as they provide shelter for the fireflies, and create a canopy to keep the ground and area moist and ambient temperature low. Check the water channels and streams regularly to make sure that the flow of water is not choked up or blocked by silt or leaf litter. Ensure that adequate leaf litter is present on the ground at all times and that the site is kept free of human-made rubbish. Grass cutting can be carried out at the vegetation edge as this would provide food for the snails. However, only manual hand-held grass cutters should be used.

Do not, through the course of park maintenance, remove leaf litter from the firefly habitat. Avoid activities or actions that would disturb the leaf litter, such as raking, because firefly larvae and pupae live in these unsightly accumulations of leaf litter. There should strictly be no application of pesticides, herbicides, and chemical fertilisers in the area. Human movement (such as trampling) within the firefly habitat should further be avoided.

It is important to note that the desired outcome of a viable and sustainable firefly population may be obtained only three to four years, or longer, into the future. It is only when a substantial population of firefly adults and larvae has been consistently present at the site that success of the restoration works can be assured (Fig. 9).

References:

Ohba, N., and S.H. Sim. 1994. "The morphology, behaviour and life cycle of *Pteroptyx valida* (Coleoptera: Lampyridae) in Singapore." *Science Report of Yokosuka City Museum* 42: 1-11.

Chen, T.R. 2003. *Fireflies of Taiwan*. Taipei City: Field Image Press.