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External morphology and ecological study of the firefly, *Pteroptyx tener* at Kampong Kuantan, Selangor, Malaysia

OHBA Nobuyoshi* and WONG C. H.**

マレーシアのセランゴール川に生息するホタル *Pteroptyx tener* の外部形態と生態学的研究

大場信義*・ウォン C. H.**

キーワード：**外部形態，生態学的研究，*Pteroptyx tener*，ホタル，マレーシア**
Key words: **external morphology, ecological study, *Pteroptyx tener*, firefly, Malaysia**

The firefly, *Pteroptyx tener* is approximately 5 mm in body length. It lives in the intertidal mangrove zone along the Selangor River, Malaysia. The fireflies congregate on the 'display' mangrove trees and flash synchronously. We did a morphological study and ecological investigations of this species in site, the native habitat, the behavior and habits, the luminescence pattern, and the population density, among others from 1998 to 2001. In addition to that, we compared them with the Papua New Guinean firefly *Pteroptyx effulgens* and with other species of firefly. As a result, the density of the population was different according to the investigation site, and it was found that female ratio increases during the day. The female luminescence color is the same as the male but, it has a different shade of green from the female of *effulgens*. The luminescence flash pattern of *P. tener* is composed of a main peak and 2-3 small peaks similar to the male *effulgens*. The flash interval is approximately 0.25 seconds. It is about 1/3 faster than that of *effulgens*. This firefly can readily change the intensity of the light of the small peaks. The flash interval of a small peak is approximately 0.1 seconds between intervals. Therefore the firefly can suddenly change the flash pattern. The 'flashing' light of female *tener* does not fade off completely and the intensity changes. This luminescence control system is similar to that of the *effulgens*. Flashing started around 19:45, when the intensity of the surrounding light was about 0.05 lx. The synchronous flashing continued to about 5:00 in the morning. Female's ovipositional behavior began at 20:30 and was not observed by about 21:30. The mating behavior of this species has improved the chance of copulation by gathering at a tree and blinks simultaneously. Male and female distinguished each other by their flash pattern and by the shape of their light organ.

集団同時明滅するホタル *Pteroptyx tener* はマレーシアのセランゴール川に沿ったマングローブ地帯に生息し，体長は約5 mmである。ホタルはヒルギ属の1種の木に年間通して多数集合する。我々は，1998～2001年の期間，本種の外部形態と生息環境，発光行動，生態学的な調査研究を行った。本種の生息密度と性比は調査地点ごとに異なっていた。特に生息密度は夜間に高く，昼間に低下する一方，雌の比率は昼間に高く，夜間には低くなった。雌の発光色は雄と同様であり，著者の一人である大場が既に明らかにしたパプア・ニューギニアのホタルの *P. effulgens* の雌の発光色とは相違した。本種の雄の発光パターンは主ピークとそれに連なる2～3の小ピークで構成され，*effulgens* に似ている。主ピーク間は約0.25秒であり，それは *effulgens* のものより短くおよそ1／3であった。本種は各ピーク

* Yokosuka City Museum, 95 Fukadadai, Yokosuka, 238-0116, Japan. 横須賀市自然・人文博物館.
** Malaysian Nature Society, JKR641, Jalan Kelantan, Bukit Perekutuan, 50480 Kuala Lumpur, Malaysia. マレーシア自然協会.
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の光の強度を自由に変えることができる。小ピークの発光間隔は約0.1秒であり，この間隔で自由に小ピークを立ち上げたり，下げたりすることができる。雌は約0.1秒間隔で非常に速く点滅しているために，一見すると瞬きを伴う連続した発光に見える。この発光パターンは，*effulgens*の雌のものとほぼ同様である。*tener*は19:45頃に周囲の明るさがおよそ0.05 lxとなったときに発光を開始し，集団同時明滅は朝5:00ごろまで続いた。雌の産卵行動は，20:30に始まって，21:30以降には確認できなかった。*tener*の交尾行動は，特定の木に集合し，雄は同調発光することで交尾の機会を高めたと考えられた。雄と雌は相互の発光パターンと外部形態の相違などによって識別していると考えられた。

Introduction

Synchronous flashing fireflies have been reported primarily from mangrove trees along brackish rivers, under tidal influence or the mangrove-*nipah* swamps. Mass synchronism occurs in Papua New Guinea (Buck J. and Buck E., 1966; Haneda, 1966; Wing *et al*, 1983; Ohba, 1992,1999, 2003), Philippines, Thailand, Malaysia (Bassot and Polunin, 1967; Case, 1980; Ohba, 1988, 1993, 2001), Indonesia, and sub-tropical India. Geographical range of synchrony has been enlarged to include Japan (Ohba, 1984). The firefly, *Pteroptyx tener*, from the Selangor River in Malaysia, is found in large population along the mangrove zone and emits light throughout the year.

The flashing behavior of this population begins just after sunset, and continues just before sunrise. The flashes are completely synchronized.

There are a few synchronous flashing fireflies known to the Southeast Asia region and some ecological behavior has been studied on the fireflies including *P. tener*. While, one of the author of this paper, Ohba have analyzed the luminescent pattern of synchronous flashing firefly, *Pteroptyx effulgens* in Papua New Guinea in detail. However, there was no analysis done on the synchronous flashing of *P. tener*.

The luminescence phenomenon of *P. tener* of the Selangor River raises people's concerns in recent years. A lot of tourists visit these habitats and how sustainably use and protection has become an important management question. In addition to that, the threats of water extraction at midstream, factory discharges, and other environmental influence such as salt intrusion have become inevitable. Therefore, the Malaysian government wants to know how to maintain the habitat for the fireflies' survival by maintaining the appropriate water level of the Selangor River at the same time providing water for the people. The ecological research of the firefly and on environmental mitigation measures was assigned to the Malaysian Nature Society (MNS) for a detailed study. The authors are to advice on the conservation of the habitat, ecological research and the biology of the *P. tener* fireflies as requested by MNS.

Below are the results of our studies from 1998 to 2001. The authors did more than five studies on the synchronous fireflies *P. tener*, over the period from 1998 to 2001, in Kampong Kuantan area, Kuala Selangor district, Selangor, Malaysia.

Materials and methods

The firefly, *Pteroptyx tener* is researched in the field and in the laboratory. This species of firefly is active nocturnally. They flash synchronously on the mangrove trees along the banks of a river in Malaysia throughout the year. The body length of the firefly is approximately 5 mm and the body color is pale brown.

The locality of the investigation is in Kampong Kuantan, Selangor River, Malaysia.

Detailed investigations and methodology are as follows:

- The external morphology of the firefly was observed through a binocular microscope.
- Finer details of the external morphology, was photographed with a scanning electron microscope, and observation was done in detail.
- A photograph of the habitat was taken, and recorded as the observation site.

- The density and sex ratio of the firefly population was calculated by the number of fireflies, which were collected from the 2 m × 2 m surface of a tree in the habitat by sweeping with an insect net.
- We examined the composition of mimic insects against the firefly population; and its seasonal variation using the same method for calculating the population density.
- We observed the activity of *P. tener* in the daytime (10:00) and nighttime (after 20:00), and recorded their behavior by taking photos.
- The all night activity habit of the fireflies was observed from sunset until predawn.
- Flash patterns were recorded by an 8 mm digital video camera (Sony Handy Cam) with Star Light Scope (light intensifier) and then analyzed with a computer software (Makino *et al*, 1994).
- We recorded the luminous behavior of the fireflies with the video camera, together with the temperature and the light intensity, etc.
- We observed ovipositional behavior along the muddy river banks and the grassland around the house.
- We collected and identified predators of the firefly population during the day and the night time.

Study Site

The study sites are mainly along the Selangor River upstream from Kampong Kuantan to Kampong Inche Bahan (Fig. 1).

Habitat of Selangor River (Fig. 2): The River flows on the west coast of Peninsular Malaysia, and the source of the river is from the Titiwangsa Range or Main Range. The average width of a river in the main habitat is about 70 m, while, further upstream where the mangrove vegetation disappears is about 30 m. The riverbank is muddy and covered with mangrove vegetations with oil palm, orchards and coconut estates in some areas. The difference in the water level is between 2 and 3 m, which is caused by the sea tidal effects which occurs twice a day. The flow of the river changes direction whenever there is a high tide. The water quality is muddy. The traditional *kampong* houses scattered along the banks of the river, with cultivated fields and small jetties. The artificial lighting has gradually increased, and increasingly affecting the firefly habitat.

Currently a high dam has been constructed far upstream, which will maintain the flow of river throughout the year. But the threat in the near future will be from the water extraction plants not far from the firefly habitat. Too much extraction will cause the water level to be lowered that will increase the water salinity further upstream. This

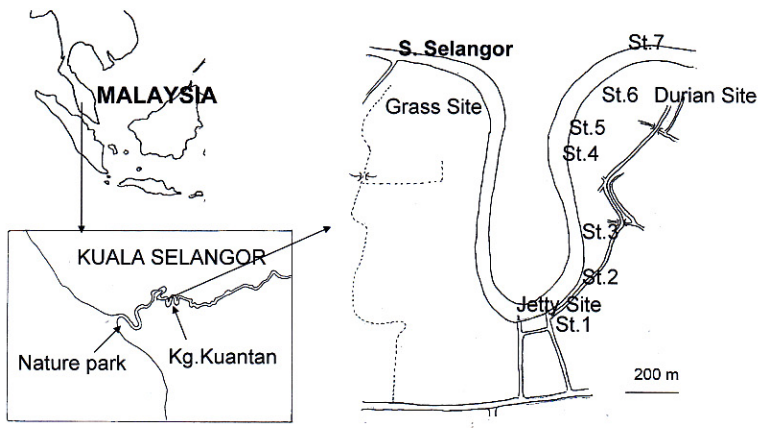

Fig. 1. The sketch map of the firefly, *Pteroptyx tener*, habitat along the Selangor River, Kampong Kuantan, Selangor State, Malaysia.

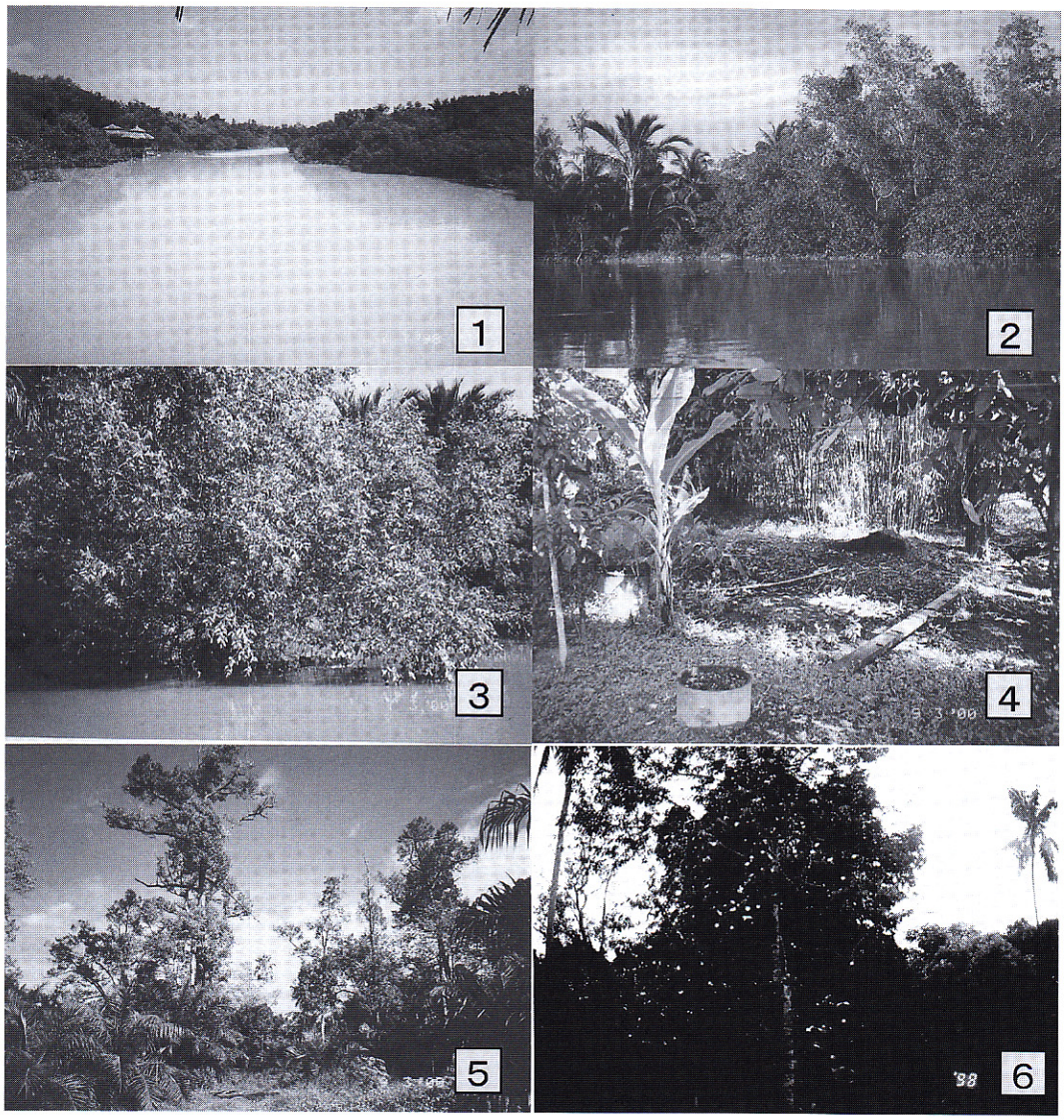

Fig. 2. Habitat environments of *P. tener* along the Selangor River, Malaysia.
1. near the jetty site, 2. near the St.6, 3.near the St.6, 4.near the St. 5, 5. Habitat of larvae (near the St. 3). 5-6. Durian site (6. lot of *P. tener* emitted light).

may have an effect on the growth of the mangrove display trees and the firefly habitat.

Results

External morphology

1) Adult (Fig. 3)

Body length of male: Average length 4.98 mm (n = 14, Max = 5.64 mm, Min = 4.25 mm, S = 0.38).

Body length of female: Average length 5.17 mm (n = 4, Max = 5.46 mm, Min = 4.95 mm, S = 0.25) (Table 1).

A relative size of each part measured is as follows (Table 2).

Male (Fig.3-1,2): Body width/Body length (BW/BL) = 0.40, Pronotum length/Pronotum

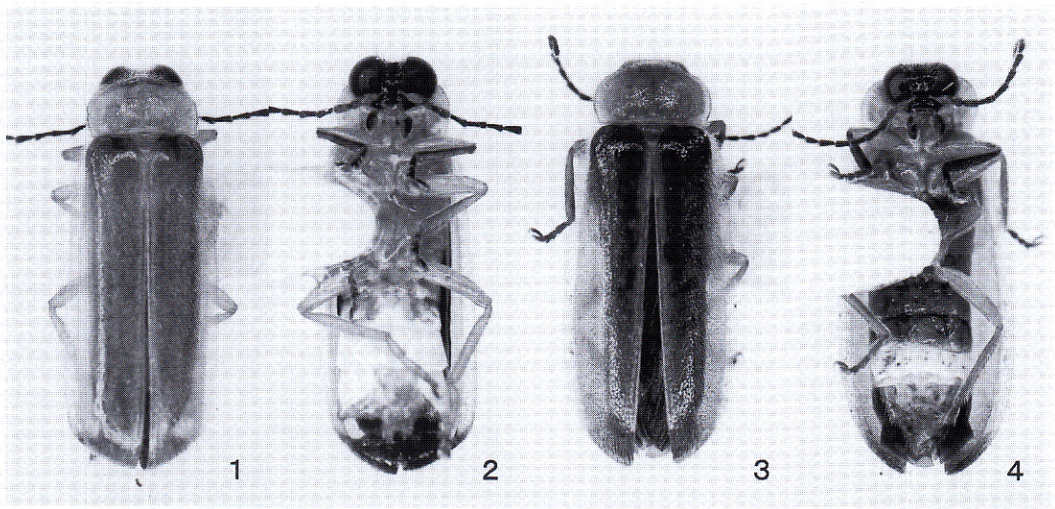

Fig. 3. 1. Dosal view of male of *Pteroptyx tenner*, 2. Lateral view of male, 3. Dorsal view of female, 4. Lateral view of female

Table 1. Measurements of body size of *Pteroptyx tener.*
BL: body length BW: body width EL: length of elytra EW: width of elytra
PL: pronotum length PW: pronotum width
Av: average, n: number Max: maxim of measurements Min: minim of measurements, s: standard deviation

	BL	BW	EL	EW	PL	PW
male						
Av	4.98	2.05	3.96	1.01	0.77	1.27
n	14	5	14	14	12	12
Max	5.64	2.19	4.61	1.28	0.92	1.50
Min	4.25	1.88	3.07	0.81	0.61	1.15
S	0.38	0.12	0.39	0.12	0.09	0.10
female						
Av	5.17	1.9	4.16	0.95	0.8	1.36
n	4	1	4	4	4	4
Max	5.46	1.90	4.33	1.03	0.93	1.48
Min	4.95	1.90	4.06	0.89	0.67	1.21
S	0.25		0.12	0.06	0.13	0.11

Table 2. Physical measurements ratio *Pteroptyx tener.*

Male	BW/BL	PL/PW	PW/PL	PL/EL	EL/PW	EW/PL	EW/PW
Av	0.40	0.61	0.32	0.20	3.11	1.30	0.79
n	5	12	12	12	12	12	12
Max	0.45	0.70	0.39	0.24	3.33	1.52	0.85
Min	0.38	0.50	0.30	0.16	2.54	0.73	0.73
S	0.03	0.06	0.02	0.02	0.21	0.13	0.04
female							
Av	0.38	0.59	0.33	0.19	3.08	1.21	0.70
n	1	4	4	4	4	4	4
Max	0.38	0.67	0.36	0.22	3.39	1.41	0.74
Min	0.38	0.45	0.30	0.16	2.81	1.08	0.64
S		0.10	0.03	0.03	0.24	0.15	0.05

width (PL/PW) = 0.61m, Pronotum length/ Elytra length (PW/EL) = 0.32, Elytra length/ Pronotum length/ Elytra length (PL/EL) = 0.20, Elytra length/ Pronotum width (EL/PW) = 3.11, Elytra width/Pronotum length (EW/PL) = 1.30, Elytra width/ Pronotum width (EW/PW) = 0.79

Female (Fig. 3-3,4): BW/BL = 0.38, PL/PW = 0.59, PW/EL = 0.33, PL/EL = 0.19, EL/PW = 3.08, EW/PL = 1.21, EW/PW = 0.70.

There is not a big difference in the physical form between a male and a female. The color of male and female is pale brown or dark brown on the whole body. It was observed that there are color variations among the *P. tener* firefly from Selangor River.

The body is long and slender, from the prothorax pronotum to the abdomen, which is almost parallel on both sides.

Apex of the male elytra bends inside (Fig. 3-2, Fig.6-1). Such an elytra is a very peculiar form in the Lampyridae family.

The elytra: The thin and transparent hind wings under the elytra can be seen. Hind wings are dark color. The epipleuron is parallel, shoulder has a little protusion, and is in lustrous dark brown. Both edges are yellowish brown and translucent, and the apex of the elytra is dark brown.

Fig. 3 shows the external morphology of the whole body of male and female.

Head: The Compound eye is large and black in color. The female's is smaller than the male's.

Antenna: 13 thin flagellums; length of the antenna is 1/2.5 of the body length. The maxillae are small and black.

Thorax: Pronotum is oblong quadrangle and the former corner is round. Center of frontal margin projects a little forward. Center of the prothorax weakly up heaves, and rounded. The central suture is indistinct. The color is yellowish brown, and a little lustrous on the whole.

The female is almost similar to the male except for the morphology of the apex of elytra and size of the compound eyes

Foreleg is yellowish brown, tibia and tarsus of forelegs is dark brown. Tarsus of mid leg and third tibia of fore leg are amber in color. The female is similar to the male.

Abdomen: There is a light organ under a transparent ventral plate, and it is separated into two parts, right and left (Fig. 4), in the sixth abdominal segment. One half of the fourth segment is milk-white (Fig. 4). It can be assumed that this is the organization of the light organ. Male light organs are in the 4th, 5th, and sixth abdominal segments (Fig. 4).

On the other hand, apex of elytra for the female is not curved inside (Fig. 6-2). The elytra suture is a little lighter color. The legs are the same as the males. The female's light organ is milk-white and at the fifth abdominal segment.

Male genitalia: lateral lobe is shorter than median lobe.

External fine morphology of the head by scanning electron microscope

Head (Fig. 5): large, and the vertex becomes hollow (Fig. 5-1,2). Width of the male's head is 1.15 mm, and the width of the compound eyes is 0.5 mm. The compound eye is large and spherical, and the facet is hexagon-shaped. The width of a facet is 20.9 μm (Fig. 5-4). Scape is 284 μm in length, pedicel is 161 μm in length, third flagellum is 252 μm in length, and the forth flagellum length is 266 μm and the length of a sensory hair is 81.5 μm in the fourth flagellum (Fig. 5-3).

On the other hand, female's head width is 1.02 mm, and the width of the compound eye is 0.38 mm (Fig. 5-4,5). Compound eyes are spheri-

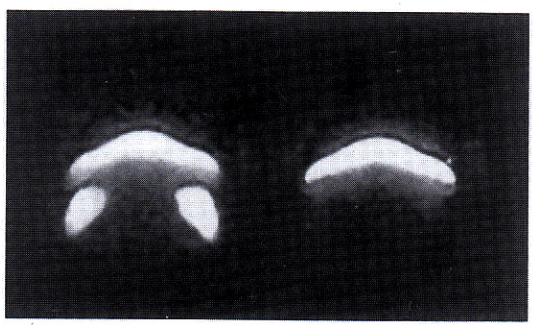

Fig. 4. Light organ of *Pteroptyx tener.*
Left: Male light organ, Right: Female light organ

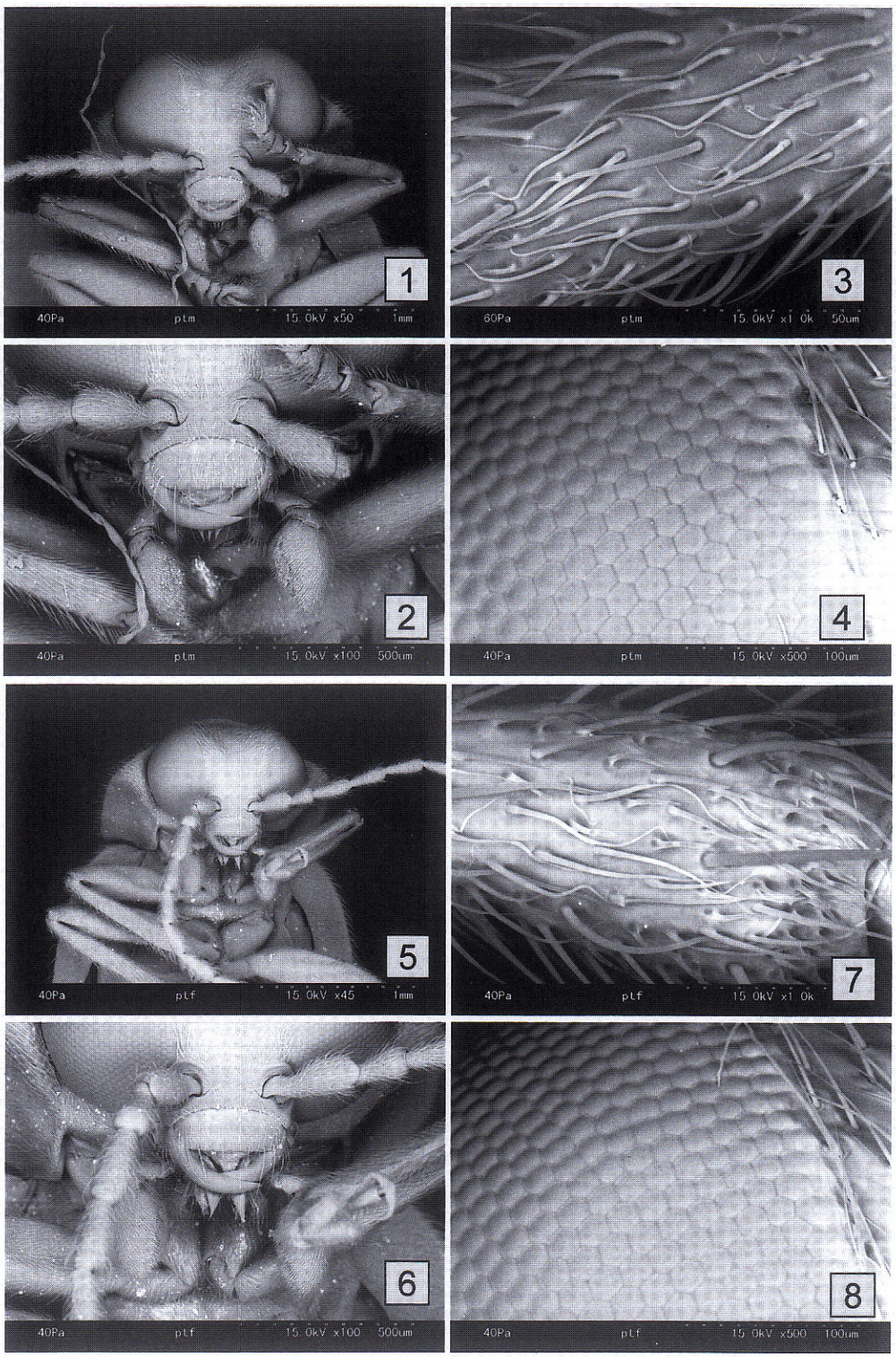

Fig. 5. Magnified details of external morphology of the firefly, *Pteroptyx tener.*
1. Head of male, 2. Mouth parts of male, 3. Antenna of male, 4. Facets of male, 5. Head of female, 6. Mouth part of female, 7. Antena of female, 8. Facets of female

cal and smaller than the males. The width of facets is approximately 20 μm (Fig. 5-8). Scape is 280 μm in length, pedicel is 161 μm in length, third flagellum is 286 μm in length, and the length of 242 μm and forth flagellum length is 242 μm, the length of a sensory hair is 99.8 μm in the fourth flagellum (Fig. 5-7).

The number of flagellum is 13, with the pedicel being the shortest. Thin long hairs are bristling in each flagellum. Mandible is curved like a crescent, and the point is sharp (Fig. 5-6).

Elytra: Apex of elytra bends inwards (Fig. 6-1).

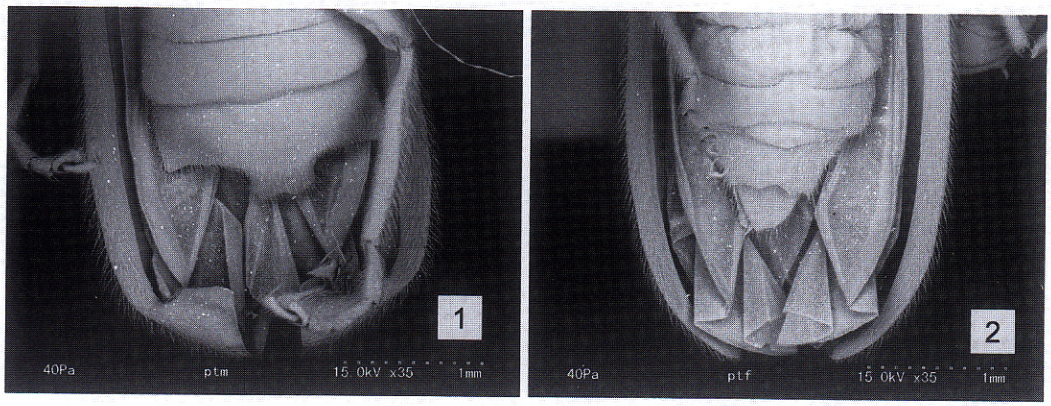

Fig. 6. Magnified details of external morphology of the male *P tener's* abdomen.
1. Male, 2. Female.

Table 3. Ambient and water temperature of the habitats of *Pteroptyx tener* in Selangor River, Malaysia.
At: Ambient temperature, Wt. Water temperature.

Date	Time	At(℃)	Wt(℃)	Notes
19980210	17:00	32.0	31.7	Ground temperature 28.9 ℃
	20:00	27.1		Synchronous flashing
	21:20	26.3		
19980211	18:22	31.4		
19980212	20:04	29.9		
	22:14	28.8		
19980213	20:40	29.9		
	22:14	28.8		
19980707	13:07	28.1	27.0	
	18:30	29.4	30.3	
	19:06	30.9		
	18:29	28.4	30.3	St.1
	19:38	27.4		
	19:40	27.3		
	19:46	27.8		
19980708	9:16	27.3	27.8	
	19:45	28.6	27.1	St.1
20000309	19:21	30.0	29.0	
20000307	9:45	34.6		
20000308	9:31	30.5	30.0	
20001007	19:37	28.2	25.9	Synchronous flashing
20001007	20:11	28.2	25.8	St.7
	21:05	28.3	25.7	
20001008	9:00	28.8	26.1	
	19:56	28.3	25.9	
	19:50	28.3	25.9	Synchroous flashing
	21:20	28.2	25.5	under flow
20000306	11:00	33.9	29.5	10.49Km from the sea
20010421	19:40	26.8		

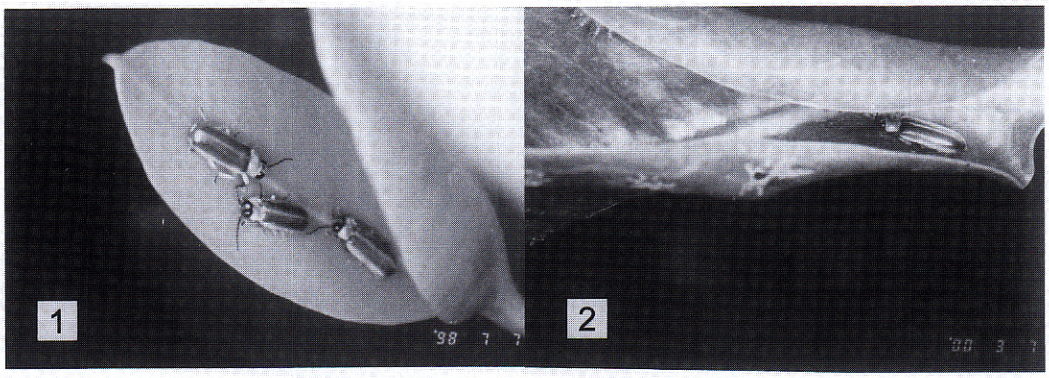

Fig. 7. Resting males on a leaf of the display tree in the habitat at Selangor River during daytime.

The rear end of the abdominal segment is scooped out on both side and has a peculiar shape. It is not scooped out in the female (Fig.6-2).

Habitat

The synchronous flashing fireflies are usually found congregating on one 'specific' berembang tree (*Sonneratia. caseolaris*) along the intertidal river (Fig. 2-3). This mangrove plant grows well in tidal rivers and is dominant when the salinity is between 3-10 parts per thousand. At the Selangor River, the plants form a thin belt of about 18 kilometers starting before Kampong Sepakat and extending beyond Tanjung Pasir. The trees are concentrated along 2 points of the river. One is about one kilometer to the west of Kampong Kuantan towards Kuala Selangor and the other is about half a kilometer to the east towards Batang Berjuntai. The trees density is often in only one row thick.

Ambient air and water temperature is shown in Table 3.

Living condition

The firefly, *P. tener* is found in the mangrove zone on both riverbanks around Kampong Kuantan along the Selangor River. The fireflies perch on the leaves of *S. caseolaris* (It is known as Berembang in Malay) (Fig. 7-1). Plantations such as oil palms and the natural sago palms are increasing but the *S. caseolaris* of the riverbank and the natural environment is rapidly changing in this place.

Table 4. Beginning flash time of *Pteroptyx tener* in Selangor River, Malaysia.

Date	Time	AT	lx
19980210	20:00	27.1	0.01
19980213	19:50		0.21
19980707	19:47	27.8	1.06
20000309	19:41	28.0	
20001007	19:35	27.3	

Activity habit

The observation results of the activity habit are shown in Observation record 1.

Starting time of flashing

The luminescence starting time for *P. tener* was between 19:35-20:00 and the light intensity was between 0.01-1.06 lx (Table 5). The temperature was between 27.1-28.0 °C when the firefly began to emit light.

It shifted gradually from a partial to the overall synchronous flashing with the passage of time. The luminescence cycle was not synchronized immediately after beginning of flashing (Table 4).

Synchronous flashing

It was after 19:45 that we could observe synchronous flashing. The flashing activity stopped during the heavy downpour and continued synchronous flashing all night after the rain had stopped. After

2:00 am, the number of flashing individuals gradually decreased; and it decreased very much until 5:00 am, then it stopped flashing by 5:15 am. The temperature of the habitat at nighttime was 28.8 °C and the temperature difference was small.

'Time lag wave pattern chain reaction of synchronous flashing

The phase and pattern of the synchronous flashing of *P. tener* will be (adjusted by the individual firefly) changed every time when the population size of *P. tener* gets larger.

If the light was emitted from the right side, the light is rapidly transmitted to the left as a chain of light wave and repeatedly. When a habitat of *P. tener* was small, we often observed a chain of light waves which is extended out like a concentric circle.

Behavior of perched individual firefly on leaves of *Sonneratia* at nighttime

The distance between each individual was 10 cm or more in a tree colony of *P. tener*. Not more than one individual firefly perched on a single leaf was observed at night.

Other irregular occurrence of fireflies are on a wide range of plant species, namely the *Hibiscus tilaceous, Sapium indicum, Metroxylon sagu, Gigantochloae ligulata, Ficus microcarpa, Ficus retusa, Urena lobata, Tetracera indica,* one occasion on a single *Avicennia* sp., and isolated durian (*Bombax* sp) and mangosteen (*Garcinia* sp) trees.

Since nearly 95% of the fireflies prefer *S caseolaris,* the study of the phenology, ecology and habitat becomes an important feature in the study of the fireflies. Despite the preference for displaying on *Sonneratia* trees, not all will have a firefly display. It is estimated only 50% of the *Sonneratia* trees have a display at any one night. There appears to be a great level of fidelity exhibited by the fireflies. The reason for this level of fidelity is uncertain. (MNS, Strategies for Conservation and Tourism Development at Sungai Selangor Riparian Forest, 1997, 5:34-36)

Daytime perching behaviour of individual firefly

The number of individuals is less than that of nighttime. More than one individual firefly perched on individual leaves is discovered (Fig. 7-1). Some individuals are found inside the abandoned nest that a moth's larva rolled up (Fig. 7-2).

Emergence of adult firefly

Whenever there is a high tide, the Selangor River water covers the field behind a private kampong house. Two individual fireflies emitted light at the grassland along the shore of a small waterway near the private Kampong house, and one individual flew while emitting light. Many larvae of *P. tener* were observed emitting light here.

Table 5. Population density of *Pteroptyx tener* in Selangor River, Malaysia.

Date	time	Number of male	Number of female	Total individuals	Female ratio	Notes
20001017	20:30	28	14	42	0.33	St.7
20001017	20:30	28	8	36	0.22	St.6
19980708	8:21	25	11	36	0.31	
19980708	9:16	20	20	40	0.50	
19980709	15:30	9	5	14	0.36	
19980709	15:30	13	8	21	0.38	
19980211	9:30	7	2	9	0.22	
19980211	9:30	4	7	11	0.64	
19980215		7	2	9	0.22	
20000306		24	3	27	0.11	
20000309		7	4	11	0.36	
20000309		2	4	6	0.67	
20000309		10	9	19	0.47	
20000309		12	3	15	0.20	
20001008	9:45	15	5	20	0.25	St.7
20010422		9	4	13	0.31	
Av		13.75	6.81	20.56	0.35	
n		16	16	16	16	
Max		28	20	42	0.67	
Min		2	2	6	0.11	
s		8.61	4.87	11.98	0.16	

Formation of a group

We observed that the formation of a group upstream of Kampong Kuantan on the April 21, 2001. We observed it at high tide, when the water level was high and the mangrove trees' canopy are lower. We were able to observe down on the fireflies from the boat. From this location, it will be easy to see new individuals that came flying and flashing to the tree. However, we could not confirm how many and whether any new individuals really came flying and flashing to the tree though the number of luminescence individuals increased in the tree.

Population density of adult *P. tener*

1) Density of population in each investigation site

The density of the imago in each investigation site was shown in Table 5 and Observation record 1.

The highest density site was St. 7. There is forest along the river. The forest width is about 100 m behind the site and after that lays the agriculture land. The density was different in each investigation site. Mangrove trees decreased, and the living density of *P. tener* also gradually decreased in the upstream region from the jetty site (near St. 1) 2 km or more.

Two kilometer or more upstream from the jetty, the mangrove trees gradually decreased, and the density of the firefly also decreased.

St. 7 has the highest density during the investigation done at 20:30 on the 17 October 2000. We counted 28 males and 14 females and the total number of 42 individuals.

Moreover, 36 males and 8 females, the numbers of total were 36 individuals in the nearby site. These were collected respectively within the range of 2 × 2 m (1-3 m in height).

2) Density of the firefly on the facing the river and facing landward from the same tree

Number of perched fireflies on leaves was obviously fewer facing landward compared with those facing the river.

3) Sex ratio

Sex ratio in each investigation site is shown in Table 6 and Observation record 1.

Sex ratio was different in each investigation site. Numbers of individuals was 14 females and 28 males at St. 5, and 8 females and 28 males in another nearby site. Female percentage was 33%, and 22% respectively.

4) Density of the firefly in the daytime

The results of sweeping fireflies with an insect net in each investigation site done during the day as well as the night-time, the numbers of individual and density during the day was obviously lower compared with during the night (Table 5).

The observation done at 09:16 on the 8 of July 1998: St. 5 had the highest density.

The number of individuals was 20 females, and 20 males respectively. In the adjoining site, number of individuals was 25 males and one female. Each female percentage was 50%, and 4%.

The number of individuals was 13 males and 8 females, at 15:30 when the temperature was high. At this time, the female percentage was 38%.

Flash pattern

In the field, there is a difference in the female and male flashing. However, the female's flash interval was irregularly in the laboratory. After sunset, the flashing gradually changes from time lagged synchronizing and irregular towards synchronizing.

Flash patterns of synchronous flashing when the males perched on leaves

Analytical results of flash patterns, which were observed on 10-16, February 1998, are shown in Fig. 8, 9 and Table 7. At 21:05, on February 10, 1998, the male flash average interval was 0.28 seconds (n = 15, s = 0), at 21:39, 0.25 seconds (n = 17, s=0).

At 22:37, 0.26 seconds (n = 16, s = 0.01). At 21:05, s = 0.01) and small peaks following the main peak was 0.11 seconds in interval (n = 17, s = 0). Recorded temperature was every 26.3 °C. Figure 10 shows the result of flash patterns and luminescent behavior observation near the Jetty site (St. 1) from 19:30, February 13 till 5:00 am of the next day.

The luminescence behavior continued until

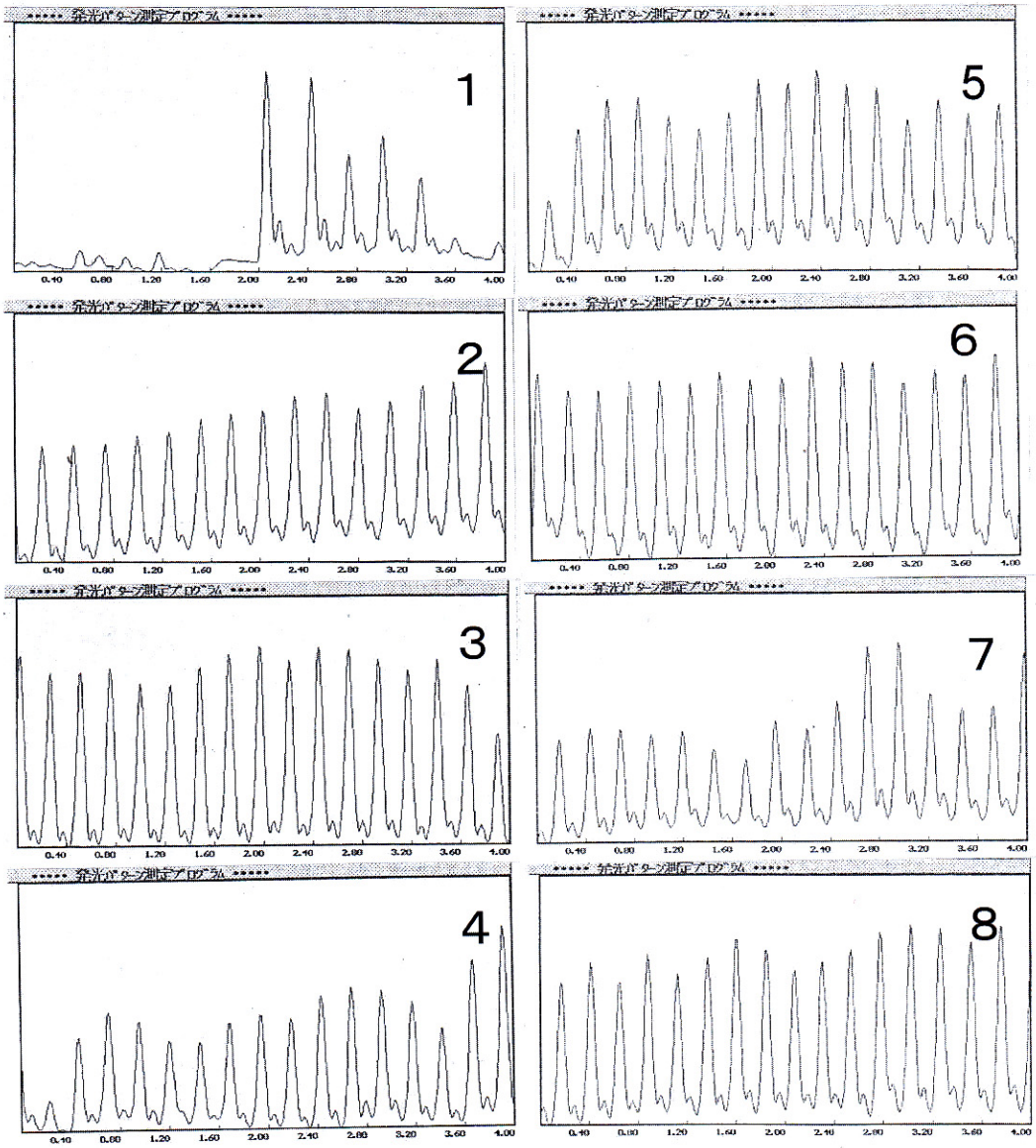

Fig. 8. Flash patterns of the firefly, *Pteroptyx tener* in Selangor River. Recorded on 10 February, 1998. Left to light recorded and recording time is 4 seconds.
1. 21:07 male begins flashing, 2. 21:36 synchronous flashing of a male, 3. 21:39 male flashing, 4. 21:45 male flashing, 5. 21:49 male flashing, 6. 21:55 male flashing, 7. 22:10 male flashing, 8. 22:37 male flashing.

about five o'clock before daybreak. Observation stopped due to about two hours of heavy rain around midnight. However, the luminescence behavior did not stop when it was raining. The synchronous flashing continued but their flash interval gradually slowed down and continued until daybreak.

At 21:15, on February 13th, the average flash interval of males was 0.25 seconds (n = 16, s = 0), and between the flash and a smaller weak flash (small peak) was 0.13 seconds (n = 10, s = 0). (Temperature 29.5 °C).

Table 6 Flash interval of *Pteroptyx tener* in Selangor River, Malaysia.

Date	Time	Temp.(℃)	No	Av(sec)	n	Max(sec)	Min(sec)	S		
19980210	21:00	26.4	74	0.41	8	0.48	0.30	0.06	female	(Fig.11-1)
19980210	21:04	26.4	38	0.27	15	0.28	0.25	0.01	flying male	
			small peak	0.11	12	0.11	0.11	0.00		
19980210	21:05	26.3	39	2.94	11	17.55	0.18	6.11	flying female	(Fig.10-4)
19980210	21:05	26.3	63	0.20	15	0.28	0.28	0.00		
19980210	21:07	26.3	64	0.35	5	0.5	0.3	0.08		(Fig. 8-1)
19980210	21:11	26.3	40	0.33	10	0.50	0.23	0.07		
19980210	21:11	26.3	45	0.27	15	0.32	0.20	0.03	flying female	(Fig. 10-3)
19980210	21:13	26.3	20	0.24	13	0.23	0.26	0.02	female	(Fig. 11-2)
			small peak	0.11	4	0.11	0.10	0.00		
19980210	21:16	26.3	46	0.25	13	0.23	0.26	0.01	flying male	(Fig. 10-1)
19980210	21:17	26.3	47	0.24	13	0.25	0.21	0.01	flying male	(Fig. 10-2)
19980210	21:18	26.3	66	0.22	18	0.25	0.16	0.03		(Fig. 11-3)
19980210	21:23	26.3	41	0.28	17	0.29	0.26	0.01	flying male	
			small peak	0.12	15	0.12	0.12	0.00		
19980210	21:33	26.3	42	0.22	16	0.38	0.14	0.06	flying female	(Fig. 10-5)
19980210	21:33	26.3	43	0.98	20	15.08	0.13	3.33	flying female	
19980210	21:36	26.3	44	0.28	14	0.28	0.28	0.00		(Fig. 8-2)
19980210	21:39	26.3	37	0.25	17	0.25	0.25	0.00		(Fig. 8-3)
			small peak	0.11	17	0.11	0.11	0.00		
19980210	21:40	26.3	48	0.12	19	0.15	0.10	0.01	stimulated	(Fig. 10-7)
19980210	21:45	26.3	51	0.25	15	0.25	0.25	0.00		(Fig. 8-4)
19980210	21:45	26.3	58	0.12	27	0.16	0.09	0.02	stimulated	(Fig.10-8)
19980210	21:47	26.3	60	0.26	15	0.26	0.26	0.00		(Fig. 8-5)
			small peak	0.11	15	0.11	0.11	0.00		
19980210	22:04	26.3	68	0.43	10	0.91	0.24	0.28	female	
			small peak1	0.10	10	0.11	0.07	0.01		
			small peak2	0.08	5	0.11	0.04	0.04		
			77	0.33	8	0.33	0.33	0.00		
			small peak1	0.11	5	0.11	0.11	0.00		
			small peak2	0.11	5	0.11	0.11	0.00		
19980210	22:10	26.3	69	0.28	12	0.28	0.28	0.00		(Fig. 8-7)
			small peak	0.12	11	0.12	0.12	0.00		
			71	0.12	22	0.16	0.10	0.03		
19980210	22:10	26.3	69	0.27	14	0.29	0.27	0.00		(Fig. 8-7)
19980210	22:24	26.3	76	0.21	17	0.31	0.17	0.04	female	(Fig. 11-4)
19980210	22:37	26.3	70	0.26	16	0.26	0.24	0.01		(Fig. 8-8)
			small peak	0.11	8	0.13	0.10	0.01		
19980210	22:45	26.3	16	0.25	5	0.25	0.23	0.01		
19980213	21:03	29.6	19	0.24	16	0.23	0.24	0.00		
19980213	21:15	29.5	22	0.25	16	0.25	0.24	0.00		(Fig. 9-1)
			small peak	0.13	10	0.13	0.13	0.00		
19980213	21:19	29.5	24	0.25	15	0.25	0.24	0.00		
			small peak	0.13	7	0.13	0.13	0.00		
19980213	21:21	28.9	25	0.25	17	0.25	0.23	0.01		(Fig. 9-2)
19980213	22:05	28.5	31	0.24	18	0.24	0.25	0.01		
19980213	23:00	28.8	17	0.24	3	0.24	0.24	0.00		
			small peak	0.10	3	0.10	0.10	0.00		
19980214	0:00		12	0.23	17	0.23	0.23	0.00		
19980214	0:00	28.8	21	0.25	16	0.25	0.25	0.00		
19980214	0:02		12	0.31	5	0.31	0.30	0.01		
			small peak	0.11	6	0.11	0.11	0.00		
19980214	0:21		15	0.21	8	0.22	0.20	0.01		
			smalll peak	0.11	8	0.11	0.11	0.00		
19980114	0:55	28	18	0.33	8	0.31	0.35	0.02		(Fig. 9-4)
			small peak	0.12	6	0.12	0.12	0.00	havey rain,,sander	
19980214	1:03		13	0.29	5	0.30	0.29	0.01	hevy rain, sander	(Fig. 9-5)
			small peak	0.10	6	0.11	0.10	0.00		
19980214	2:02		3	0.30	12	0.30	0.30	0.00		
			small peak	0.11	10	0.11	0.11	0.00		
19980214	2:09		4	0.30	12	0.30	0.30	0.00		(Fig. 9-6)
			small peak	0.12	12	0.12	0.12	0.00		
19980214	2:10		5	0.30	8	0.30	0.30	0.00		
			small peak1	0.11	3	0.11	0.11	0.00		
			small peak2	0.11	2	0.11	0.11	0.00		
19980214	2:18		6	0.30	12	0.31	0.29	0.01		(Fig. 9-7)
			small peak	0.12	13	0.12	0.12	0.00		
19980214	2:25		7	0.29	6	0.30	0.29	0.00		(Fig. 9-8)
			small peak	0.10	12	0.11	0.11	0.00		
19980214	5:55	28	33	0.25	14	0.23	0.25	0.01		
			small peak	0.12	6	0.14	0.12	0.01		
19980216	21:20	29.5	23	0.25	13	0.25	0.24	0.00		

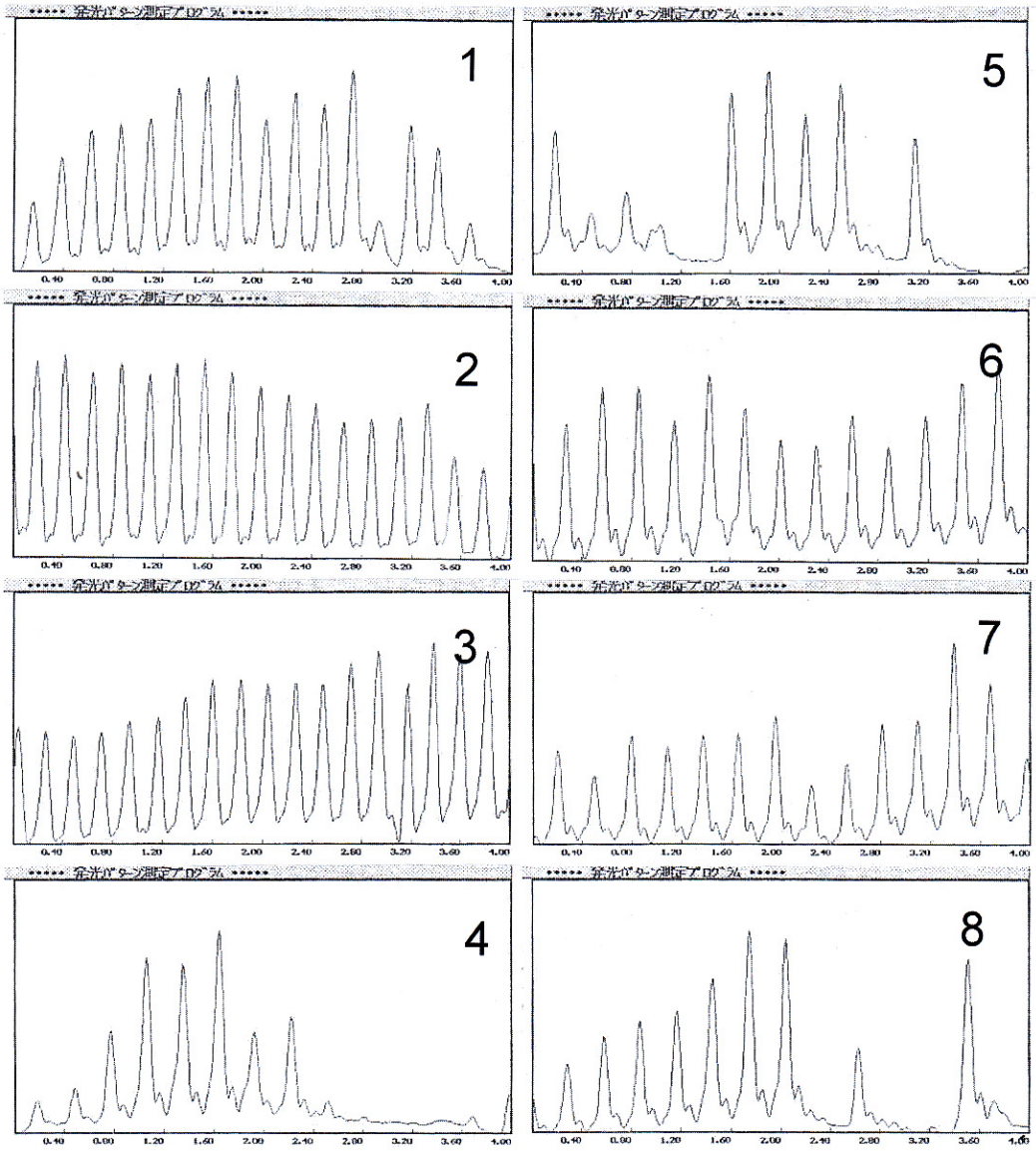

Fig. 9. Flash patterns of the firefly, *Pteroptyx tener* in Selangor River.
Recorded from 13 to 14. February, 1998. Recording time is 4 seconds
1. 21:15 male flashing, 2. 21:21 male flashing, 3. 22:05 synchronous flashing, 4. 0:55 male flashes in rain and sander, 5. 1:03 male flashes in rain and sander, 6. 2:09 male flashing, 7. 2:18 male flashing, 8. 2:25 male flashing.

At 22:05, the male flash interval was 0.24 seconds (n = 18, s = 0.01) (Fig. 9-3).

At 00:00, on February 14, the flash interval was 0.23 seconds (n = 17, s = 0).

At 02:20, the flash interval was 0.3 seconds (n = 12, s = 0). The small peak interval was 0.11 seconds between first small peak and the 2nd small peak.

At 05:55, the flash interval was 0.25 seconds (n = 14, s = 0) and 0.12 seconds between the main peak

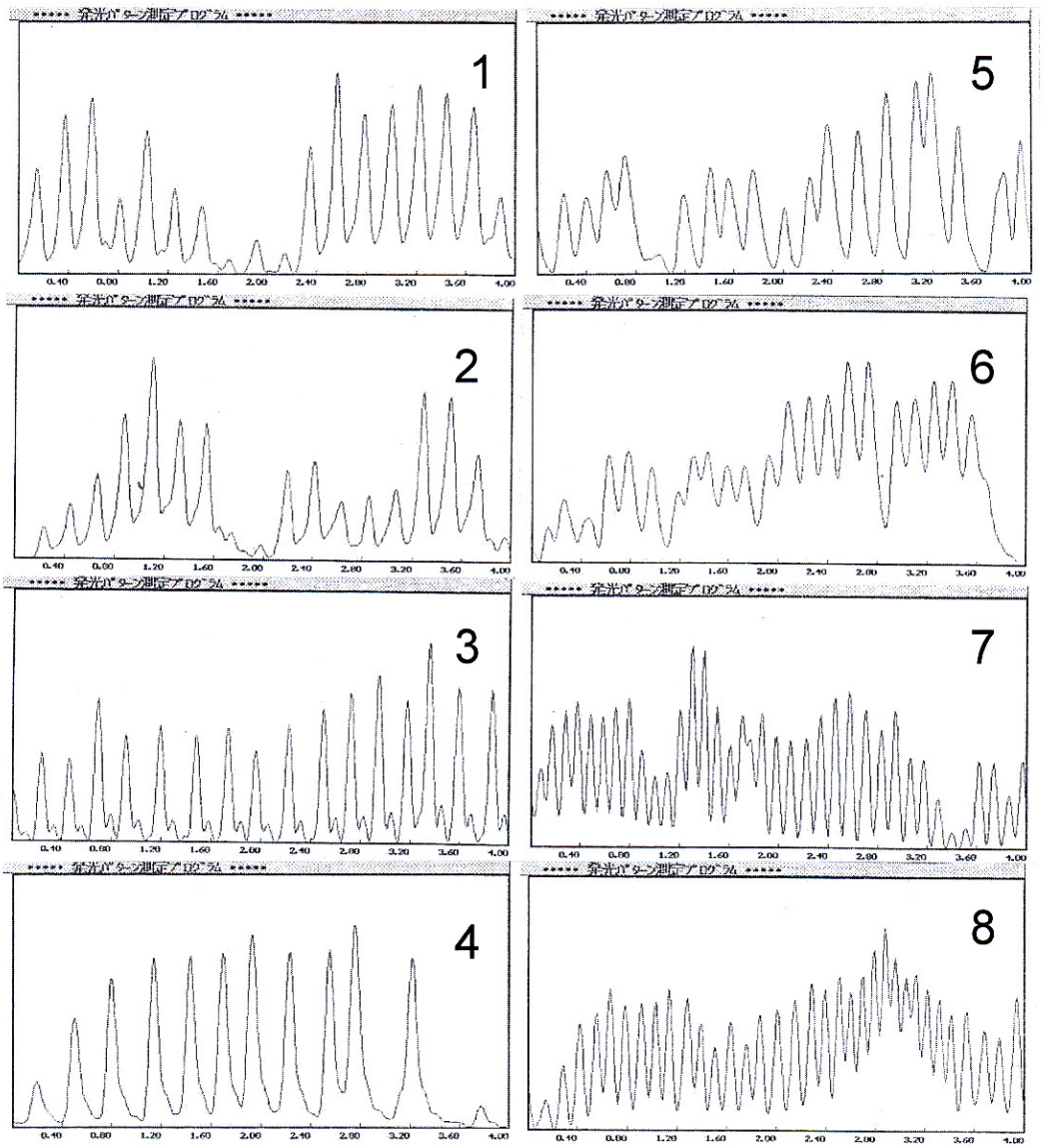

Fig. 10. Flash patterns of flying firefly and stimulated flash patterns of *Pteroptyx tener* in Selangor River on 10 February 1998. Recording time is 4 seconds.
1. 21:16 flying male flashes, 2. 21:18 flying male flashes, 3. 21:13 flying female flashes, 4. 21:11 flying female flashes, 5. 21:32 flying female flashes, 6. 21:34 flying female flashes, 7. 21:40 stimulus male flashes, 8. 21:45 stimulus male flashes.

and the first small peak.

Flash pattern of a male in flight

The flash pattern of a flying male is regular and almost similar to a perched male's flash pattern. When a flying male came to the firefly colony on a tree and in close range, it blinked at a faster. However a male almost stopped flashing when flying male came into the colony on a tree. On the other hand, males did not emit light when flying away.

At 21:16, on February 10th, the flash interval of a male in flight was 0.25 seconds (n = 13, s = 0.01) at 26.3 °C (Fig. 10-1).

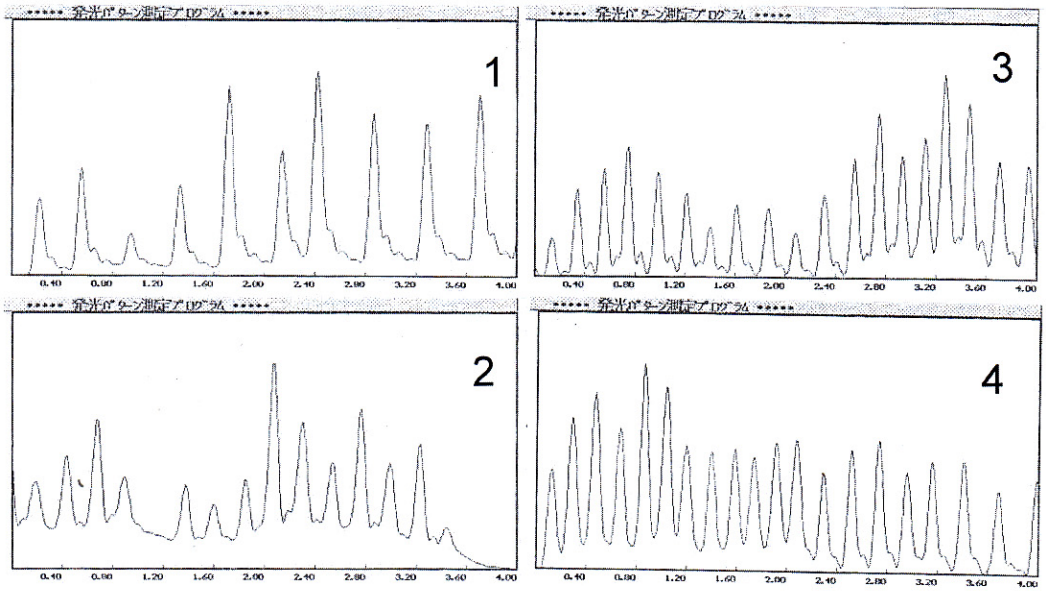

Fig. 11. Flash patterns of female *P. tener* firefly in Selangor River.
Recording time is 4 seconds
1. 21:10 on10 February 1998, female flashes, 2. 21:13 on 13 February 1998, female flashes, 3. 21:18 on 10 February 1998, female flashes, 4. 22:24 on 10 February 1998, female flashes.

At 01:23, the flash interval was 0.28 seconds (n = 18, s = 0.03) (Fig. 10).

Flash pattern of a female in flight

A female firefly leaving from the colony on a tree after copulating; the female firefly flew about 1m from the ground. The flash pattern of this female was observed with the naked eye as a continuous blinking light. The result of analyzing the flash pattern was as shown in Fig. 11. It was a peculiar luminescence pattern that her light was continuously blinking. The female flash interval was not constant as a male's.

At 21:04, on February 10th, 1998, the average luminescence interval was 0.27 seconds (n = 15, s = 0.01) at 26 °C and small peak interval was 0.11seconds (n = 12, s = 0).

At 21:17, flash interval was 0.24 seconds (n = 13, s = 0.01).

At 21:33, it was 0.24 seconds (n = 16, s = 0.06) (Table 6).

Male flash interval when a female was put in a net and approached the male

At 21:45, average flash interval was 0.12 seconds (n = 19, s = 0.01) (Fig. 10-8), at 26.3 °C, 0.12 seconds (n = 27, s = 0.01), and its flash interval became very short.

Flash pattern in the laboratory

At 11:30, on 7 March 2000, we recorded the flash pattern of a firefly indoors with a photomultiplier VTR camera. We arranged two transparent plastic bag of 40 × 60 cm and 20 males put in one of the bag and 20 females put in the other bag. Then we observed each flash pattern of *P. tener*. As a result, the flash interval became shorter for both sexes. Each male and female's flash rhythm became very fast without any synchronous flashing. Even if the number of individuals put into the plastic bag was decreased, the synchronous flashing was never observed.

Luminescence color

Luminescence color of both male and female is yellowish- green.

Fig. 12. Mimic insect (Cantharid-beetles) in the colony of *Pteroptyx tener* in Selangor River, Malaysia.

Copulation behavior

Copulation was observed at St.4 (N: 03.21.41.1, E: 101.18.05.3) at 20:40, on July 9th, 1998. Male and female copulated by turning backward to each other. The male inserted its apex of elytra that is bent inside under the female elytra and lifted the abdominal segment of the female with the hook of the elytra.

Ovipositional behavior

It was a fine day and temperature was 27.5 °C on the 10th February, 1998. The female flew blinking at 50 m inland from the riverbank (Fig. 2-4). The flight height was between 30-100 cm above the ground. Some of individuals flew down on the ground. Such behavior suggested that the female seeked suitable site to lay eggs. We could confirm 10 individuals within a range of 50 m. Such luminescence individuals were hardly seen after 21:30. There were few individuals that moved to the oviposition site between 19:30-20:00. At 20:00, the firefly colony was synchronously flashing on the mangrove trees. There were few fireflies in the inner side of the mangrove tree, but a lot of it by the river side.

Predators

The intertidal river mangrove zone river may be a good habitat for the firefly as the tidal water and mud banks prevented the predator red ants (or *Kerengga* in Malay) from preying on the fireflies.

Mimic insects in the population of *P. tener*.

The insect color looks like the *P. tener* is assumed to be a mimic insect is shown in the observation note 1, and Fig. 12.

At 9:30 on February 15. Nine firefly individuals, eight leaf beetles individuals, and one small Cantharid-beetles were included in the population, and mimetic insect's ratio was 50%.

On March 9 2003, at St. 5, four firefly individuals and one individual yellow large-size Cantharid-beetle were counted, and the mimetic insect's ratio was 20%.

At St.3, six firefly individuals, five medium yellow Cantharid-beetles individuals and one black Cantharid-beetle were included in the population. This mimic insect's ratio reached 46%.

At St 5, the firefly was 19 individuals including two species of Cantharid-beetles (large and small species) and 2 individuals of leaf beetles in the population. The ratio of the mimic insect percentage was 17%.

In this study, we could assume that the confirmed mimic insects were of three species of Cantharid-beetles and two species of leaf beetles.

Firefly and mimic insect's ratios were observed to have never exceeded 50%.

Population of *P. tener* in the Durian tree site

Fine and calm weather, atmospheric pressure was 1004 hps on July 9.

A tall Durian tree in the orchard located inland up to 100 m from the river. Mangosteens and bananas are cultivated around the Durian tree and even coconut trees too (Fig. 2-5). The place was over grown with grasses, as the owners did not maintain the place well. The drainage goes through, and a lot of small terrestrial snails live in the place. We confirmed two species of fireflies here, one of which was *P. tener* that gathered and flashes on the durian tree.

The temperature and the intensity of illumination of this *P. tener* are as shown in observation record 1.

Then in 1998, the fireflies moved to a mangosteen tree across the canal, which is about 50 m away (Fig. 2-6). In 2000, there were only a few fireflies opposite the mangosteen tree on another durian tree, which is about 100 m away. The tidal waters of the canals in the area are suitable to the prey of the firefly. We also observed another species of firefly in a peripheral meadow of this place. The firefly, *Luciola* sp. was larger than a *P. tener* and its elytra and pronotum is yellow. The firefly, *Luciola* sp. emitted light in the peripheral meadow.

Discussions

External morphology

Female firefly is larger than the male in terms of the compound eyes size and the body size which are the width (PW) of the prothorax and length (PL) of the prothorax, (EL) width (EW), length (BL) and width (BW), but the difference is not recognized in a relative size of each part.

The male's head and the compound eye's facet size are relatively larger than that of the females. The male's head width is 1.12 times of a female as observed with the electron microscope. The male's compound eye width is 1.31 times larger; mandible length is 1.05 times and facet (average) is 1.14 times. Clearly, the width of the compound eye is larger than that of females. It is considered that the male's form is adapted to seek a calling signal from a female. The difference size of the sense organ, which includes the compound eye, is reflected in another species (Ohba, 1978, 1983,).

The end of elytra is not curved in the female whereas the male have bent elytra at the end which curves inside. The hook of elytra of the male has the function to clamp securely onto the female abdominal segments when copulating with the female. In addition, the structure of the light organ differs clearly from the female. The different light organ structure is an important factor for mutually recognizing the male and the female.

Habitat

The synchronous flashing fireflies are usually found congregating on one 'specific' berembang tree (*Sonneratia caseolaris*) along the intertidal river. This mangrove plant grows well in tidal rivers and is dominant when the salinity is between 3-10 parts per thousand. In Kuala Selangor, the plants form a thin belt of about 18 kilometers starting before Kampong Sepakat and extending beyond Tanjung Pasir. This is the important micro-habitats of the Selangor River, where the fireflies come to display themselves at night.

The adult preference to congregate along the riverbank may be due to (i) the condensation of water and high humidity, (ii) the ability to communicate across the river due to the open space, and maybe (iii) the trees are protected by the tidal water from the predators e.g. red ants (kerengga).

The high-density site of the firefly is limited, and the forest and the woods exist behind that. Similarly the habitat of the larvae of *P tener* is limited and survives in the range where a lot of small land snail as prey that is in the grassland within 100 m from the riverbank. When it is a high tide, the water of the River covers the grassland near the house. We think that predator such as red ants, on the ground, do not gather easily on a tree where the firefly is during a high tide. Because the base of the tree is often covered with water, therefore the predator can't go up the tree.

Ambient temperature, water temperature, and ground temperature of each investigation site

Ambient temperature (At) and water temperature (Wt) on February, March, April, July and October from 1998 to 2001 are shown in Table 3.

A change of the water temperature and the ambient temperature of the habitat over time during a day is large although it does not vary much in a seasonal change. It becomes 28 °C or less at night after 19:30 and the temperature becomes 30 °C or more after 9:00 during the day. It is likely to become 30 °C or less when it is a cloudy during the day, even when it is fine weather the ambient temperature reaches to 35 °C and above. The fluctuation of the temperature is large because of the micro climate is very different at

each site.

The temperature rapidly goes down after dusk. However It stabilizes at about 27 °C after 19:30. It provides the suitable condition for thirsty fireflies because the dew condenses on the leaves when the temperature goes down and fireflies can suck the dew.

The water temperature is between 26.1 and 30 °C, we think that the fluctuation of water temperature is caused by the tidal effects.

The seasonal change of air temperature and water temperature is not large.

The time and the light intensity change in each investigation site. The intensity of light differs in each habitat is greatly affected by the conditions of the location and the microclimate of the habitat. The intensity of light changes only slightly as measured in different places.

At 19:43, it becomes 2 lx or less, and moreover, at 20:00, it becomes 0.01 lx or less.

Change in light intensity over time

The comparison of the light intensity measurements with time (about 18:20, 19:05, 19:43, 19:50, and 20:00) is shown below.

10 Feb. 1998	11 Feb. 1998	13 Feb. 1998	7 July 1998
Durian site			
18:22 535 lx			
19:04 33.0	19:11 194 lx	19:07 103 lx	
19:30 30.0	19:30 25.6	19:30 10.0	
19:43 1.05	19:44 2.51	19:43 0.85	19:43 1.88
19:43 0.85			
19:50 0.18	19:50 0.21	19:50 0.25	19:50 0.08
20:00 0.01	20:00 0.01	19:54 0.08	19:52 0.05

When the light intensity diminishes rapidly after 19:30, it changes from 10-30 lx to 1 lx in about 15 minutes. However, the reduction of the light intensity begins earlier during cloudy weather, but on the other hand, the reduction is slower during full moon.

It is not clearly seen in the difference of light intensity in a season.

The other habitat, "Durian' site" of *P. tener* is a solitary durian tree and in 1997 there is emergence from the surrounding damp areas. The site is away from the main firefly colonies, which are beside the river. This phenomenon may happen in other areas. This behavior is similarly observed in *P. effulgens*, which uses an imposing tall solitary tree, with the larvae sites surrounding the tree (Ohba, 1999, 2001). The area of emergence will depend on the availability of prey in high density. The size of *P. effulgens* habitat is 600-700 m in diameter.

The open spaces, which are gardens or plantation support a lot of invertebrate prey, especially snails, for the larvae to feed on. Debris of dropped fruits and leaves provide very suitable habitats for the snails to breed. The kampong houses are spaced apart with lighted areas for the larva to breed.

Ecology of *P. tener*

The compound eye is very sensitive to the ultraviolet light and sensing 0.021 lx of sunlight activates the flashing. The main element to trigger the flashing could be ultraviolet light.

Luminescence starting time and the light intensity

The fireflies begin to emit light between 19:35 to 20:00. The light intensity when flashing started was between 0.01 and 1.06 lx (Table 8).

This fluctuation of light intensity is caused by the different measuring point and condition of each location. Therefore, we measured the light intensity at a close range to the firefly. The typical measurement of the light intensity is 0.05 lx. when luminescence begins.

The temperature is usually at 27-28 °C when the fireflies begin to emit light.

Behavior of *P. tener* during the day

The number of individuals in the colony is far lesser during the day than at nighttime, with some individuals rested on the leaf or in a rolled leaf that was made by moth's larva. Sometimes, two or more individuals are discovered from a leaf. Therefore, it is assumed that some of the fireflies

that gathered at nighttime behind the forest were located nearby. And also some of the fireflies move to the forest before dawn.

Emergence

The possibility of adult emergence is high in the meadow and along the small waterway to the bank where the larva lives, and the imago emits light in that place.

We cannot confirm the number of individuals gathering, and the number of individuals' on the tree gradually increased.

Population density of the adult firefly

The highest density site is St.7. There is a green tract of land behind the site where the larva lived, therefore the high density of population is conducive by such environment. For this reason, the density is not the same depending on the difference of forest area behind each habitat. Based on our observation, the density of *P. tener* is about ten individuals per meter square. It is noted that a spatial density is different because of the fireflies found inside the tree foliage.

Firefly density facing on the river and facing landward on the same tree

The number of flashing individuals on the tree is obviously a lot on the river side, but very few on the landward side. It is thought that new imago can easily 'see' the light of the group, because there is no obstacle and the view is good on the river side.

Sex ratio

Sex ratio is different in each investigation site. Female ratio differs during nighttime and daytime. Female percentage is average 33% but came to 22% in certain places. However, the change in the female ratio becomes more profound during the day where the female ratio reaches 67% (Table 5). This shows that the possibility of a lot of male individuals move away after dawn.

Population density during the day

The number of individuals is lesser during the day than that of nighttime, and also the density is very much lower (Table 5). The highest population density ever reached was 40 individuals at 09:16. The most number of individuals is 21 at 15:30 midday when the temperature is high.

It is thought that the number of individuals is still a lot in the morning because the number of individuals moving away is few in the morning. However, it is presumed that the moving individuals gradually increased during the day when the temperature rises.

Flash pattern of synchronous flashing

The shape of the light waves unit (analyzed light signal of the firefly by a computer software) is composed of a main peak and 1-3 small peaks continuously. The light wave unit changes between 0.24-3.0 seconds depending on the time and the place, etc. The unit is very steady at intervals when the condition is the same. The interval itself is extremely constant that is between 0.11-0.12 seconds between the main peak and the small peak and in addition between first and second small peak (Table 6).

This flash pattern is basically the same as in the Papua New Guinea's firefly *P. effulgens* (Ohba, 1999), the Singapore's firefly *P.valida* (Ohba, 1993; Ohba and Sim, 1994), and the Japanese firefly, *Hotaria parvula* (Ohba, 1980, 2000). However, both the latter species do not flash synchronously.

It is found that the *P. effulgens* and *P. valida* can instantaneously start up a small peak and shorten the luminescence interval at any moment (Ohba, 1999). *P. tener* also changes the flash interval at any moment. When a male is stimulated, or the male make an approach to a female, the male flash pattern suddenly shortens its intervals, and comes to approximately 0.1 seconds.

This interval is the same between the small peaks, and it can be interpreted as the shape of flash pattern to start up all small peaks.

The luminescence behavior continues until about five o'clock before daybreak and the lumi-

nescence activity doesn't stop after the rain either. However, it was seen that the flash interval tends to be longer and after midnight the flash frequency gradually decreases.

Flash pattern of a male firefly in flight

It is almost similar to a male flash pattern of synchronous flashing on a tree. Only when a flying male approaches a group, the male emits light in this manner. On the other hand, the male doesn't emit light when leaving or during flight. It is an adaptive behavior, as the energy is not wasted.

Flash pattern of a female firefly in flight

When the female succeeds in copulating, she flies away in a low flight direction of about 1 m from the ground. Her light is continuous blinking. Otherwise, the luminescence pattern is basically the same as the male. The only difference is that the flash interval is not as constant compared with the male.

At 21.45, we approached the male with a female in a net, the male's flash interval was 0.12 seconds on average ($n = 19$, $s = 0.01$) (Fig. 10-8) at 26.3 °C and 0.12 seconds ($n = 27$, $s = 0.02$) (Fig. 10) and it becomes an extremely short flash interval. It can be thought that the male firefly received stimulation by the female's light, and then entered the state of excitement, and extended all the small peaks.

Flash pattern of the firefly in laboratory observation

The blinking cycle becomes extremely fast out of synch with each other when it put in a transparent plastic bag or the net separate for male and female. Even if the number of individuals is decreased in the plastic bag, they are not in synch with each other.

On the other hand, the male of *P. effulgens* exhibited the normal synchronous flash interval in the laboratory (Ohba, 1999).

Regulating the flash pattern

The male freely changes the luminescence interval regularly from 0.3 to 0.1 seconds.

It is possible to change it instantaneously by increasing the luminous intensity of these small peaks. The time interval of small peak is 0.1 seconds therefore the flash pattern is regulated freely at least 0.1 seconds. It is thought that the firefly regulates the flash pattern by extending the small peak, and thus erases a main peak. The regulation of flash pattern of *P. effulgens* is also quite similar to *P. tener.*

Synchronous flashing

The luminescence cycle does not become complete when they begin to emit light; however it shifts gradually from a partial synchronization tune to the full synch overall tune over the passage of time It is thought that the individuals of a small group will first synchronize their flashing then tune in further with the other small groups. The flashing behavior shifted the luminescence cycle from this to mutually follow the entire tune soon.

Males only synchronize their flashing, and the sensory organs such as their compound eyes are more developed than the female. Males of the firefly synchronized their flashing was observed clearly after 19:45. The luminescence activity is disturbed, and stops temporarily by the rainstorm and continued all night synchronous flashing. When the heavy rain stops the synchronous flashing begins again. Then the number of luminescence individuals gradually decreases, and stop luminescence activity until dawn. Synchronous flashing was noticeable during full moon, but was not observed easily. The moonlight was too bright for us to see the fireflies light.

Multiple time lag chain reaction wave patterns

The phase of synchronous flashing changes every moment when the surface area or size of the mangrove forest foliage is large in the riverbank. When the mangrove forest is small, it looks like the lights of a ferris wheel.

Such a luminescence phenomenon is thought to be the time lag when the nearest individual receives light signal from the other individual and

it is repeated from the first individual to the last individual (chain reaction) and it be came a spread of a light wave.

'Some patterns shifts from two directions horizontally zones then vertical zones then concentric outwards, then inwards, then in a circular motion then reverse the order again.'

Moreover, there is the time difference when the luminous individual is approximately half of the whole colony, where half of the individuals emits light and the other half doesn't emit light but do so alternately and continued so, the light wave of various patterns is simultaneously repeated on this species, as had shown in *P.effulgens.*

Behavior of perched individual flashing on a leaf.

The distance between individuals that emit light is 10 cm or more, and one individual perches only on a leaf. It is considered that each individual have their own territory during mating behavior at nighttime. The male emits light while walking along the edge of the leaf (Fig. 13), and transmits a light signal to the nearest individual efficiently. The male twists his abdomen and emits a light signal therefore it is a very suitable behavior to communicate with other individuals.

Mating behavior

Based on our observation, the mating behavior of *P. tener* is presumed to be as follows. The gathering of synchronously flashing males on a *S. caseolaris* tree attracted peripheral imago (both male and female). The chance of a male meeting a female has been improved by the density of the population. The female flash pattern does not synchronized with the male's flashes. When a male approaches a female, the female emits light but her flash interval is not constant. The flash pattern changes to about 0.1 seconds and blinks very fast when the male recognizes the female luminescence signal. The male and the female identify each other's light organ structures and began to copulate.

Fig. 13. The male of *P. tener* emited light signal while walking along the edge of the leaf.

Copulation behavior

Male and female copulate by a back to back pose. The male clamps on to the female abdominal segment by inserting its bent elytra and hold on tightly to prevent the female from parting. It is thought that this behavior is successful for copulation. The female could not easily be parted by this mode of clamping.

This copulation behavior is often observed at the back of the leaf in the day by *P. effulgens* (Ohba, 1999). But, copulating time is very long in this species. However, the period of copulation is shorter in *P. tener.* We also observed copulating behavior in the daytime in *P. tener* hence, *P. tener* is similar to *P. effulgens* on the form and the habit.

The copulation individual is hardly found in daytime, the copulation behavior is confirmed to 20:40 in this observation. In addition, copulation is done at night and presumed to have finished copulating before dawn from our observation. It is thought that the female stays on after copulating in the tree during the day and scatters from the group for egg lying at night. It is thought that a female ratio's rose during the day as reflected from the above.

Ovipositional behavior

The female flies away and emits a blinking light after copulating. The female moves inland from the riverbank at a height of 30-100 cm from the ground between 19:30-20:00. It can be presumed an ovipositional behavior. Several individual are

flying and landing on the ground. It seems that the female seeks a suitable place to lay eggs. The female individual decreases after 21:30 from this oviposition place. Such a scattering of female individuals was counted and ten individuals were within a range of 50 m.

It is considered that such a female copulated the previous night, In the oviposition behavior of the Japanese Gengi-firefly, *Luciola cruciata*, the females gather in a specific tree for resting after copulating (Ohba, 1988). The females rested on the tree for more than a day then flies and emits continuous light to seek ovipositon site beside the river bank. This may be a similar behavior for *P. tener* too.

Predator

The mangrove habitat with the intertidal river may be a good habitat for the firefly as the tidal water and mud banks prevented the predator red ants (kerengga) from preying on the fireflies.

The predator of the firefly is confirmed as follow. There are a lot of ants and spiders on the trees. Other predators are assumed to be amphibians, reptiles and birds or small mammals such as rodents and bats. It can be thought that the predation pressure such as birds with high learning ability is larger. However, it is difficult to confirm that in the field. If *P. tener* is preyed by birds, However, if birds like the firefly, it is difficult to keep the high density population at the same place throughout the year. It can be assumed that a lot of fireflies become good food for predator if the firefly has no defensive material for the enemy. It is thought that *P. tener* is able to keep forming a large group because there is a main cause to prevent the predation pressure from birds now.

The Lampyrids releases a nasty smell when stimulated, and secretes a body fluid. One of the authors, Ohba has reported reflex bleeding of Japanese fireflies. Based on the report, the fireflies emit bad smell and defensive material. It is clarified that this habit evades some predators (Ohba and Hidaka, 2002).

From the above, the possibility of secreting the defensive material to which the enemy is evaded is higher in *P. tener.*

A lot of different kinds of mimic insects are confirmed in the colony as in *P. effulgens* (Ohba, 2003), and mimic similar to *P. tener* is confirmed, and it may be considered a universal phenomenon based on our investigation.

Mimicry

The other insects that are found on the mangrove leaves are mainly leaf-beetles and Cantharid beetles, and many smaller varieties of spiders, grasshopper, mantis, ants, caterpillars, aphids, hornets, bees, wasps, flies, mosquitoes, etc.

The mimics have a resemblance to the fireflies in color patterns. They are mostly from the Cantharid beetles, and a moth was also found to look like one. The mimics looked like fireflies and their color may be totally yellow, or with an orange head and a black body or totally black. The *P. effulgens* from Papua New Guinea also have their own set of mimics (Ohba, 1999, 2003).

Who mimics who? Why do the other insects want to mimic the fireflies? Evidence of the abundance of the black form Cantharid beetle, during a sample sweep in the afternoon of 2000, it is found at the lower reaches of the Selangor River near Bukit Belimbing. This may suggest that perhaps another suspected firefly *P bearni*, which resembled it, may have existed here a long time ago. When the vegetation changes as the land advances to the sea, the firefly may have died out and taken over by *P tener* and the mimics continued to flourished. Therefore the black Cantharid-beetles may be their mimics.

The fireflies contained a kind of noxious or poisonous substance, which does not taste good (Ohba and Hidaka, 2002) and this could be a reason for the mimics to roost on the same trees with the fireflies.

The mimics may be use as an indication of the diversity of the firefly habitat. Further work work is needed to determine the health of the habitat from the density of these mimics as a bio- indicator. The ratio of the mimics in relation to the fire-

fly has not been fully studied.

Various mimic insects in the colony of *P. tener*.

The Cantharid-beetles or leaf beetles are the majority that is presumed to be a mimic insect as the color looks like *P. tener*. The composition and number of individual mimic insects changes during the day and during nighttime.

In the daytime, there are a lot of mimic insects, but did not increased more than the mimic insect's ratio of nearly 50%. The mimic insect's ratio is usually between 20-30% from our observations. Such mimetic insect's ratio greatly varies from different locations. For example, mimic insects increased their range by securing the wider greenery behind the habitat of *P. tener*. The composition ratio of a mimic insect is higher than we had expected in this observation. It is postulated that mimetic do not like *P tener* to gather on a mangrove tree whenever mimic insects was observed to exceed 50%. The mimic insects like the Cantharid-beetles include the poisonous material in which the enemy is evaded as well as the firefly. Therefore, it can be interpreted that mimetic has been proven because a Muller mimetic type had happened.

Population of *P. tener* on the durian tree

Two species of fireflies are confirmed, and one of the species is *P. tener* that congregates and emits light on the durian tree, and the other species is a larger species. The congregations of *P. tener* in the tall durian tree emitted light on February, 1998. However, the group moved to the different mangrove tree that is situated about 50 m in distance during July, 1998. Usually, *P. tener* gathers on the mangrove tree, *S. caseolaris* along the river. Here the durian tree grows away from the river in a field. Such synchronous firefly habitat may be uncommon in this region. From this fact, *P. tener* need not be necessarily on a particular mangrove tree, and this suggests that the size of the leaf, the leaf density and arrangement, and the conditions of tree locations are the critical factors.

In case of *P. effulgens*, it is an important factor for gathering fireflies are the size and the form of a tree, the leaf shape and size, the conditions of tree locations. (Ohba, 1999, 2003).

Possible migration of fireflies

Personal communication with the boatmen of the Kampong Kuantan Firefly Watching Ecotourism Center says that the firefly's shifts site after a while. The frequency is quicker if there are a lot of disturbances, which he refers as to the visitor's boats. The firefly colony will shift from one site to the next, which may either be across the river or to the next row of trees or the next few rows thereof. The firefly emergence area is around 100 m from the riverbank. This behavior is also observed in the *Pyrophanes sp.* from Indonesia, which migrates every week. The *P valida* also were observed to migrate, such as the ones in Kuala Selangor Nature Park, Selangor, about 20 minutes drive downstream from Kampong Kuantan.

The protection of the loops of Selangor River may be important to the survival of the fireflies. At the Kampong Kuantan loop the boatmen sometimes take the visitors up or down stream and it may seemed that the loops which is constantly flooded by the river helps keep the prey population in supply for the fireflies population. These may act as an emergence site for the fireflies, which may roost at either side of the river (up/downstream). What determines the roosting sites is still unknown at this moment.

Food

It has also not been established what the adult fireflies feed on. Fireflies tend to live three times longer when provided with a sugar solution (sucrose 10%). This is an indication that the adult do feed, or at least take in water (MNS, 1997). The riverside habitat provides dew water condensed on the leaves of the *Sonneratia* trees in the evening with the rapid drop of temperature and lack of air movement. Such moist air supplies evening dew to the firefly's large population. According to Mr. Rasaintharan, the then park manager of the Kuala Selangor Nature Park, the fireflies feeds on the

sugary secretions from tiny pores on the leaves. (pers comm.)

Change of habitat and threats

The plantation of oil palm extends out to the Selangor river valley, the mangrove plants are gradually decreasing, and the plantation extended right to the riverbank. Plumes of black oil discharge flows into the river from the palm oil factories from time to time, and increasingly polluted the river. The industrial estate on the mid stream region, and further upstream the river from the Main Range is being dammed up to meet the demands of the Klang Valley for consumer and industrial use.

The mangrove tree on the banks of a river is being cleared in certain places, and *P. tener's* habitat is being fragmented .The deterioration of the native habitat is changed by the development of the grassland around the traditional kampong houses which is the larva's habitat. Moreover, the influence of the artificial lighting is gradually increasing due to the clearing of the mangroves at human settlements.

To control the threat to the habitat, 1) The water extraction should leave an optimal flow for the survival of the mangrove trees, for the dilution of the salt water intrusion and industrial effluent 2) cleaning up the river pollution 3) Build retention sludge pond for the palm oil plantations before releasing directly into the river, 4) The regeneration of mangrove tree, 5) The consideration of preventing too much artificial lighting into the habitat, helps.

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Observation record 1.

The observation result in Kampong Kuwantan was as follows.
February 10, 1998 full moon

Time	Ambient temperature (°C)	Light intensity (lx)
17:00	32.1	28.9
18:30	31.6	
18:38	28.9	
19:30	27.9	
19:40	27.4	
19:43	27.5	1.05
19:45		0.78
19:46		0.59
19:47		0.46
19:48		0.32
19:49		0.23
19:50	27.5	0.18
19:51		0.13
19:52		0.10
19:53		0.08
19:54		0.06
19:55		0.05
19:56		0.04
19:57		0.03
19:58		0.02
19:59		0.02
20:00	27.1	0.01
Flashing		
20:10	27.9	
20:20	26.8	
20:30	26.6	
20:40	26.4	
20:50	26.5	
21:00	26.4	
21:10	26.3	
21:20	26.3	

6:00-9:00 on February 11, 1998
Male and female ratio is about 3:1 (7 males and 2 females).
Nearby site, four males and seven females were confirmed. Mimetic insects collected are ten individuals.

February 11, 1998
Air temperature and the light intensity of habitat.

Time	Temperature (°C)	Light Intensity(lx)
18:22	31.4	535
18:10		
19:00		805
19:04		327
19:10	31.6	234
19:15		133
19:20		36.9
19:30		30.7
19:35	9.8	9.3
19:38	29.6	5.1
19:44	2.51	

February 12, 1998 Kampong Kuantan
19:00, six star worm (*Diplocladon* sp.), 3 larvae of *P. tener* and 2 *P. valida* were collected.
On February 13, 1998

Time	Air temperature (°C)	Light intensity (lx)
19:41		1.35
19:42		1.11
19:43		0.85
19:45		0.76
19:46		0.63
19:47		0.47
19:48		0.37
19:49		0.28
19:50		0.21 flashing
19:51		0.15
19:52		0.12
19:53		0.01
Nearby site		
19:54		0.04
19:55		0.03
19:56		0.02
19:57		0.02
19:58		0.02
19:59		0.01
20:00		0.01
20:04	29.9	
20:14	29.2	
20:24	28.7	
20:34	28.9	
20:44	29.3	
20:54	29.1	
21:04	29.6	
21:14	29.5	
21:24	28.9	
21:34	28.9	
21:44	28.5	
21:54	28.7	
22:00, rainstorm. Stop flashing.		
22:04	28.5	
22:14	28.8	
00:00 Luminescence restart		
2:00 (full) moon is out, decrease number of flashing individuals		
5:00 Small number of flashing individuals.		
5:15 End		

9:30, February 15, 1998.
7 males and 2 females were collected. Sex ratio was about 3:1.
8 individuals of leaf beetles and small Cantharid-beetles were collected.
Nearby site, 4 males and 7 females were collected. The sex ratio was 4:7.
One species of leaf-beetles and one species of Orthoptera were collected.
Another site, male and 4 females were collected.

Population density of fireflies in July 7, 1998.
Landing site (old jetty)
1:07, air temperature 28.1 °C, water temperature 27.0 °C. Cloudy, low tide.
1:22 air temperature 30.2 °C, ground temperature 27.2 °C. (100m from old jetty)
1:24 air temperature 28.8 °C. ground temperature 23.5 °C. (drainage site)

Investigation site (E: 03.21.45.6, E: 101.18.12.4).
18:30, air temperature 29.4 °C, water temperature 30.3 °C.
18:36, air temperature 30.2 °C, the intensity of illumination is 580lux.
Mimic insects collected in this group were pale brown, black small Cantharid-beetles, and leaf-beetles.
Sonneratia flower is in bloom.
19:00, air temperatures 31.1 °C, first female caught the light intensity was 250 lux.
19:04, air temperatures 30.8 °C, the light intensity was 185 lux.
19:05, air temperatures 30.5 °C, the light intensity was 208 lux.
19:06, air temperatures 30.9 °C, first male caught. The light intensity was 189 lux in July 7, 1998.

Investigation site (N: 03.21.45.7, E: 101.18.11.4)
18:29, air temperature 29.4 °C, water temperature 30.3 °C.

Investigation site (N: 03.21:44.5, E101.18.05.7)
nearly full moon, calm

Time	Air temperature (°C)	Light intensity (lx)	
19:11	30.1	194	
19:12	31.1	180	
19:14	30.3	207	
19:16	30.2	191	
19:17	29.8	183	
19:18	29.3	164	
19:19	28.9	142	
19:20	28.5	140	
19:21	28.1	132	
19:22	28.0	123	
19:23	28.3	93.2	
19:24	28.1	85.4	
19:25	27.8	68.6	
19:26	27.9	63.9	
19:27	28.6	50.0	
19:28	28.5	41.0	
19:29	28.4	32.9	
19:30	28.5	25.6	
19:31	28.4	23.0	
19:32	27.1	24.3	
19:33	27.2	29.1	
19:34	27.8	33.3	
19:35	27.7	42.3	
19:36	27.4	42.4	
19:37	27.4	35.2	
19:38	27.4	22.0	
Cloud moved in, darker			
19:39	27.6	11.2	
19:40	27.3	5.82	
19:41	27.5	3.62	
19:42	27.6	2.58	
19:43	27.7	1.88	
19:44	27.7	1.43	
19:45	27.6	1.06	one flashed
19:46	27.8	0.82	
19:47	27.4	0.60	
19:48	27.6	0.45	
19:49	27.9	0.32	
19:50	27.7	0.25	
19:51	27.4	0.18	
19:52	27.4	0.12	

19:53	27.3	0.10
19:54	27.2	0.08

19:30, evening glow, air temperature 28.5 °C.
19:36, darkens suddenly. 8.87 lux., air temperature 27.3 °C.
19:47 fine weather, a calm, air temperature 27.8 °C, the intensity of illumination was 1.06 lux.
20:42, 1.0 lux., began flashing

On July 8 1998 at 8:10; at jetty side. High tide, calm, clear and sunny.
Investigation site (N: 03.21.41.0, E: 101.18.07.0) Not facing sun.
8:21, Water temp. 27.8 °C.
Investigation site (N: 03.21.41.6, E: 101.18.09.6) facing the sun.
9:16, Air temp. 27.3 °C

July 8, 1998
8:21, air temperature 27.8 °C.
Investigation site (N: 03.21.41.5 E: 101.18.06.7) shaded area
Males were 25 individuals, and females were 11 individuals. Male and female sex ratio was about 5:2.
9:16 , air temperature 27.3 °C.

Investigation site (N: 03.21.40.2, E: 101.18.06.6) facing the sun
20 males and 20 females are collected. Male and female sex ratio was 1:1. One species of leaf-beetles and Cantharid-beetles were collected. The Cantharid-beetles was black and its pronotum was orange yellow in color.

July 8, 1998
Investigation site (N: 03.21.41.5, E: 101.18.03.8)
19:22 air temp. 28.5 °C, water temp. 27.1 °C.
The male and the female were put in a net (20x20x20cm) with 20 individuals respectively, it is hung on the branch in the habitat, and the luminescence behavior was observed.
The individual in the net was not blinking simultaneously. It was a luminescence pattern that was abnormally short. The luminescence interval, was different from the outdoor individuals.

Time	The light intensity (lx)
19:44	0.45
20:47	0.17

July 9, 1998
9 males and 5 females were collected. at 15:30.
Male and female sex ratio was 2:1.
The result of the investigation in the nearby site was 13 males and 8 females, and the sex ratio was 3:2.
Yellow cantharid-beetles were included in this group.
3:40-5:00 on 9 July, 1998, rain and thunder

Investigation site (N: 03.21.41.1, E: 101.18.05.3)
The number of individuals of *P. tener* was fewer at 20:37.
20:40, copulation individuals was discovered.

March 9, 2000
19:20, air temp. 30 °C, water temp. 29 °C. A species of bat and a kingfisher bird were seen.
19:27, air temp. 29 °C
19:30 air temp. 28 °C
19:34, evening light.
19:41 Luminescence began.
19:46, the number of individuals luminescence rapidly increased.

March 6, 2000.
24 males and 3 females were collected within the range of 2 × 2m; the sex ratio was 8:1.
March 7, 2000.
Fine, air temp. 31.9 °C, 70% in humidity.
9:42, air temp. 33.4 °C.
A lot of fireflies.
9:45, air temp. 34.6 °C and 65% in humidity.

Teluk-Siam. Village
9.51, air temp. 34.2 °C, 65% in humidity.
There is a plantation of oil palm.
Air temp. 34 °C, water temp. 38.0 °C.
Oil sludge flowed in the river (Alur Stor)
10:24, mangrove tree, *Sonneratia caseolaris* (It is called Berembang in this place) became scattered. Air temp. 34.5 °C.
About 10.49 Km point from the mouth of the river.
Parit Maidin Air temp. 33.9 °C, water temp. 29.5 °C. Only oil Palm was cultivated.
11:07
Teluk Putus
Traditional kampung house was along the riverbank. Width of the river was about 25 m.
12:33, fireflies' second firefly watching point (Bukit Belimbing) were passed. Air temp. 30.5 °C.

Investigation site (St.5)
9:31 fine on 8 March, 2000, water temp. 30 °C.
The imago was not able to gather in the mangrove tree.
Larva of *P. tener* was confirmed in 09:31 by the banks.
Black Cantharid-beetles which resembled dark color type of *Pteroptyx* sp were collected. The imago was seen on the leaf of *Sonneratia*. The number of total individuals was five males and seven females.
12:08, male and female ratio was 5:7.

9 March, 2000.
The water level was high.
Fine, air temp. 28 °C, high-tide. There was rain until dawn.
Investigation site (St.5)
7 males and 4 females were collected. The sex ratio was about 7:4.
A lot of small Cantharid-beetles were collected. Another species of Cantharid-beetles (Large and orange yellow in color) was included in the same tree.
At a nearby site, 2 males and 4 females were collected in St.3, male and female ratio was about 1:2. The black of Cantharid-beetles was collected 19 individual and the copulation behavior was seen in this group.
Ten males and 9 females were collected from the colony in the upstream on March 9; 2000. Male and female ratio was about 1:1. Two species of orange yellow Cantharid-beetles and small leaf-beetles were included in this population.
Investigation site (St.3)
12 males and 3 females were collected. The sex ratio was about 4:1.
Investigation site (St.5)
30 males and 6 females were collected. The sex ratio was about 5:1.
Investigation site (St.6)
19:00-22:00, on October 7, 2000
Last1, male and female sex ratio was 28:14 = 2:1
Last2, male and female sex rato was 28:8 = 4:11
Last point High density
Third point High density

October 7, 2000
19:35, began flashing
19:37, partially (in synch) tune luminescence. High tide, air temp. 27.3 °C, water temp. 26.7 °C.
19:52, air temp. 28.2 °C, water temp. 25.9 °C. A lot of fireflies synchronized flashing.
20:11, last Point, Air temp. 28.2 °C, water temp. 25.8 °C.

20:45, recorded flash pattern.
21:05, air temp. 28.3 °C, water temp. 25.7 °C.
22:00 ended.

October 8, 2000
09:00, air temp. 28.8 °C, water temp. 26.1 °C.
09:45, last point. 15 males and 5 females were collected. Male and female ratio was 3:1.
10:25, 3rd point. There was no firefly.
10:30, 4th point. One female was collected.
10:35, downstream. The mangrove deforested.
11:00, 2 female and one male were collected. The sex ratio was 2:1.
19:50, air temp. 28.3 °C, water temp. 25.9 °C. Synchronous flashing.
20:30, second point. Synchronous flashing.
21:20, downstream region, air temp. 28.2 °C, water temp. 25.5 °C. Cloudy.
21:47, near the new jetty site.

October 9, 2000.
14:00, inland of the last point.
14:25 Jack fruit, durian, mangosteen site.
14:40, house garden was the best environment for fireflies. A Rambutan tree was planted near traditional house.

April 21, 2001.
Fine, Kampong Kuantan, Selangor River
19:40, air temp. 26.8.

April 22, 2001.
Male and female sex ratio was 9:4.

July 9, 1998
Air temperature and the intensity of illumination of investigation site (durian site).

Time	Ambient air temp. (°C)	Light Intensity (lx)	
19:07	27.6	103	
19:08	27.5	97.5	under shade
19:10	27.3	80.2	
19:12	27.2	57.9	
19:14	27.1	54.0	
19:15	27.4	50.0	
19:16	27.2	44.0	
19:17	27.1	40.3	open area
19:18	27.1	36.3	
19:19	27.2	33.4	
19:20	27.1	31.0	
19:21	27.1	27.8	
19:23	26.9	28.3	
19.24	26.7	26.6	
19:25	26.7	22.5	
19:26	26.9	19.3	
19:27	26.9	17.0	
19:28	26.8	15.2	
19:30	26.7	13.3	
19:31	26.6	12.4	
19:32	26.5	11.1	
19:33	26.6	9.41	
19:35	26.7	5.74	
19:36	26.4	4.77	
19:37	26.3	4.23	

19:38	26.3	3.51
19:39	26.2	2.8
19:40	26.3	2.3
19:41	26.6	1.85
19:42	26.3	1.49
19:43	26.6	1.19
19:44	26.2	0.93
19:45	26.5	0.72
19:46	26.6	0.53
19:47	26.4	0.41
19:48	26.3	0.28
19:49	26.3	0.13
19:50	26.0	0.08
19:52	—	0.05

19.57 1 started flashing