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The morphology, behaviour and life cycle of *Pteroptyx valida* (Coleoptera:Lampyridae) in Singapore

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シンガポールにおけるプテロプティックス・バリダ（甲虫目：ホタル科）の形態・習性および生活史

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筆者らは1992～1994年に，シンガポールに生息するホタル *Pteroptyx valida* の形態・生態・生活史および生息環境などについて野外生態観察および室内飼育観察を実施した結果，次のことを明らかにした。*P. valida* の幼虫は小型のマングローブに生息するカワザンショウガイ *Sphaerassiminea brevicula* (PFEIFFER,1854), カワウツボ属の1種 *Fairbankia* sp. および陸生のオカクチキレガイ *Subulina octona* BRUGUIERE, 1792 を摂食した。幼虫は一時的にマングローブ海水に短時間ならば生息可能であり，尾端にある一対の発光器から持続光を放った。成虫雄の翅端は内側に折れ曲がっていて，*Pteroptyx* 属の特徴を備える。成虫はクランジ地区に僅かに残るマングローブ林に生息し，年間を通して発生するが生息密度は低く，８mほどの木に約50個体が集合して発光する。*P. valida* の成虫集団は発光周期を同調することなく，また発光色も同じである。このようなことから雌雄を発光パターンから区別することは困難であるが，交尾済と考えられる雌成虫はしばしば樹上から瞬きを伴う光を放ちながらマングローブ林床へ降下飛行する。この発光行動は同属の *P. cribellata* でも観察され，産卵場所の探索行動と考えられる。雄成虫は常に樹冠で発光していた。樹冠で発光する個体の発光間隔はコンピュータによる波形解析から 2.5～4.0 秒であり，時間経過とともに短縮される傾向にあった。成虫を透明容器に移して室内で発光パターンを観察した結果，野外での結果に比較して，雌雄ともにきわめて早く点滅し，両者の区別は困難であった。室内飼育によって，雌成虫はマングローブの湿った泥やガーゼに約70個産卵し，30 ℃，湿度100％ 下で12日間で孵化した。一齢幼虫は体長約2 mmであり，陸貝の稚貝を摂食して終齢幼虫に達し，体長約８mmとなった。蛹化は孵化後139日後であった。マングローブの泥でない内陸の土を飼育土に用いた場合には，最高45日間蛹化が早まった結果を得た。成虫の寿命は室内飼育下では最長17日，最短３日間であった。

Introduction

There are species of fireflies around Southeast Asia which have the unique characteristics of large aggregations and synchronous flashing. The flash communication, morphology and behaviour of *Pteroptyx* species has recieved much research (BALLANTYNE, 1968; BASSOT and POLUNIN, 1967; BUCK and BUCK, 1966; CASE, 1980; HANEDA, 1966; OHBA, 1983; 1984; 1986; WING *et al.*, 1983). However, the life cycle of these species and their larval stages were hardly known. In order to study these, we conducted several field studies, during the period from 1992

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to 1994, on *Pteroptyx valida* and its habitat in Singapore. We have also undertaken indoor culture and breeding of this species both in Singapore and Japan.

P. valida is losing most of its mangrove habitat due to coastal development in Singapore in recent years. Singapore Zoological Gardens is building an ecological habitat and plan to display this and other tropical species of fireflies in its night attraction; the Night Safari in Singapore (OHBA 1993). The present study both in the field and indoor culture is important in filling the gulf on morphology, behaviour and life cycle of *P. valida*.

Habitat of *Pteroptyx valida*

The mangrove swamp at Kranji Dam (lies between Sungei Buloh Nature Park and the Kranji Reservoir) located in the northeastern part of Singapore is an important habitat of *P. valida*. This area has mature mangrove trees of species such as *Avicennia, Sonneratia* and *Rhizophora*. However, with the present construction of a crocodile farm, the main breeding site of *P. valida* had been destroyed.

1. Habitat at Kranji Dam in 1992 (Fig. 1)

This mangrove site is about 400 m away from the seashore and there was a bund (4 m wide) which ran west to east with a fresh water stream (4 m width × 2.5 m depth) running alongside it. Alongside the bund, were species of mangroves and other flora such as sea hibiscus, *Hibiscus tiliaceous*, acacia, *Acacia auriculiformis*, sea holly, *Acanthus ilicifolius*, paku raja, *Acrostichum aureum* and *Derris* sp. The ambient temperature of the shaded bund ranged from 27–29 °C and relative humidity remained at 85% during day and night (up to 2200 hours). At high tide, sea water flooded the banks of the stream and at low tide, fresh water (from rain and underground) diluted sea water and flowed out of the stream to the sea (Fig. 2). On the mud, mangrove snail, *Sphaerassiminea brevicula* (PFEIFFER, 1854) and *Fairbankia* sp. gathered in the fallen dead leaves. One other species of mangrove snail, *Laemodonta punctatostriata* (H. et A. ADANMUS, 1855) was found along the slopes of bank (Fig. 3) and a species of non-marine snail, *Subulina octona* (BRUGUIERE, 1792) was found along the walking bund. Tiny snails (unidentified live-bearing species) were seen on the underside of leaves of plants growing along side of the bund. Although the slopes and bund were not receiving much impact from the tidal inundation, the soil was saline. The banks and bund sustained non-marine land snails. Adults of *P. valida* were resting on *Avicennia alba* growing on both sides of walking bund and the numerous larvae were on the mangrove mud and along the bund. The larvae can be found up to 3m high on tree trunks during wet nights. The mangrove trees are up to 20 m high.

Fig. 1 Habitat of *Pteroptyx valida* at Kranji Dam in 1992.

2. Habitat at Kranji Dam in 1993 (Fig. 4)

The mangrove swamp at the southern side along the stream was completely destroyed and earth-filled. The source of the fresh water stream was also covered with earth. Tragically, the bund was also earth-filled. Only portion of mangroves on the northern side, including the *Avicennia* trees which the adult fireflies gathered remain. In this cleared land, a crocodile farm is in the process of construction. The remaining mangrove swamp mentioned, adjacent to the crocodile farm, has been ear-marked for development. In September 1993, we found very few larvae and adults have also decreased.

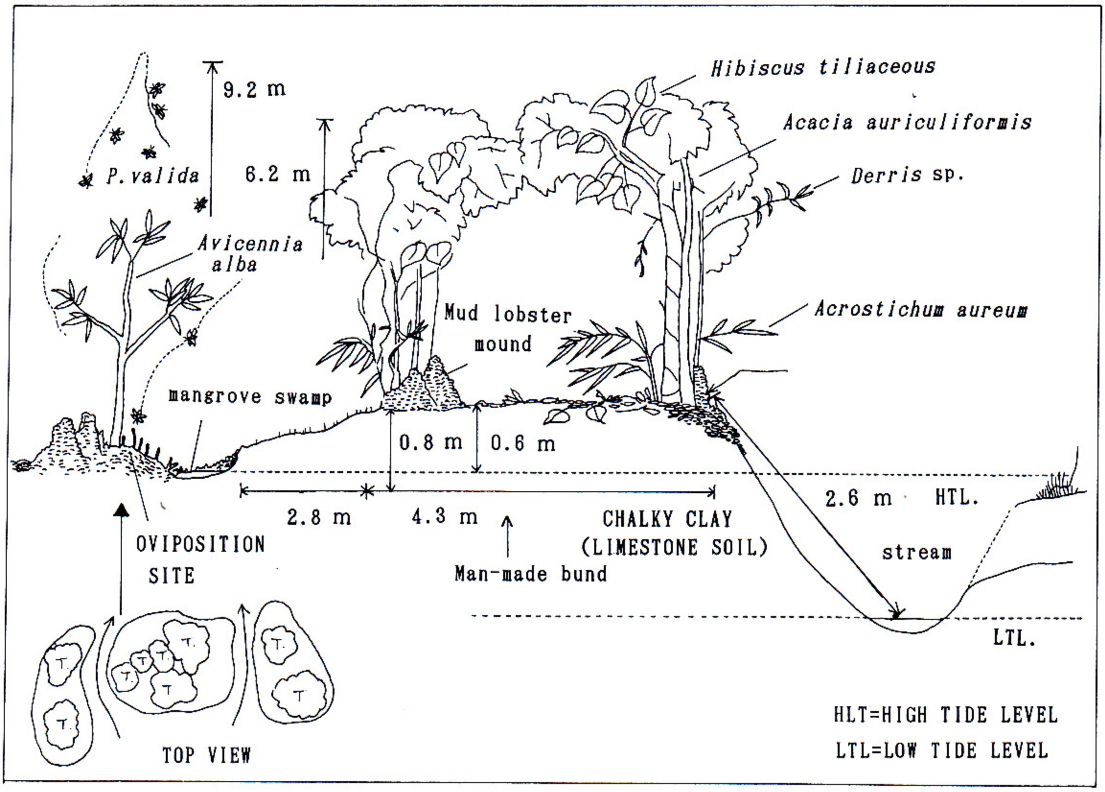

Fig. 2 Schematic habitat of *Pteroptyx valida* at Kranji Dam.
At night, glowing larvae are found along the bund and blinkering adult fireflies on the *Avicennia alba* trees.

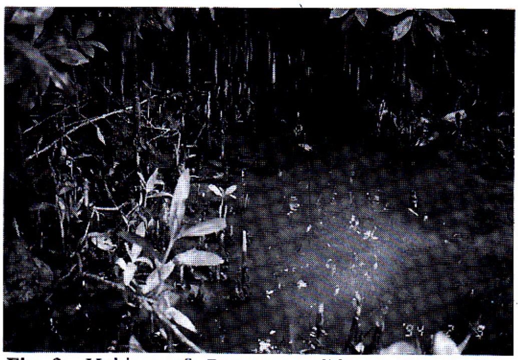

Fig. 3 Habitat of *Pteroptyx valida* at Kranji Dam during daytime.
Mangrove snails live in tidal water and tree bed.

Fig. 4 Habitat of *P. valida* at Kranji Dam in 1993 showing part of the study site earth-filled.

Result and consideration

Morphology Morphological study was conducted by stereomicroscope using living materials, but some from preserved specimens in alcohol. Adults and larvae were collected from the field. Eggs and pupae were obtained from indoor culture.

Egg: aproximately 0.5 mm in diameter, round and yellow.

Larva (Fig. 5): The 2 mm first instar larva is ashy grey in colour, narrow and long in shape. The pronotum is narrow and long. It has prothorax, mesothorax, metathorax and nine abdominal segments accompanied by two pieces of ventral plate. The mesothorax is the widest part of all. The nine abdominal segments were the narrowest of all parts, and are almost rectangular in shape. The head is small and is normally hidden underneath the pronotum. In the 10–12 mm larva (Fig. 5), the shape is similar to the first instar larva. However, the ventral plate has much chitin and is dark brown or pale yellowish brown. As for the legs, both femur and stipes are dark brown and ending with one claw. The head and eyes are small. The mandibles are curved inward and the tip is sharp and pointed. A pair of creamy white luminous organs is located in the eight abdominal segment and the abdomen ends with the abdominal hold fast organ.

Pupa (Fig. 6): Eyes of male are larger than female. Hind wings are folded under fore wings and both pair of wings are small. There is a pair of filaments at the apex of the abdominal segment. Also on both abdominal sides, bristle is seen in each abdominal segments. The colour of pupa is milky white. Before emergence, pupa became much darker in colour, the eyes in particular changed from brown to black. Sexual dimorphism can be detected at this stage.

Adult (Fig. 7): Adult male (Fig. 7.1) is aproximately 9 mm in body length and adult female (Fig. 7.2) ranges from 8 mm to 10 mm. The elytra of both male and female is pale yellow. The apex of elytra in male is folded inward (Fig. 7.4), which is characteristic of *Pteroptyx* species. It has a pair of compound eyes and each antenna is black and having eleven segments. The second segment is the shortest and third segment is the longest. The compound eyes in female are slightly smaller than male but antennae are alike (Fig. 7.3–4). The ratio of compound eye against the width of

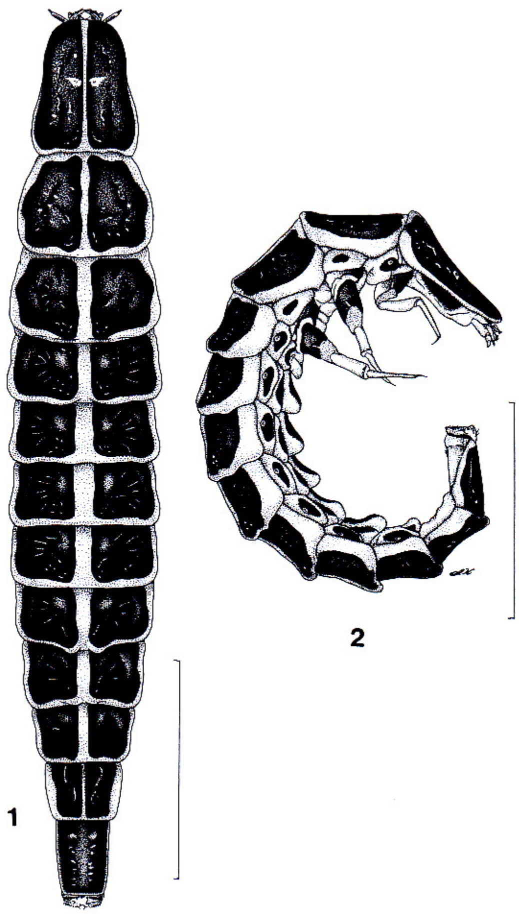

Fig. 5 Larva of *Pteroptyx valida* (Mid-instar).
1. dorsal view, 2.lateral view. scale: 3 mm

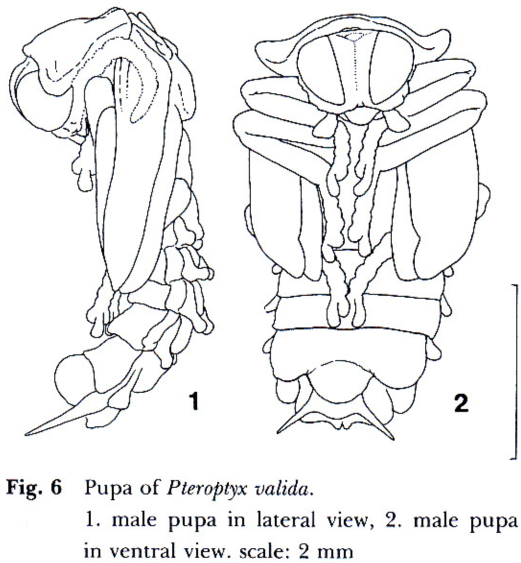

Fig. 6 Pupa of *Pteroptyx valida*.
1. male pupa in lateral view, 2. male pupa in ventral view. scale: 2 mm

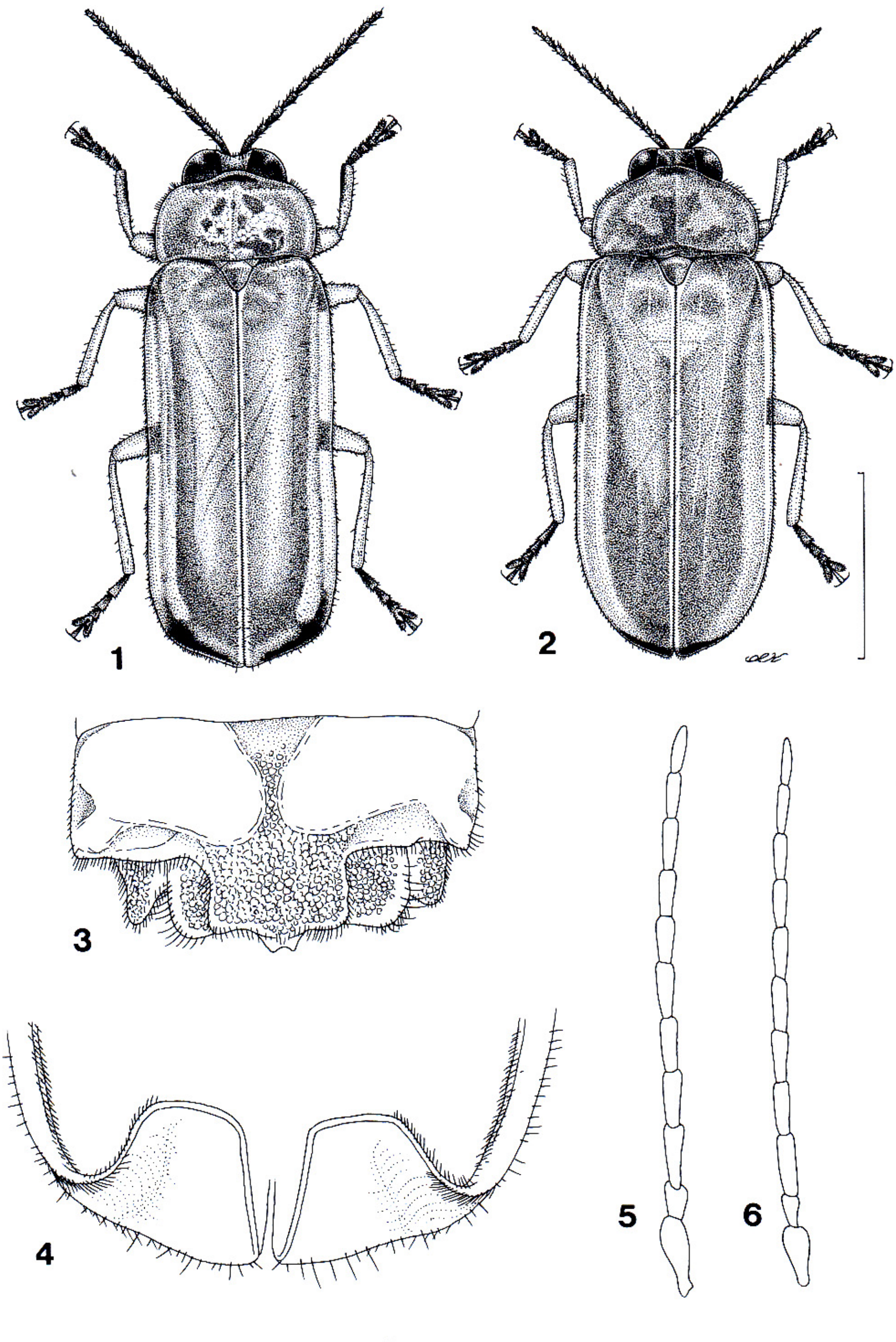

Fig. 7 Morphology of adult *Pteroptyx valida*.
1. male, 2. female , 3. Sixth abdominal segment of male adult in ventral view, 4. The folded wings of the male which is typical for the genus *Pteroptyx*, 5. antenna of male adult, 6. antenna of female adult. scale: 3 mm

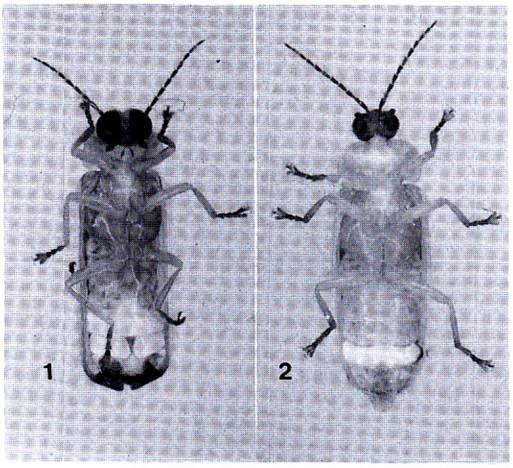

Fig. 8 Adults of *Pteroptyx valida* in dorsal view.
1. male, 2. female.
Male firefly has two segments of creamy-white lanterns whereas female firefly has only one. This sexual dimorphism is clearly pronounced from the pupal stage.

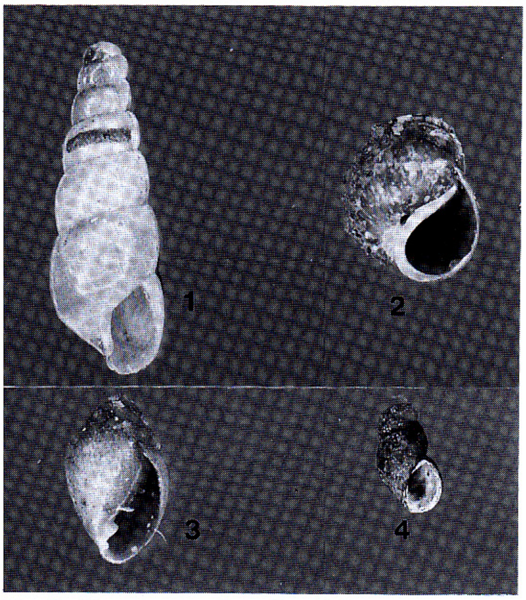

Fig. 9 Mangrove snails at Kranji Dam.
1. *Subulina octona* (BRUGUIERE, 1792), 2. *Sphaerassiminea brevicula* (PFEIFFER, 1854), 3. *Laemodonta punctatostriata* (H. et A. ADAMUS, 1855), 4. *Fairbankia* sp.
1, 2 and 4 were eaten by larva of *Pteroptyx valida*.

pronotum is 0.25 in male and 0.17 in female. Scutellum is yellow and triangular in shape. Legs are large and black. The legs have coxa, trochante, femur, tibia, tarsus and each leg ending with two hook-shaped claws. The creamy white luminous organs are located at the fifth and the sixth abdominal segments. In male adults, the first luminous organ is rectangular in shape whereas the second luminous organ is divided into two in the middle to form twin lanterns (Fig. 7.3). In female, the apex of elytra is not folded and only the fifth abdominal segment is luminous (Fig. 8.2).

Food Adults do not consume food at all but capable of imbibing fluid (water, fruit juice or extrafloral nectar). The known species of snails that *P. valida* larvae consume in the mangrove habitat are *Subulina octona* (BRUGUIERE, 1792), *Syphaerassiminea brevicula* (PFEIFFER, 1854), *Fairbankia* sp. and the unidentified tree snails (2 mm in size) found in the habitat (Figs. 9, 10). The predatory larva often climbs onto the shell of a snail and attacks it from above and behind. We observed that larger snails that overcome the attack did not die. Ivan POLUNIN (pers. communication, 1992) video-taped and studied the larvae under high magnification pointed out that larvae tore out and ate the flesh of snail.

Fig. 10 Larva feeding on *Subulina octobna* which is a common leaflitter snail.

Luminescent behaviour

Adult: On 16th September, 1993, males were observed resting on the leaves at the canopy of trees and giving off the bright and long yellowish flashes; characteristic of male *P. valida*. They flashed once in aproximately 8 s. First flashes commenced at 1932 hrs and full display was observed by 1945 hrs (27°C, relative huminity was 86%). Flash pattern captured with highly sensitive VTR camera was replayed on monitor and traced with photosensor, which converted the flash pattern into electrosignals which were digitaised into digital signals through AD board (Analog Digital board). These digital signals were then input into the computer using software to analyse the flash pattern. In the field, the flash intervals of males gradually become shorter. The flash pattern was 4.0 s in interval at 2032 hrs, and 2.5 s in interval at 2058 hrs, (Fig. 11.1–2). Males were observed giving off long flashes to attract females which were observed to fly up from the undergrowth. The adult population only numbered 20-50 aggregating in the trees. We did not observe synchronous flashing. Adult males did not fly down from the trees, which made collecting them difficult. However, we climbed the tree and ramdomly collected some for examination and the ratio of the male to female was 7:6. Adult males put in transparent plastic bag in the darkened room was moving and flashing rapidly (Fig. 11.3-5). The flash pattern of the males was 0.45 s in interval at 2346 hrs.

Synchronous flashing was not observe even when more males were added into the plastic bag. Adult males gave off lights from either their fifth abdominal segment or both the fifth and the sixth segments. The twin luminous organs located at the sixth abdominal segment is considered an ideal shape for sending signals (Fig. 7.3).

It was hard to differentiate the sex of *P. valida* from their flashing pattern when they were resting in the mangrove trees. Male and female adults produced the same colour of light and flashed irregularly. Female adults frequently flew down from the trees to tree beds giving off its blinkering light (Fig. 11.6). Occassionally they were observed flying slowly and rested on the leaves and also the surface of the ground. Similar flashing pattern as this was also observed in the adult females of *Pteroptyx cribellata* in Papua New Guinea after mating. This behaviour is considered one of adult females looking for egg laying site(OHBA, 1992). The same behaviour was observed in *Curtos costipennis* found in Okinawa Island in Japan(OHBA, 1983).

Females in the wild perched on trees and flashed at interval of 0.26 s. in average at 2249 hrs.

Females in transparent plastic bag in the laboratory flashed at interval of 0.45 s. in average at 2244 hrs and thereafter the flash intervals gradually shortened (Fig. 11.3–5). Adult females collected from the muddy bed of the mangrove trees and placed in a plastic container in which wet mud was provided were observed to rest on the mud and inserted their ovipositors into the mud; bending abdomen slightly inward. They laid eggs not only in the mud but also on the wet gauze placed in the plastic bags or collecting containers.

Larvae: The field study conducted on 4th March, 1992 was met with heavy thunderstorm at 1920 hours (28°C) which stopped the observation. A visit on the following night saw hundreds of larvae 'leech crawling' on ground surface and climbing to three meters high on the wet tree trunks and branches giving off intermittent light. Larva, when moving lifted its back and walked, firmly fixing the tip of tail supporting its body. Once the body was stretched, the larva moved hold last organ forward, then repeat the same movement, similar to that of inchworm. Larvae avoided light by resting under soil, stones and leaf litters during the day and emerged during the night. Larvae emitted light for about 4 s from the pair of luminous organs located at the eight abdominal segment. On 15th September 1993, a larva was observed in 4 cm of saline water and gave off light at the mangrove swamp. On 20th April, 1994, a larva was observed consuming snail, *Fairbankia* sp. at the bank and glowing. The time of first glowing of larvae was later than the

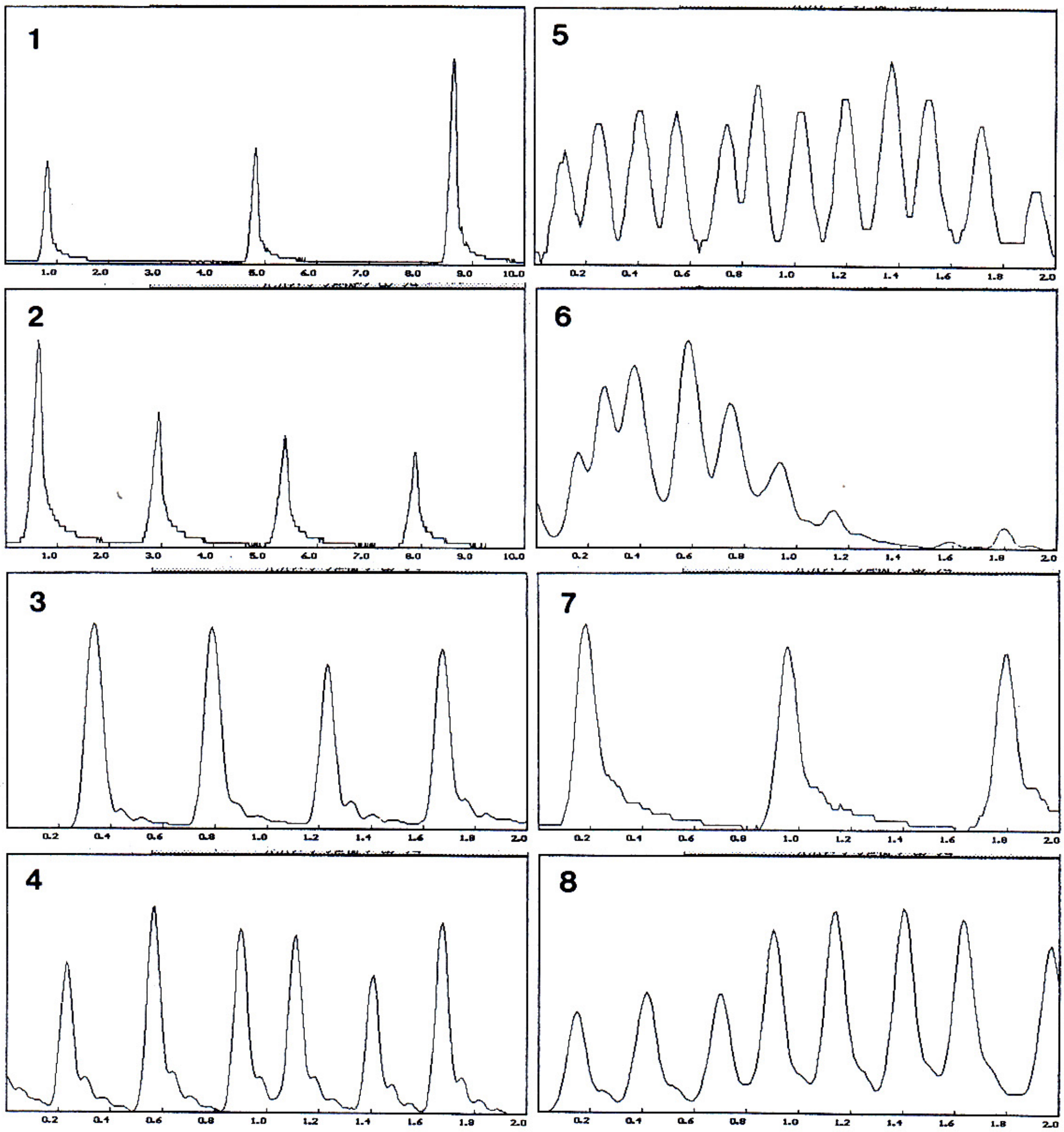

Fig. 11 Flash patterns of *Pteroptyx valida*.

1, 2. male perched on a tree. 1. Flash interval is 4.0 s in average at 2032 hrs; 2. Flash interval is 2.5 s in average at 2058 hrs; 3–5. males flashing in a plastic bag in the laboratory; 3. Flash interval is 0.45 s in average at 2244 hrs; 4. Flash interval is 0.27 s in average at 2246 hrs; 5. Flash interval is 0.16 s in average at 2254 hrs; 6. Female flew a short distance from the tree and emitted blinkering light. Flash interval is 0.14 s in average at 2051 hrs; 7,8. Females flashing in plastic bag in the laboratory; 7. Flash interval is 0.81 s in average at 2252 hrs; 8. Female perched on a tree, flash interval is 0.26 s in average at 2249 hrs.

Recording left to right. Ordinate:relative intensity, Abcissa:time, the scale as indicating 1 s (1, 2) and 0.2 s (3–7).

adults, around 2000 hrs when the habitat and the bund was almost pitch-dark. Larvae do not glow all the time. It was observed that after the rain, larvae gave off more light, which indicated that the weather has a crucial influence in their activity and flashing. Larva when walking, sticked its head out from the pronotum and stretching its antennae, but retract heads when touched. After consuming snail, larva demonstrated mud cleaning behaviour; removing mud sticked on the head and body using the filamentous abdominal hold fast organ.

Reproductive behaviour and life cycle Few studies have been made on the courtship and mating behaviour in the genus *Pteroptyx* (CASE, 1980; BUCK and BUCK, 1966; HANEDA, 1966; OHBA, 1992; WING *et al., 1983*). The observation on reproductive behaviour in *Pteroptyx valida* under red light also indicated that the male of this species mounted the female and gave off bright flashes aimed at the female's compound eyes and at the same time using its rear pair of legs to stroke at the female's abdomen; similar to *P. tener* (CASE, 1980). Male of *P. valida* was also observed, after flooding light at the female's compound eyes (at an intensity weaker than its long flashes) to tilt its abdomen, almost parallel to its head, and with its lanterns over the female's eyes. It then tapped on the female's pronotum with its abdomen and at the same time giving off two tiny point lights from its twin lanterns. Of the 18 to 21 times the male tapped on the female's pronotum, the first six taps bore the point lights. Male then vigorously attempted to establish terminalia contact while still mounted on the female. An interloping male was observed attempting to dislodge the male from the female and subsequently mounted on the male and was attempting without success to reach for the female's terminalia. Mated pair assumed the tail-to-tail posture for several hours.

Male used its folded elytra to clamp on the female's terminilia(WING *et al.*, 1983). During copulation, the pair would either off their lanterns or intermittently gave off very weak flashes.

From the authors' observation, males of *P. valida* have the ability to control the light production from its luminous organs. When captured at night, wild-caught male *P. valida* may produce light from only the lantern on its fifth abdominal segment and be mistaken for female. The long bright flashes of the male are produced by the two luminous segments flashing simultaneously. On close observation (in a jar) the naked eyes can detect the flickering of these long flashes.

The third night after the mating, the mated female was observed to move on the wet mangrove soil to oviposit (Fig. 12). Eggs were laid singly and a female can lay up to 70 yellowish eggs on the mangrove soil (Fig. 13). The female will lay till it expended its adult life (average 12 days and longest 17 days).

Each egg is ovoid and yellowish at time of laying but faded to whitish after a few days. Fertile eggs will hatch after 12 days at 30°C ambient temperature and at 85–100% relative humidity.

Experimenting with indoor-bred adults, it was observed that two females mated by the same male produced viable eggs.

The tiny (aproximately 2 mm in body length) first instar larvae reared on wet tissue paper were fed with baby *Subulina octona* snails. These tiny larvae can also be fed with crushed adult snails. The first instar larvae were then transferred onto moist mangrove soil at a week old and began to

Fig. 12 Female of *Pteroptyx valida* moved on the wet mangrove soil to oviposit.

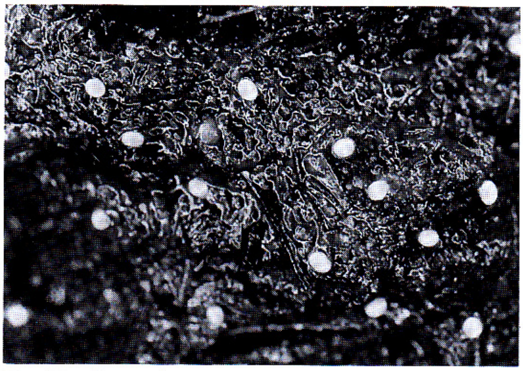

Fig. 13 Eggs of *Pteroptyx valida*.
Adult firefly lays up to 70 yellowish eggs on wet mangrove soil. Eggs are aproximately 0.5 mm in diameter and laid singly. These hatched after 12 days.

moult in the soil or tiny subterranean chambers created at two weeks old. During the moulting period (5 to 9 days), the larvae remained dormant in C-shaped posture. After 110 days on moist mangrove soil, the fourth instar larvae built their last subterranean chambers (chambers are about 10 mm in diameter or approximate larval length) and spent their prepupal stage as a C-shaped dormant larvae in the chambers for five days. Larvae in chambers emitted weak continuous light at all times.

On the 120th day after hatching, the larvae became creamy white pupae (approximately 8 mm in length) and did not emit light. On the 122nd day, the pupae commenced to emit weak continuous light from its lanterns (throughout day and night). During the pupal stage, the sex of the *Pteroptyx* firefly can be determined. Pupae were sensitive to light and moved away from light source by flexing its abdomen downwards. The brownish compound eyes darkened to a darker shade of brown and then to black. Similarly , the milky white pupae also darkened.

On the fifth day of becoming pupae, the antennae and legs became discernable. By the sixth day, the pupae metamorphosed into adults, leaving a lump of white pupal case at the bottom of each chamber. The newly-formed adults remained inactive in their subterranean chambers for three days, giving off weak flickering light. During this period, the elytra darkened and the adults finally emerged from beneath the soil at night and took their first maiden flight into the air.

On moist mangrove soil, the stages of development from eggs to adults took a minimum of 139 days. Those reared on non-mangrove soil became adults in 91 to 136 days from eggs. Larvae of the same batch did not develope at the same pace after the first instar stage. The difference in the period of emergence as adults can be up to 45 days. *Pteroptyx valida* fireflies are found throughout the year and larvae of various sizes (6–14 mm) were found during the numerous visits at the study site. The life-span of adults *P. valida* in the wild is not known but average life span of captive adults of *P. valida* was 12 days (shortest being three days and longest 17 days).

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