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LARVA OF THE PHYTOTELM-BREEDING DAMSELFLY, *PERICNEMIS STICTICA* SELYS FROM FORESTS IN SINGAPORE (ODONATA: ZYGOPTERA: COENAGRIONIDAE)

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***ABSTRACT.* —** The final instar larva of *Pericnemis stictica* Selys is described and illustrated here for the first time, based on the exuviae of specimens reared in captivity. The emergence sequence was documented for a male and a female specimen. The larvae were obtained from phytotelms in forests at the Bukit Timah Nature Reserve and Central Catchment Nature Reserve. A comparison is made with the only other known species in the genus, *Pericnemis triangularis* Laidlaw (from Borneo). Possible future research on the biology and conservation of *Pericnemis stictica* is suggested.

***KEY WORDS.* —** damselfly, larva, phytotelm, *Pericnemis*

INTRODUCTION

The damselfly, *Pericnemis stictica* is a relatively large and distinctive species, with the adults measuring up to 66 mm in body length (Tang et al, 2010). Although it is widespread in Sundaland (Orr, 2005), records in Singapore have been scarce. It is a forest-dependent species and has been sporadically witnessed in shady understorey in close proximity to phytotelms (small water bodies contained by plants from ancient Greek: 'phytos' = plant; 'telma' = pond), especially water-filled tree holes. Other forms of phytotelms include water collected in leaf axils, buttress pans or bamboo stumps.

Throughout the tropics, at least 47 odonate species (in 24 genera) have been recorded breeding in phytotelms (Corbet, 1999), the majority being damselflies (suborder Zygoptera). Orr (1994, 1997) analysed communities in water-filled buttress pans in mixed dipterocarp forest in Borneo, where larvae of *Pericnemis triangularis* lived in association with the anisopterans, *Indaeschna grubaueri* (Aeshnidae) and *Lyriothemis cleis* (Libellulidae). Extensive research has been conducted in Central and South America. In Panama, detailed studies were made on odonate communities in large tree holes, with species studied including *Gynacantha membranalis* (Aeshnidae), *Megaloprepus coerulatus*, *Mecistogaster linearis*, and *Mecistogaster ornata* (Coenagrionidae—formerly Pseudostigmatidae) (e.g., Fincke, 1996, 2011; Fincke et al., 1997). Throughout the Neotropics, the profusion of bromeliad plants (family Bromeliaceae) has enabled certain damselflies to utilise the phytotelms formed when water accumulates at the bases of their leaf axils. Examples include *Bromeliagrion rehni* (Coenagrionidae) from Brazil (Torreias et al., 2008), and *Leptagrion andromache* (Coenagrionidae) from Argentina (Muzón et al., 2009). In the Afrotropical region, detailed studies of the ecology, behaviour and systematics of *Coryphagrion grandis* (Coenagrionidae) and *Hadrothemis* species (Libellulidae) breeding in tree holes have been carried out (Clausnitzer, 2004).

MICROHABITAT DESCRIPTION AND EX-SITU REARING

In Singapore, the larvae of *Pericnemis stictica* were encountered in water-filled tree holes and buttress pans within the Central Catchment Nature Reserve (CCNR). Along Fern Valley at the Bukit Timah Nature Reserve (BTNR), a mid-instar larva (total length: 15 mm) was found in a tree hole, situated just above eye-level, on 28 Sep.2010 (Fig. 1). The surface of the water was ca. 12 × 6 cm, and had a depth of ca. 3 cm. The water was clear, with a substrate of fine detritus. The larva was photographed in-situ and not collected.

Also at the BTNR, a buttress pan containing a greater volume of water was investigated. This microhabitat was formed by the buttress roots of a mature tree (*Parishia insignis*, family Anacardiaceae) that was growing along South View Path (Fig. 2a). It was situated at knee-level and the water surface was ca. 40 × 18 cm, with a depth of ca. 8 cm. There

Fig. 1. This tree hole at Fern Valley, Bukit Timah Nature Reserve, was inhabited by a mid-instar larva of *Pericnemis stictica* (inset, total length: 15 mm) on 28 Sep.2010. The tree hole was just above eye-level and the water surface was ca. 12 × 6 cm, with a depth of ca. 3cm.

Fig. 2. (a) Water-filled buttress pan at the base of a mature *Parishia insignis* tree along South View Path, Bukit Timah Nature Reserve, where three damselfly larvae were collected on 5 Oct.2010 and reared to eclosion. This phytotelm was at knee-level and the water surface was ca. 40 × 18 cm, with a depth of ca. 8 cm. (b) Tree hole of a mature *Calophyllum* species at Bukit Kallang, MacRitchie Reservoir forest, where three larvae were collected (two reared, one preserved as larva) on 15 Oct.2010. The tree hole was just above waist-level and the water surface was ca. 28 × 11 cm, with a depth of ca. 4 cm.

was an accumulation of dead leaves and twigs within, but the water was clear. On 5 Oct.2010, three larvae were collected from this site and reared in captivity.

At Bukit Kallang, MacRitchie forest, a tree hole of a mature tree (*Calophyllum* species, family Guttiferae) was investigated (Fig. 2b). It was situated at waist-level and its water surface was ca. 28 × 11 cm, with a depth of ca. 4 cm. The water was largely clear, with a few dead leaves and small pieces of peeled bark. There was a shallow layer of brownish detritus at the bottom. A total of three larvae were obtained from here on 15 Oct.2010, of which two were reared to eclosion and one was preserved in its larval form.

In captivity, larvae were reared in small aquaria with shallow water (6–8 cm depth) and fed with tubifex worms on a daily basis. Similar sized larvae were reared together in the same aquarium, without demonstrating any signs of aggression or agonistic behaviour towards each other. As the larvae matured and approached the pre-eclosion phase, a thin stick was provided to facilitate its climb out of the water. All specimens were preserved and catalogued at the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research (RMBR), National University of Singapore. A summary of these specimens is provided in Table 1 (see: Material Examined). Measurements of the adults include total body length (TBL) and hindwing length (HW).

LARVAL DESCRIPTION AND COMPARISON

Mature larvae were 16–17 mm long (excluding the caudal lamellae). The dorsal view of a typical larva is illustrated, based on a mature specimen from Bukit Timah Nature Reserve (Fig. 3a, ZRC.ODO.1792). The larva was overall slender and elongate, rather typical of coenagrionids. It was overall dark brown and hairless. The wing pads and eyes were initially inky black. At this point, the wing pads appeared flattened and compressed over its abdomen (Fig. 4). The tips of the wing pads just reach the posterior margin of the fourth abdominal segment (S4).

The head is broad with the greatest width between the eyes at ca. 4 mm. Three ocelli indicated as light spots are obvious within the ocellar triangle. The eyes are large and protruding. The antennae are five-segmented, progressively tapering from the first segment to a fine last segment of 3 mm length. The first two antennal segments are of a darker brown colour than the distal segments. The prementum of the labium, is triangular shaped, with a series of fine spines along its lateral margin (Fig. 3b). Small, serrated teeth are present along the anterior border of the median lobe. Serrations are absent along the inner margin of the labial palp which bears a sharp terminal hook. Among the specimens examined, four or five long setae are present on each labial palp. The abdomen is elongated and cylindrical. Ventrally, the gonapophyses may be observed at S9. The legs are light brown in colour. All six tarsi are three segmented.

The caudal lamellae are 4 mm long. Each is narrow proximately, expanding to a broadly elliptical shape in lateral view (Fig. 3c). The lamellae end in a fine, pointed tip. The distal three quarters is densely pigmented in intense, dark purplish colours. In life, these three lamellae are rhythmically clapped together and parted regularly for prolonged periods. The frequency of this rhythmic beating of the caudal lamellae typically ranges between 45–55 beats min^{-1}. A video clip of this activity was recorded and uploaded online (http://www.youtube.com/watch?v=rwloWTcqr30).

The expanded, leaf-like caudal lamellae are reminiscent of other Zygopteran larvae that inhabit phytotelms exclusively. This appears to be a form of convergent evolution driven by the need to survive in the oxygen deficient conditions of such confined microhabitats (Clausnitzer, 2004). This form of lamella occurs also in *Teinobasis*, *Amphicnemis*, and *Papuagrion*, all relatives of *Pericnemis* and in some cases living in phytotelms (A. G. Orr, pers. comm.).

When compared with the larva of *Pericnemis triangularis* (from Borneo), there is no apparent difference in the habitus. The labium, however, shows some minute differences. The prementum of *Pericnemis triangularis* is slightly narrower than that of *Pericnemis stictica*. In addition, among the specimens examined, there are either four or five setae on the labial palp but never six as reported for *Pericnemis triangularis* (Orr, 1994). Hence, the number of setae on the labial palp may be a useful diagnostic character to distinguish the larva of these two species.

However, it must be noted that this observed difference is based on a relatively small sample size. In addition, phenotypic differences due to environmental factors can sometimes occur. For example, the prementum of *Hemianax papuensis* in deep versus shallow ponds can be of different shapes, probably due to different foraging techniques (Orr, in litt.) Mikolajewski et al. (2010) also reported larvae of *Leucorrhinia* species having a loss or reduction in larval spines when in fishless lakes compared to larvae in lakes with fish as top predators.

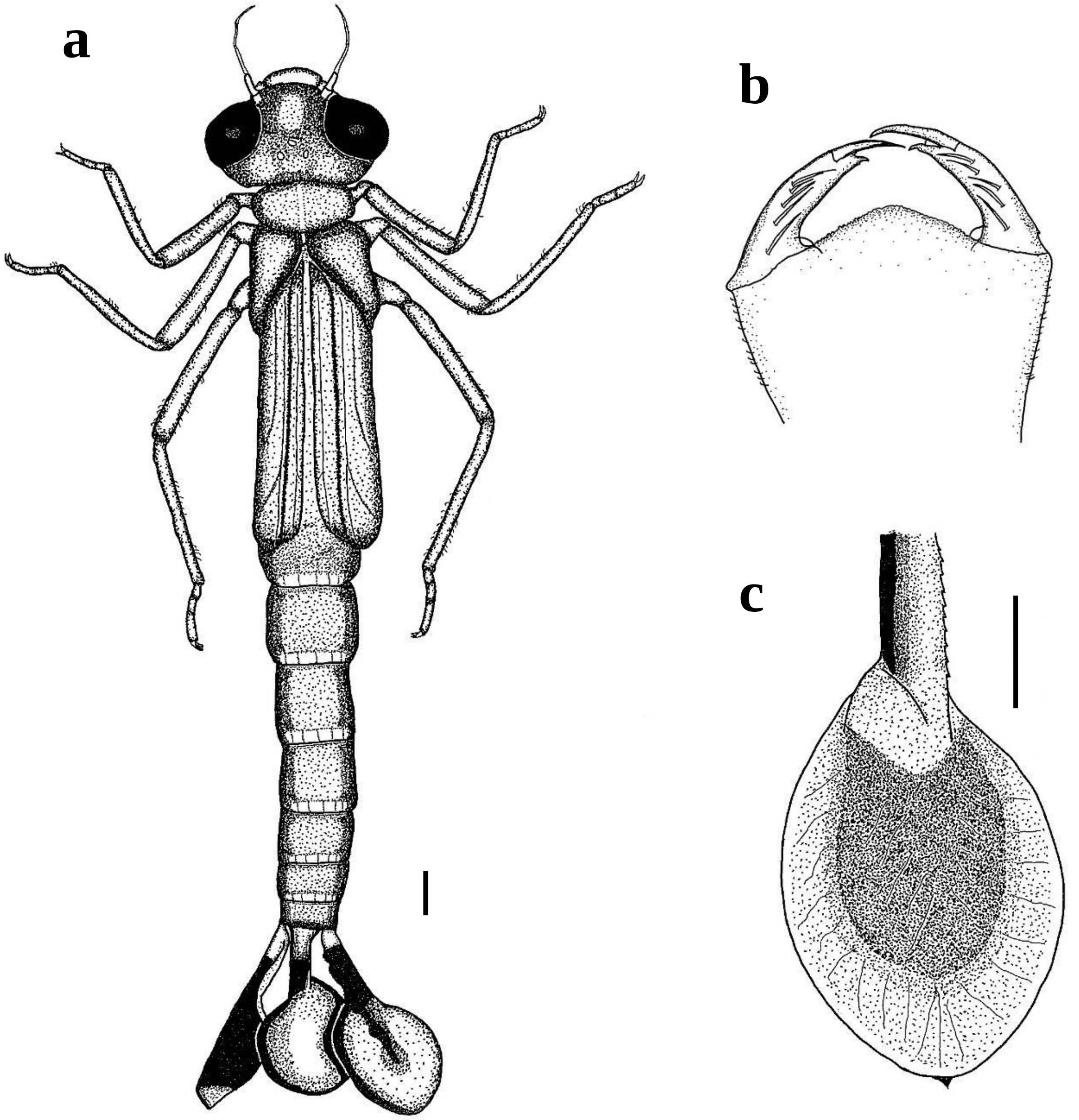

Fig. 3. (a) Dorsal view of mature larva of *Pericnemis stictica*, based on a specimen collected from Bukit Timah Nature Reserve on 20 Oct.2010 (ZRC.ODO.1792). Scale bar = 1 mm. (b) Dorsal view of the extended labium. Scale bar = 1 mm. (c) Lateral view of caudal lamella. Scale bar = 1 mm. (Illustrations by: R. W. J. Ngiam).

EMERGENCE SEQUENCE

As larval development progresses, noticeable signs foretell the onset of eclosion. These include a change in eye colour to a cloudy grey, as well as a change in the colour of the wing pads to a chestnut brown (Fig. 5). The wing pads also appear more cylindrical and inflated than before (compare with Fig. 4), with each of the four wings distinct with clear demarcation of main veins. Eventually, when the eyes become entirely ivory white (Fig. 6), we can be certain that the moment of eclosion is only one or two days away.

On the morning of 17 Oct.2010 (ca. 0805 hours), a mature male larva climbed out of the water and perched on a twig in anticipation of its final moult to adult. Its thorax and head first emerged through a mid-dorsal split in the larval exuvia at ca. 0815 hours, followed shortly by the wings as they were liberated from their individual sheaths. At 0819 hours, its abdomen still remained within the exuvia (Fig. 7a). At 0824 hours, the entire abdomen was extricated, allowing the well-formed anal appendages to be clearly seen (Fig. 7b). At this point, there was a brief pause (Fig. 7c), just before the onset of wing inflation. At 0829 hours, the proximal half of the wings began expanding, while the distal half remained crumpled (Fig. 7d). By 0832 hours, the expanding wings had already surpassed the tip of its abdomen (Fig. 7e).

Fig. 4. Lateral (a) and anterior (b) views of final stadium larva (female) obtained from tree hole at Bukit Kallang (Fig. 2b), photographed on 22 Oct.2010. Note the inky black wing pads and eyes.

Fig. 5. Lateral (a) and anterior (b) views of final stadium larva (female, as in Fig. 4), photographed on 5 Nov.2010. Its wing pads had turned brown and become noticeably inflated. Its eyes had begun to turn cloudy.

Fig. 6. Dorsal view of pre-eclosion larva (male) photographed in-situ within the tree hole at Bukit Kallang (Fig. 2b) on 15 Oct.2010. Note the prominent, ivory white eyes and distinct, brown wing pads. It subsequently eclosed on the morning of 17 Oct.2010 (see Figs. 7, 8).

As soon as the wings had almost attained their final dimensions, abdominal elongation quickly followed. At 0854 hours, the anal appendages had just surpassed the wing tips (Fig. 8a). The abdomen continued to become progressively longer and thinner. By 0920 hours, its full length had almost been attained (Fig. 8b). By the next day (18 Oct.2010), the male damselfly had developed the characteristic colour patterns of the species (Fig. 9), the synthorax metallic blue-green dorsally, with yellow flanks, and eyes greenish yellow, with a tinge of orange dorsally. Adult measurements were: TBL = 58 mm, HW = 33 mm. The specimen was subsequently preserved (ZRC.ODO.1791a).

The emergence sequence of a female was also documented in detail when it emerged on the morning of 8 Nov.2010 (ca. 0815 hours onwards). As soon as its entire abdomen was liberated from the larval exuvia, the ovipositor at S9 could be clearly observed (Fig. 10a). By the following day, the damselfly had developed its adult body colouration (Fig. 10b). The white pterostigma near the apices of the fore- and hindwings were distinct (Fig. 11). Adult measurements were: TBL = 61 mm, HW = 38 mm. The specimen was subsequently preserved (ZRC.ODO.1791b).

DISCUSSION

Within Sundaland, a handful of dragonfly species have also been known to breed in phytotelms. Examples include the libellulids, *Lyriothemis cleis*, *Lyriothemis magnificata*, and *Cratilla metallica* (Orr, 2005). However, the latter are not obligate phytotelm breeders and would only do so if the microhabitats were sufficiently large or disturbed. Such scenarios may include large buttress pans of huge trees or flooded cavities in large, fallen logs.

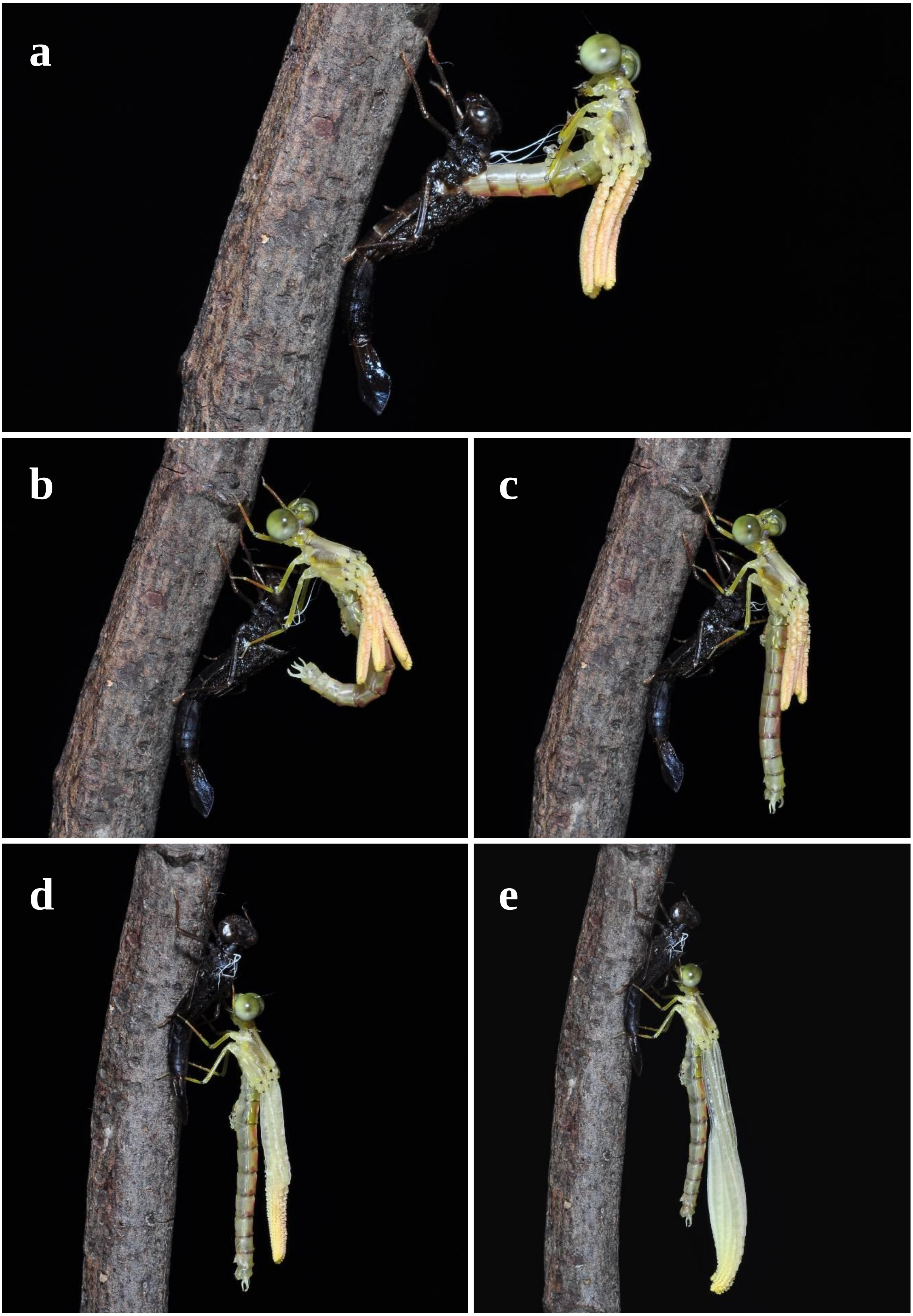

Fig. 7. Eclosion sequence of a male on the morning of 17 Oct.2010 at: (a) 0819 hours, (b) 0824 hours—abdomen extracted, anal appendages visible, (c) 0825 hours, (d) 0829 hours—wings rapidly unfurl, (e) 0832 hours—wing tips surpass abdomen.

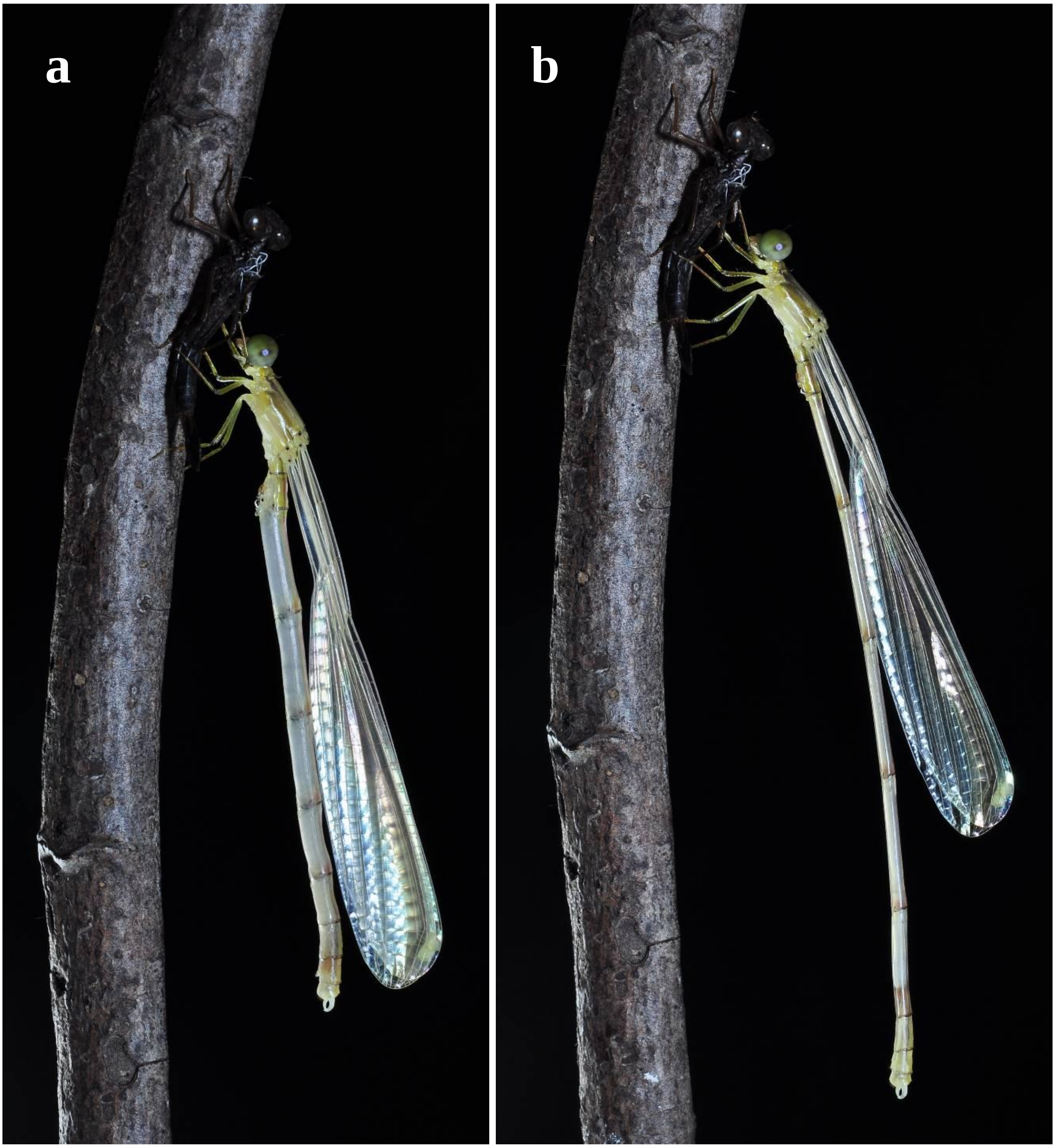

Fig. 8. Eclosion sequence of male damselfly (continued from Fig. 7) at: (a) 0854 hours—wings almost attained full length while abdominal segments continue to elongate, (b) 0920 hours—abdomen almost attained full length.

Conversely, smaller phytotelms present a host of challenges for the survival and development of odonate larvae. Key factors, such as the levels of dissolved oxygen, would be influenced by the surface area of the water, its volume, depth, as well as the abundance of organic matter (decomposing leaves, branches, animals, etc.) within a given phytotelm. Another factor would be the availability and relative abundance of potential prey items. During our multiple visits to investigate treeholes and buttress pools within the Central Nature Reserve, we have often encountered aquatic dipteran larvae within such phytotelms. They largely belong to culicids (mosquitoes), chironomids (midges), or tipulids (craneflies). Future ecological studies on *Pericnemis stictica* locally would thus benefit from comprehensive assessments of both abiotic and biotic parameters, as was conducted by biology students of Universiti Brunei Darussalam (UBD) at Bukit Patoi as part of their ecology field course (Orr, 1997).

In addition, we wish to highlight the fact that forest phytotelms are highly dependent on the rains to be adequately filled. Prolonged dry spells, accompanied by high temperatures, lasting for weeks or months on end would thus be unfavourable for phytotelm-breeding organisms; as such microhabitats can dry up entirely (T. M. Leong, pers. obs.).

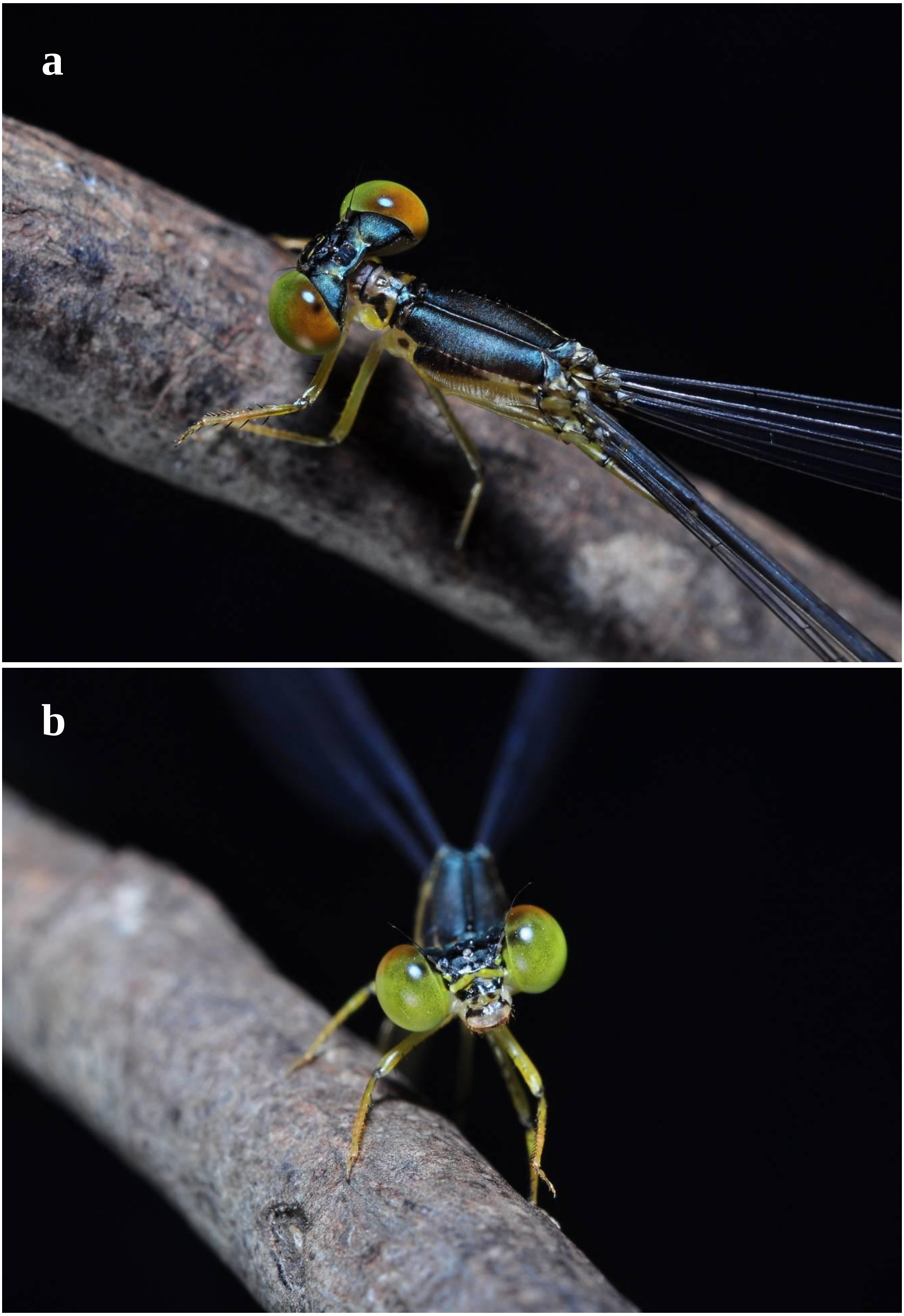

Fig. 9. Dorsal (a) and frontal (b) close-ups of male damselfly (as in Figs. 7, 8) one day after eclosion (18 Oct.2010). Specimen details: ZRC.ODO.1791a, TBL = 58 mm, HW = 33 mm.

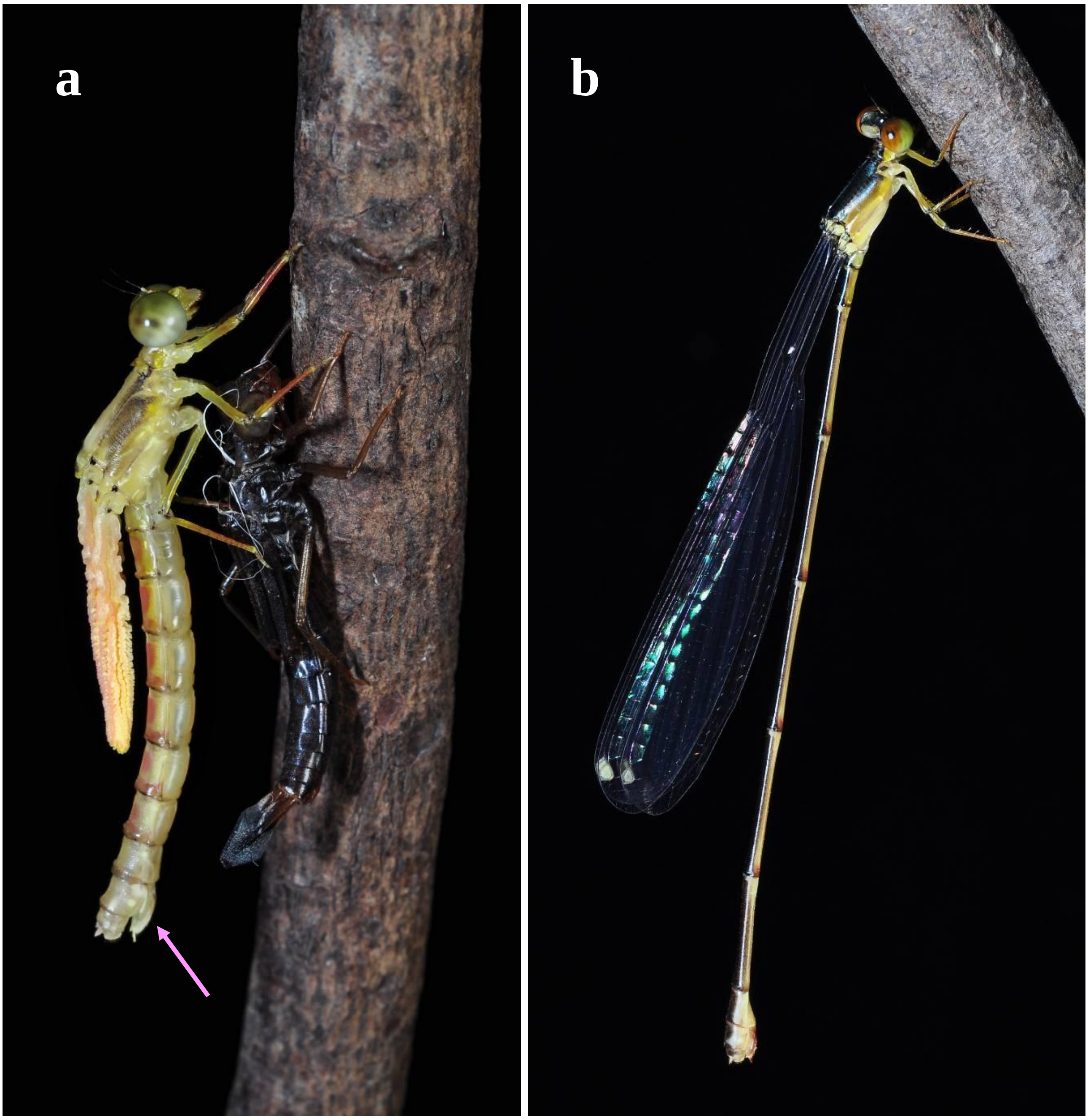

Fig. 10. (a) The female damselfly (larva as in Figs. 4, 5) eclosed on the morning of 8 Nov.2010 (ca. 0830 hours). Its ovipositor (arrowed) was clearly visible. (b) The damselfly exhibited its diagnostic adult colouration on the following day. Specimen details: ZRC.ODO.1791b, TBL = 61 mm, HW = 38 mm.

Perhaps in the event of such near-drought conditions, we could attempt to intervene by ‘rehydrating’ such phytotelms and allowing the damselflies, and other associated fauna to continue with their amphibious life cycle. While complete drying out of phytotelms has happened regularly (seasonally) in Panama, the drop in water level has not exceeded 1 cm for big buttress pans in Brunei (A. G. Orr, pers. comm.). Another important determinant of the rate and extent of evaporative water loss from phytotelms would be the relative openness of the forest. Factors such as the density of the vegetation and continuity of the canopy would certainly play a part. A final aspect to consider would be the relative adaptability/resilience of the larvae of various odonate species to prolonged dessication. For example, *Lyriothemis* have been known to withstand severe desiccation (A. G. Orr, pers. comm.).

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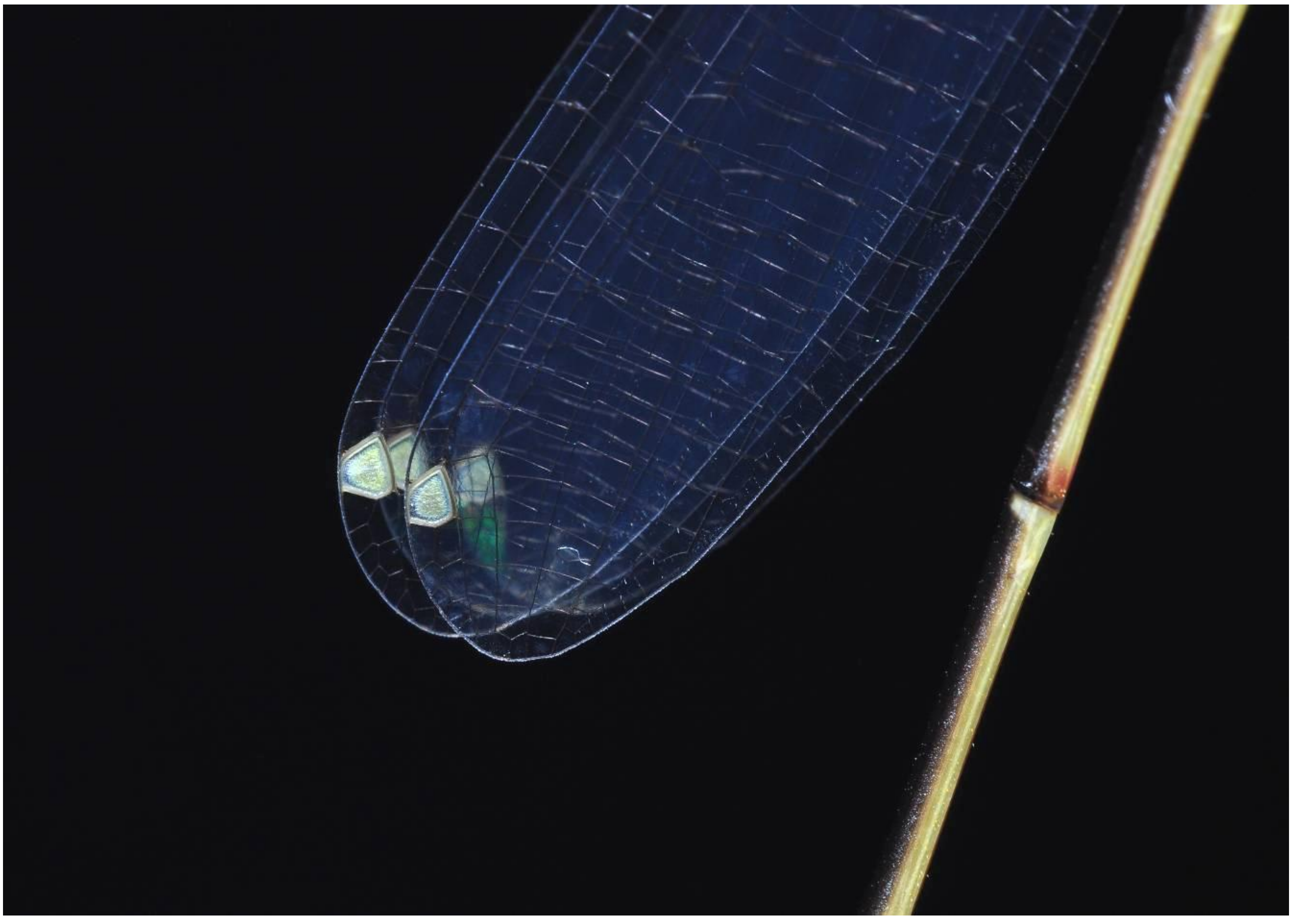

Fig. 11. Close-up detail of the white pterostigma in the wings of the female (as in Fig. 10b).

MATERIAL EXAMINED

Table 1. Summary of *Pericnemis stictica* specimens deposited at ZRC (RMBR). M = Male, F = Female, TBL = Total Body Length, HW = Hindwing Length.

ZRC.ODO.	Locality/other details	Date of moulting/eclosion	Sex	TBL (mm)	HW (mm)
1790a	Bukit Timah Nature Reserve: South View Path; from buttress pool of mature *Parishia insignis* (Anacardiaceae). Coll. T. M. Leong & R. W. J. Ngiam (5 Oct.2010). Larvae reared by R. W. J. Ngiam.	Emerged: 29 Oct.2010	F	61	37
1790b		Moulted: 12 Oct.2010 Emerged: 9 Nov.2010	F	62	39
1790c		Moulted: 7 Oct.2010, 15 Oct.2010, 24 Oct.2010, 11 Nov.2010 Emerged: 15 Dec.2010	M	63	37
1791a	MacRitchie forest: Bukit Kalang; from treehole of mature *Calophyllum* species (Guttiferae). Coll. T. M. Leong (15 Oct.2010). Larvae reared by T. M. Leong.	Emerged: 17 Oct.2010	M	58	33
1791b		Emerged: 8 Nov.2010	F	61	38
1791c		Larva preserved	?	—	—
1792	Bukit Timah Nature Reserve: South View Path; from buttress pool of *Parishia insignis* (Anacardiaceae). Coll. T. M. Leong (20 Oct.2010).	Larva preserved	F	—	—
1793	Bukit Timah Nature Reserve: South View Path; freshly eclosed larval exuvia from buttress of *Parishia insignis* (Anacardiaceae). Adult sighted flying away. Coll. T. M. Leong & Rita Chung (7 Dec.2010).	Emerged: 7 Dec.2010	?	—	—

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