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Description of the final instar larva of *Cephalaeschna risi* Asahina, 1981 with notes on its semi-terrestrial lifestyle (Odonata: Aeshnidae)

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Abstract: The final instar larva of *Cephalaeschna risi* Asahina, 1981 is described for the first time based on material from Taiwan. In Taiwan, the larva of *C. risi* can be separated from other aeshnid larvae by its relatively short antennae and presence of small protuberances on the legs. Diagnostic characters to distinguish it from other known larvae of *Cephalaeschna* are also discussed. A comprehensive description, detailed illustrations, bionomics and observations of the semi-terrestrial lifestyle of *C. risi* are presented. Finally, a key to the genera of Aeshnidae in Taiwan is proposed.

Keywords: dragonfly, Anisoptera, taxonomy, key, bionomics, Taiwan

Introduction

The genus *Cephalaeschna* Selys, 1883 is restricted to Asia with 28 species known (Schorr & Paulson, 2020), including a few species that were described in recent ten years (Zhang et al., 2013; Zhang & Cai, 2013; Joshi & Kunte, 2017; Sasamoto & Lien, 2018; Dawn, 2021). *Cephalaeschna risi* Asahina, 1981 is a widespread but cryptic species, known only from Taiwan, Fujian, Guangdong and Zhejiang (Asahina, 1981; Lieftinck et al., 1984; Zhang, 2019).

So far, the morphology of the larva and the natural history of *Cephalaeschna* are poorly understood. Needham (1930) described the larva of *Cephalaeschna* for the first time, but of an unidentified species. Fraser (1943) described the larva of *C. orbifrons* Selys, 1883 based on specimens collected from sluggish streams. Later Asahina (1961) illustrated the larva of an unidentified *Cephalaeschna* species and Wilson & Tam (2006) illustrated the larvae of *C. klotsi* but descriptions were not provided in either publication. Jiang & Zhang (2008) described the exuviae of *C. patrorum* Needham, 1930, this represented only the second description of the larva identified to species from this mysterious genus.

In 2018, we found a series of larva of *Cephalaeschna* in Datong Township, Yilan County, Taiwan. By rearing the larvae to adulthood in the laboratory (Figure 1), we confirmed that they belong to *C. risi*. Here we describe the larva of *C. risi* for the first time. Additionally, the bionomics of the species, including its semi-terrestrial behavior are discussed.

Material and methods

Specimen examination, measurement and photographs

Specimens of larva and exuvia were examined using a Leica M205 C stereoscope. Measurements were taken with a Leica M205C stereomicroscope and a Leica MC170 HD digital camera with LAS software

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(version 4.4.0, Leica Application Suite, Wetzlar, Germany) or digital callipers. Measurements are given in mm, measured characters are abbreviated as follows: BL– length between anterior margin of labrum and cerci; HW–maximum width of head; HL–length from base of labrum to nuchal ridge; AL–length of antenna; PL–length from anterior margin of prementum to posterior margin of permentum (movable hooks are not included); MHL–length from base of movable hook to tip of movable hook; MFL–length of metafemur; MTL–length of metatibia; ABL–maximum length of abdomen; APL–length of anal pyramid; EL–length of epiproct; MCL–length of male cercus; FCL–length of female cercus; MPL–length of male projection; PVVL–length of primary ventral valvula. The photographic method used follows Hu (2020). Photographs of mandibles were taken using a Canon EOS 760D SLR camera with a Canon MP-E65 f2.8 1–5x Macro lens. Others photos were taken using an Olympus OM-D E-M1 digital camera with an Olympus M. ZUIKO DIGITAL ED 30 mm F3.5 Macro lens. Photos of morphological characters were montaged using Helicon Focus 7 software. Figures were modified using Adobe Photoshop CS5 and Adobe Illustrator CS5 if needed. The supplementary videos of the hunting behavior of the larva are available from the following link: https://zenodo.org/record/4274456#.X7Dl-GgzY2w.

Specimen depositories. Specimens examined for this study are deposited in the following collections:

FSHc Fang-Shuo Hu, private collection, Taichung, Taiwan;
NMNS National Museum of Natural Science, Taiwan (Jing-Fu Tsai);
ILLc I-Lung Lee, private collection, Taipei, Taiwan;
LCHc Lung-Chun Huang, private collection, Taipei, Taiwan.

Results

Figure 1. Newly emerged adult female of *Cephalaeschna risi* Asahina, 1981 in the laboratory (Photo by Hsin-Hisung Chen).

Material examined

3 final instar exuviae (1 male, 2 females, reared), 4 final instar larvae (2 males, 2 females). TAIWAN: (1 male, 2 females) final instar exuviae, (1 male, 1 female) final instar larvae, Yilan County, Qilan, Datong Township, ca. 1650 m, 29-VII-2018, leg. F. S. Hu & I. L. Lee (FSHc, NMNS, ILLc, LCHc); (1 female) final larva, same data as previous ones except 15-IV-2020, leg. L. C. Huang (LCHc); (1 male) final instar larva, same data as previous ones except 29-IV-2020, leg. L. C. Huang (LCHc).

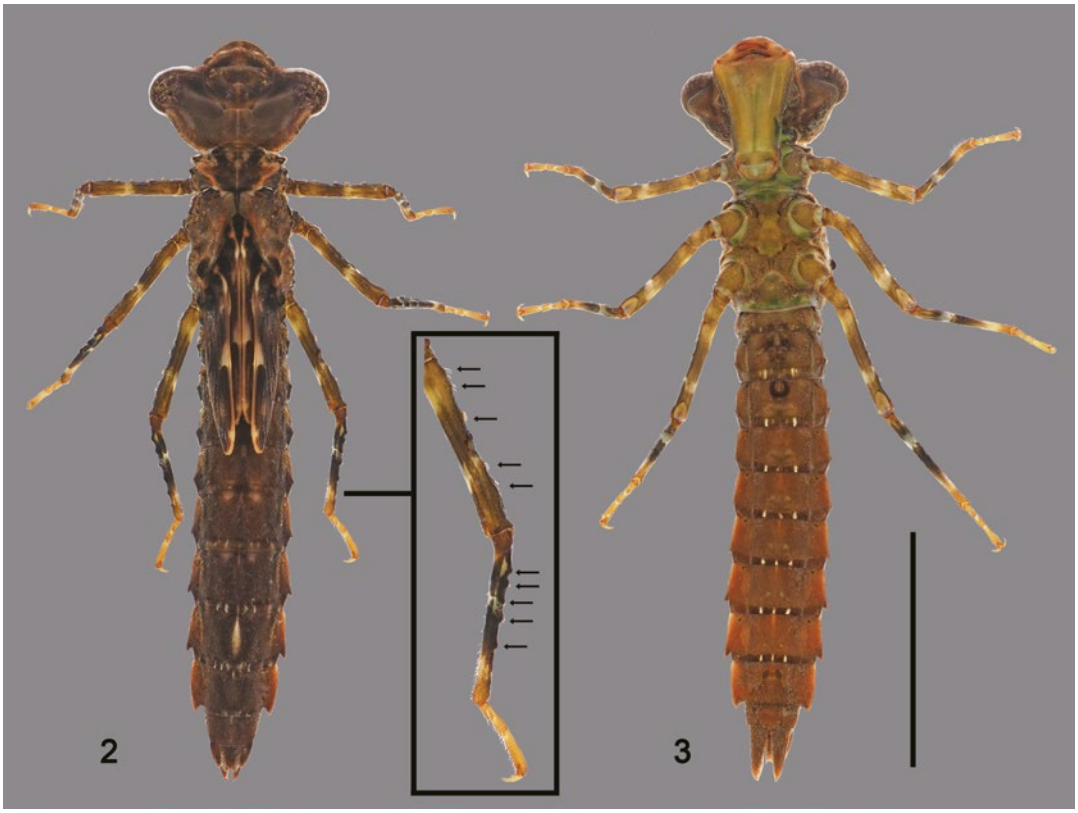
Measurements

2 exuviae (1 female and 1 male) and 1 larva (1 male) were measured. BL– 32.92 (32.13–33.88); HW–8.15 (8.05–8.23); HL–5.41 (5.35–5.50); AL– 2.21 (2.14–2.28); PL–5.29 (5.22–5.36); MHL–1.36 (1.32–1.44); MFL–5.59 (5.41–5.80); MTL–6.92 (6.81–7.07); ABL–21.56 (20.86–22.22); APL–2.54 (2.37–2.70); EL–0.53 (0.53–0.53); MCL–1.47 (1.43–1.55); FCL–1.04 (1.03–1.06); MPL–1.24 (1.22–1.25); PVVL–5.16 (5.16–5.16).

Description

Habitus

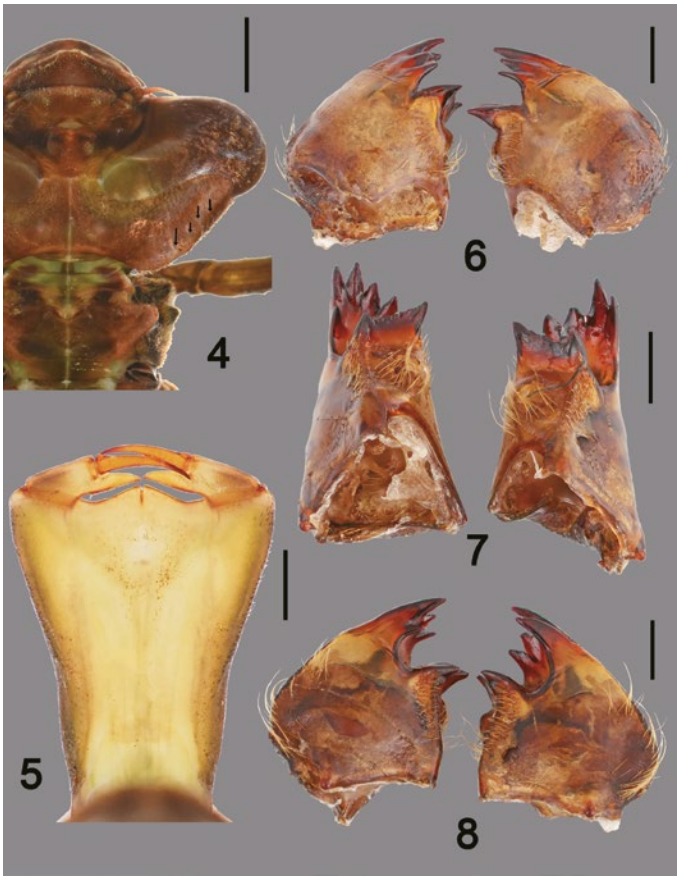
Medium-size larva, body elongated and narrow, covered with small protuberances



Figures 2–3. Habitus of the final instar larva of *Cephalaeschna risi* Asahina, 1981. (1) Dorsal view; (2) Ventral view. Scale bar: 10 mm. The photo of the right hind legs is enlarged, the arrows indicate the small protuberances on femur and tibia.

Head.

Head (Figure 4) large, wider than long; wider than the width of thorax or abdomen, with large pyriform eyes. Postocular portion of head approximately as long as length of eyes. Occiput ochre, with short and stiff setae, occipital lobe with comb-shape protrusion (Figure 4). Three white and distinct ocelli located in the middle of the head, combine as a large and spherical protrusion. Labrum pale brown with black, short and stiff setae on the surface; anterior border widely convex with an external row of long, dense, light gray setae. Clypeus pale brown, near trapezoidal with a protrusion in the middle, with few brownish setae. Antennae very short, filiform, 7-segmented; 1st segment very short, shorter than 1/2 half of 2nd segment, the 3rd segment the longest, ratio of segments 1–7 as follows: 0.36: 0.73: 1.00: 0.34: 0.50: 0.40: 0.32. Mandibles (Figures. 6–8) with molar crest, mandibular formula: L 1234 y a (m) b /R 1234 0 a (m1, 2, 3, 4, 5 or 6) b, both mandibles tooth a>b>m; the numbers of both molar crest are indefinite. External process of mandible and below molar crest with long, dense, golden setae. Maxillae galeolacinia with seven moderately incurved, sharp teeth covered dense, golden setae. Ventral pad of hypopharynx with short, dense, golden setae on the anterior margin. Prementum (Figure 5) brownish yellow, near trapezoidal, longer than wide, with short, black setae on the margin of first half; median cleft distinct, without protrusion nearby. Ligula convex brownish yellow, moderately prominent, distal margin with short but dense brownish setae. Labial palp brownish yellow, with a few short setae on the apical margin and a row of irregular protrusions on the inside margin; moveable hook long, sharp, moderately incurved, slightly shorter than labial palp, without setae; tips of internal lobes sharp.



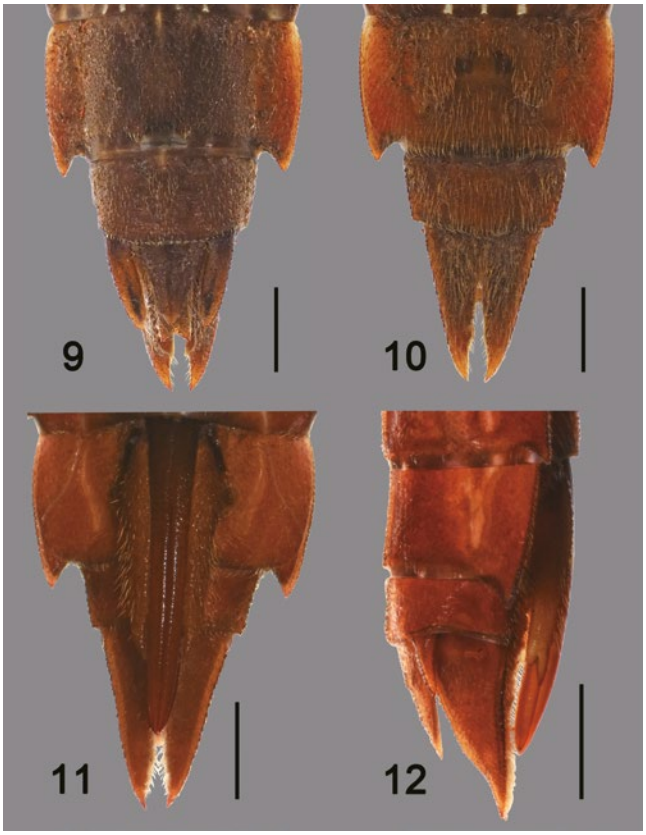
Figures 4–8. Head, thorax, prementum and mandibles of the final instar larva of *Cephalaeschna risi* Asahina, 1981. (4) Head and thorax (dorsal view); (5) Prementum (dorsal view); (6) Mandibles (dorsal view); (7) Mandibles (lateral view); (8) Mandibles (ventral view). Scale bars: 4 = 2.5 mm, 5–8 = 1 mm. The arrows indicated the comb-shaped protrusion on the occipital lobe.

Thorax.

Thorax brownish, narrower than head. Pronotal disk sub-hexagonal, with a V-shape black stripe covered dense golden setae on the margin; lateral margin of pronotal disc rounded. Prothoracic apophyses well developed. Thorax granulose with dense golden setae laterally. Wings dark brown with three white areas on the apical margin of each; anterior wing cases reaching the middle of S3; posterior wing cases reaching posterior margin of S3. Legs long and striped, tibiae and femora with many patches of short golden setae and small protuberances on the surface.

Abdomen.

Abdomen brownish, granulose and elongated. Every segment with dense short golden setae dorsally; S1–8 covered with sparse short golden setae laterally; S9–10 covered with dense short golden setae ventrally; S6–9 with distinct spines laterally; S4–5 with a white area by the posterior margin dorsally; S6-8 with a row of white spots on the posterior margin dorsally; S8 with a vertical white line in the middle of the segment dorsally; S1–4 with two white spots on the posterior margin ventrally; S5–7 with three white spots on the posterior margin; S6–9 with medio-longitudinal keel in dorsal view. Cerci digitiform, spinous, slightly shorter than S10. Epiproct rectangular and smooth with dense, golden setae; split into two apically, rounded apically (Figures 9–10). Basal lamina of epiproct present in both sexes. Paraprocts digitiform with long and dense golden setae; much longer than cerci; inner margin smooth; outer margin spinous (Figures 9–10). Primary lateral valvula almost 1.5 times longer than S9, densely covered with golden setae (Figures 11–12). Primary ventral valvula bar long and slender, almost 2.5 times longer than S9 (Figures 11–12).



Figures 9–12. Abdominal terminalia of both sexes of the final instar larva of *Cephalaeschna risi* Asahina, 1981. (9) Male (dorsal view); (10) Male (ventral view); (11) Female (ventral view); (12) Female (lateral view). Scale bars: 1 mm.

Diagnosis.

Within the genus *Cephalaeschna*, the larva of *C. risi* may be separated from that of *C. partrorum* (illustrated in Jiang & Zhang (2008)) by the cerci of *C. risi* longer than its male projection (the cerci of *C. partrorum* shorter than its male projection); the epiproct slightly longer than male projection (Figure 9) (the epiproct of *C. partrorum* much longer than its male projection). Furthermore, in *C. patrorum* a pair of distinct protrusions are present near the median cleft but these are absent in *C. risi* (Figure 5). *Cephalaeschna risi* can be separated from *C. orbifrons* (illustrated in Fraser (1943)) by the posterior margin of its epiproct with a distinct emargination (Figure 9) and the tips of the internal lobes of labium relatively sharper than in *C. orbifrons*. Even though the description of *C. klotsi* was not provided in Wilson & Tam (2006), based on the illustration which the authors provided, *C. risi* can separated from *C. klotsi* by its primary ventral valvula reaching to half the length of the paraproct. In Taiwan, the larva of *C. risi* can be readily separated from other aeshnid larvae by the presence of relatively short antennae and presence of small protuberances on the tibia and femur.

Microhabitat and behavior

In Taiwan, the adults of *C. risi* occurr in mountain forests (between 300 m and 1700 m) from August to September. The adults are active on rapid streams or at waterfalls in primary forest (Figure 18) during the early morning or the late afternoon.

Figures 13–16. Photos of live specimens of *Cephalaeschna risi* Asahina, 1981. (13) First instar larva stood on moss in the field; (14) Final instar larva on moist leaf litters in the wild; (15) Final instar larva hanging under the leaf of a Cyperaceae plant in the wild; (16) Final instar larva hunting prey on the ground in the laboratory.

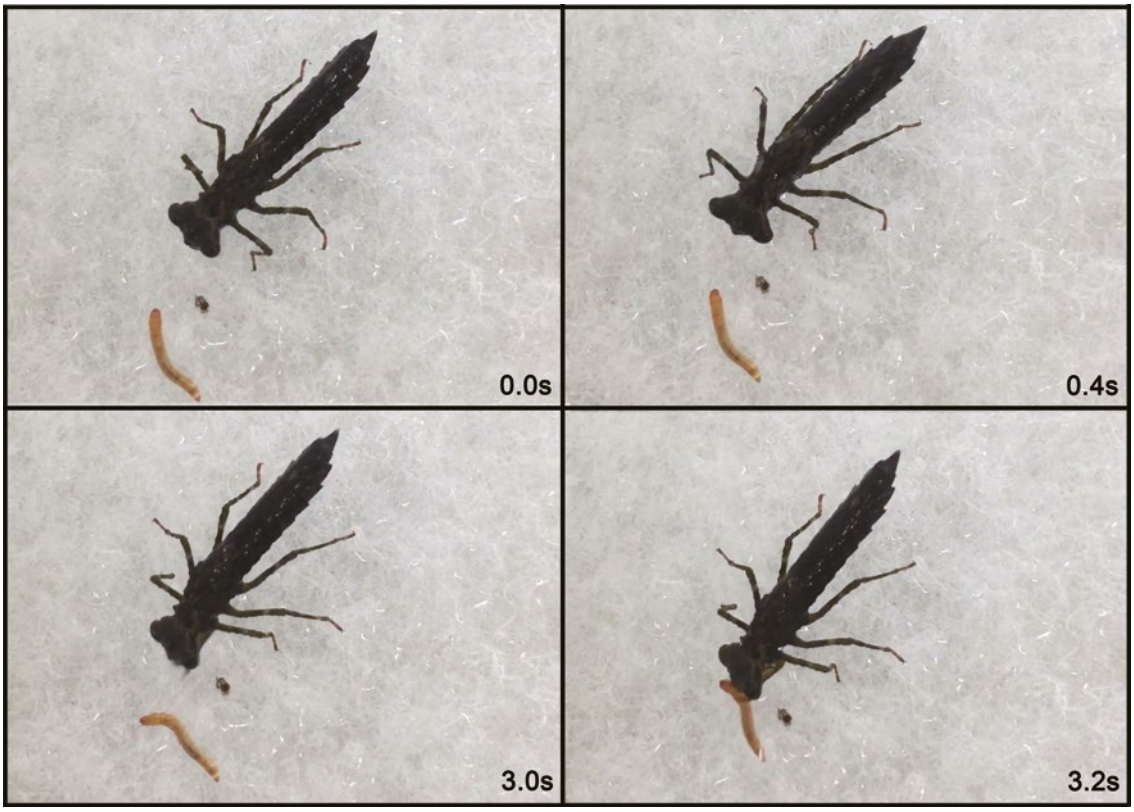


Figure 17. The hunting behavior of a larva of *Cephalaeschna risi* Asahina, 1981.

Figures 18–19. Habitats of adults and larvae of *Cephalaeschna risi* Asahina, 1981. (18) The habitat where adults are active in Manyueyuan, New Taipei City, Taiwan (photo by C.-H. Ma); (19) The habitat of the larvae in Qilan, Yilan County, Taiwan.

The larvae of *C. risi* were found in shallow pits on a hillside covered in abundant moist fallen leaves (Figure 14) and some rotten wood and rocks, located in a mixed coniferous-broad-leave forest in north Taiwan at about 1700 m (Figure 19). The larvae were nocturnal, a final instar larva was found upside down under the leaf of a Cyperaceae plant (Figure 15) and multiple larvae were active on mossy rocks. The larva of *C. risi* co-occured with the larva of *Rhipidolestes aculeatus aculeatus*, which has the same habitat preferences.

Remarks

The larva of *C. risi* usually stand or walk on the ground, out of water. In the laboratory, we provided tissue paper or filter cotton as a terrestrial substrate then added few water (not covering the tissue paper or filter cotton) in the container. During our observations not only final instar larvae but also early instar larvae remained out of the water, standing on the tissue paper or filter cotton most of time. We provided *Gryllus assimilis* and larvae of *Tenebrio molitor* as food resources. The larva of *C. risi* was observed to usually hunt the prey on the ground (Figures 16–17). The larvae of *C. risi*, with a flexible abdomen, sometimes shakes the abdomen in response to apparent threats.

In our field observations, early instar exuviae were found hanging under the moist stone walls in the habitat (Figure 19), further demonstrating the semi-terrestrial behavior since the larvae are not moulting under the water like normal aeshnid larvae. However, the emergence site remains unknown. Multiple early instar larvae were found to co-occur with final instar larvae in early August (Figure 12). Therefore, we conjecture that the oviposition site is near to the habitat of the final instar larvae.

Key to the final instar larvae of Taiwanese genera of Aeshnidae (Modified from Chan (2009)

1. Antennae less than 7-segmented . . . . . *Periaeschna*
   Antennae 7-segmented 2
2. Small protuberances present on tibiae and femora . . . . . *Cephalaeschna*
   Small protuberances absent on tibiae and femora 3
3. Antennae length same as head length . . . . . *Sarasaeschna*
   Antennae length less than 2/3 of head length 4
4. Eyes not protruding; posterior margin of eyes with very shallow emargination. . . *Anax*
   Eye protruding; posterior margin of eyes with shallow to deep emargination 5
5. Pair of distinct protrusions always present on anterior margin of prementum near median cleft . . . . . *Planaeschna*
   At most a pair of indistinct protrusions on anterior margin of prementum near median cleft, these protrusions sometime absent. 6
6. A pair of indistinct protrusion on anterior margin of prementum near median cleft present 7
   Pair of protrusion on anterior margin of prementum near median cleft absent. . . . 8
7. Lateral setae present on labial palpus. . . . . *Gynacantha*
   Lateral setae absent on labial palpus . . . . . *Polycanthagyna*
8. Long setae present on moveable hooks . . . . . *Anaciaeschna*
   Setae absent ons moveable hooks. . . . . *Aeshna*

Discussion

We have proposed a diagnosis to distinguish the known larvae of species of *Cephalaeschna*. However, we doubt the identification of the final instar larva of *C. patrorum* described by Jiang & Zhang (2008). Jiang & Zhang (2008) did not mention the prementum of the larva of *C. patorum* in the description but it appeared in the illustration. Based on presence of a pair of distinct protrusions on the anterior margin of prementum near median cleft which is one of the major diagnostic characters for the genus *Planaeschna* (Ishida, 1996; Zhang et al., 2010; Xu & Zhang, 2011), we consider the larvae described as that of *C. patrorum* in Jiang & Zhang (2008) is most likely to actually be that of a *Planaeschna* species.

Only a few cases of semi-terrestrial behavior of anisopteran larva have been reported (*Antipodophlebia asthenes* (Tillyard, 1916) and *Pseudocordulia* sp.), in both cases larvae were collected from the moist leaf litter on the forest floor (Watson & Theischinger, 1980; Watson, 1982). The larvae of *C. risi* were also collected from moist leaf litter on the forest floor and we observed it active on the ground both in the wild and the laboratory. The functions of the rectum include respiration and locomotion in anisopteran larva. The larva respires in the water by using the rectal gill to exchange oxygen from the water and can move forward by expelling water from the anus (Snodgrass, 1954). However, we did not observe rectal propulsion in the *C. risi* larvae and rectal propulsion was reported to not be effective in the *Pseudocordulia* sp. with terrestrial larvae reported by Watson (1982). Larvae of both *C. risi* and the *Pseudocordulia* sp. reported on by Watson (1982) can respire out of water in moist conditions for a long time. The structure and function of their rectal gill will be an interesting topic for further studies.

In summary, we provide a detailed description of the final instar larva of *C. risi*, a representative of the enigmatic genus *Cephalaeschna*. The description should provide useful information for future morphological phylogenetic studies within the family Aeshnidae. In addition, we provide information on the semi-terrestrial behavior of *C. risi*.

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