

Tarbiat Modares University Press
Entomological Society of Iran

Research Article
Faunistic

<https://doi.org/10.61186/jibs.10.3.443>

ISSN: 2423-8112

<https://zoobank.org/urn:lsid:zoobank.org:B06F8070-3788-4371-BE8C-F6F9812A6ACF>

New findings of the *Caenis ulmeriana*-group (Ephemeroptera: Caenidae) in the Western Ghats, India

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ABSTRACT. *Caenis ulmeriana* Malzacher, 2015 is recorded for the first time from the Western Ghats, India. Prior records of this species encompass Java, Sumatra, Thailand, Myanmar, and the Philippines. Notably, the Indian population of *C. ulmeriana* showcases variability, including slight changes in the shape of forceps in the male subimago and increased denticulation in the midclaw, a reduced number of setae in the Y-ridge of tergite II, and differing shape of sternum IX in the larvae compared to other continental and island populations. The species number of *Caenis* Stephens, 1835 has now increased to twelve in India. A distributional map detailing the range of *C. ulmeriana* in the Oriental region is also provided herein.

Keywords: *Caenis*, mayflies, morphological variability, new record, Tamil Nadu

Received:

11 January, 2024

Accepted:

26 March, 2024

Published:

03 July, 2024

Subject Editor:

Nikita Kluge

Citation: Srinivasan, P., Sivaruban, T., Barathy, S. & Isack, R. (2024) New findings of the *Caenis ulmeriana*-group (Ephemeroptera: Caenidae) in the Western Ghats, India. *Journal of Insect Biodiversity and Systematics*, 10 (3), 443–451.

INTRODUCTION

The genus *Caenis* Stephens, 1835 is the largest mayfly genus in terms of species number which accounts for about 165 species based on published records and globally widespread genus, except in the New Zealand, Antarctica and various oceanic islands (Malzacher, 2022; Srinivasan et al., 2023b). However, Indian Caenidae has ineffectively been investigated compared to other parts of the Oriental region with only two genera. So far, five species of *Clypeocaenis* Soldán, 1978 (Muthukatturaja et al., 2020; Balasubramanian & Muthukatturaja, 2021; Srinivasan et al., 2022) and seven species of *Caenis* (Malzacher, 2015; Srinivasan et al., 2021, 2023a, 2023b; Muthukatturaja & Balasubramanian, 2021) have been discovered in the last decade. However, the number of undiscovered species in Caenidae is probably high compared to the discoveries that were made. Until now, twelve species of *Caenis* were recorded in India: *C. incurva* Malzacher, 2015, *C. picea* Kimmins, 1947, *C. piscina* Kimmins, 1947, *C. srinagari* Traver, 1939 from North India and *C. kimminsis* Ali, 1967, *C. maratha* Malzacher, 2015, *C. americani* Srinivasan, Sivaruban, Barathy, Malzacher & Isack, 2021, *C. maduraiensis* Balasubramanian & Muthukatturaja, 2021, *C. kaegies* Srinivasan, Sivaruban, Barathy & Isack, 2023, *C. venkataramani*

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Srinivasan, Sivaruban, Barathy & Isack, 2023, *C. arunachalami* Srinivasan, Sivaruban, Barathy & Isack, 2023 and *C. limai* Srinivasan, Sivaruban, Barathy & Isack, 2023 from South India. However, the validity of *C. kimminsis* is highly questionable by several authors (Staniczek et al., 2020; Srinivasan et al., 2021) and Srinivasan et al. (2023a) proposed *C. kimminsis* as 'species inquirenda'.

The Western Ghats of India span a length of approximately 1600 kilometers, stretching from Gujarat in the west to Kerala in the south. Renowned as a global biodiversity hotspot, as designated by Myers et al. (2000), this region has an exceptional array of endemic flora and fauna. Additionally, the presence of diverse geo-climatic barriers and gradients further underscores the significance of the Western Ghats as a landscape for investigating evolutionary processes and resulting phylogeographical patterns (Sivaramakrishnan et al. 2023). Continuing the ongoing exploration of mayflies in this region, *Caenis ulmeriana* Malzacher, 2015, has been documented for the first time in the southern Western Ghats based on larval specimens. This discovery adds to the growing understanding of mayfly diversity and distribution within this biodiverse region.

MATERIAL AND METHODS

The larvae of the new record were collected in December 2020 by hand-picking from the Anai Pillayar Kovil Dam in the Theni district in Tamil Nadu. The collected specimens were preserved in 80% ethanol. The morphological characters were studied with the help of LABOMED Luzeo 6Z stereo zoom and LABOMED Lx400 microscopes and photos were acquired using a MiaCam CMOS AR 6 pro microscope camera and editing of photos was done by Adobe Photoshop ver 7.0. The distributional map was done with the help of the software SimpleMappr (Shorthouse, 2010). The subimaginal characters are extracted from the male last instar larva, as the genital structures didn't change during larval and subimaginal moult (Kluge, 2004). The species identification is based on the original description and keys of Malzacher (2015) and Malzacher & Sangpradub (2021) respectively, and the derivation of terminology is mostly based on Malzacher (1991, 2015). The materials are deposited in the American College Museum (AMC), Madurai, Tamil Nadu, India.

RESULTS

Taxonomic hierarchy

Class Insecta Linnaeus, 1758

Order Ephemeroptera Hyatt & Arms, 1891

Family Caenidae Newman, 1853

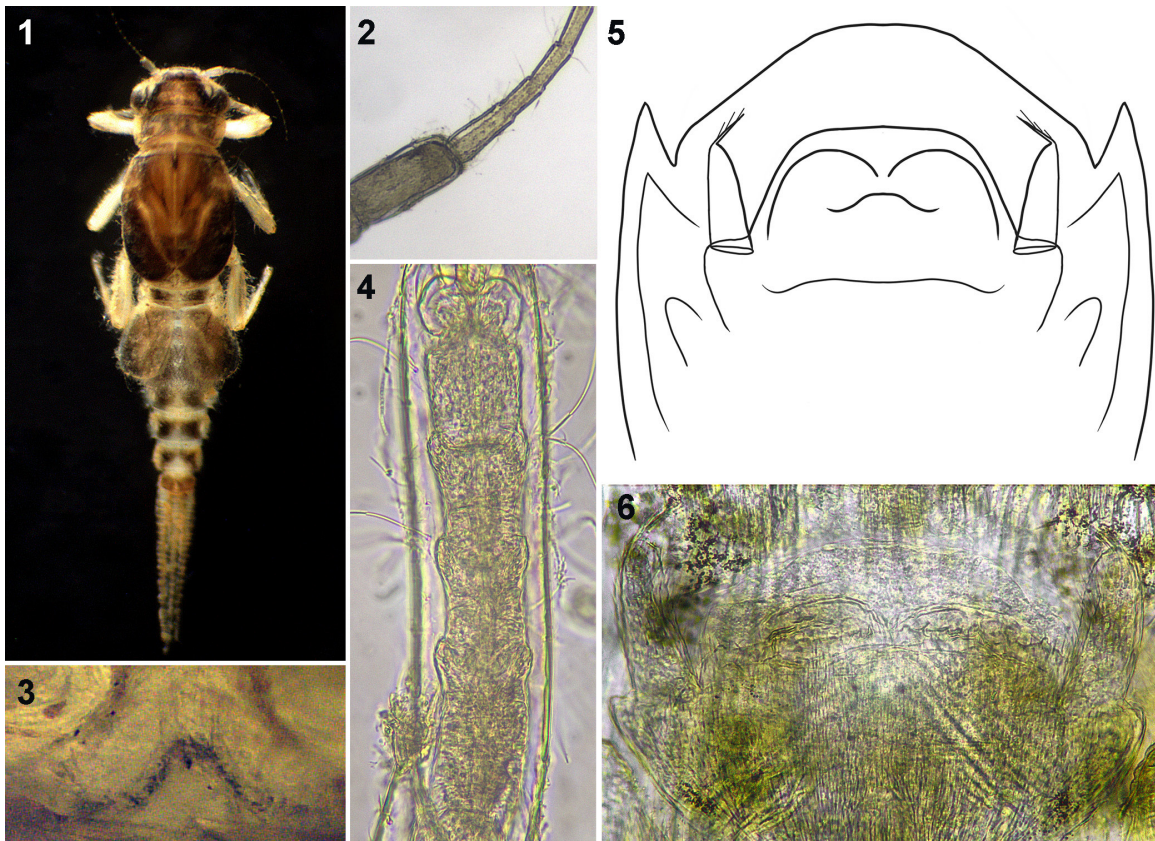
Genus *Caenis* Stephens, 1835

***Caenis ulmeriana* Malzacher, 2015 (Figs 1–28)**

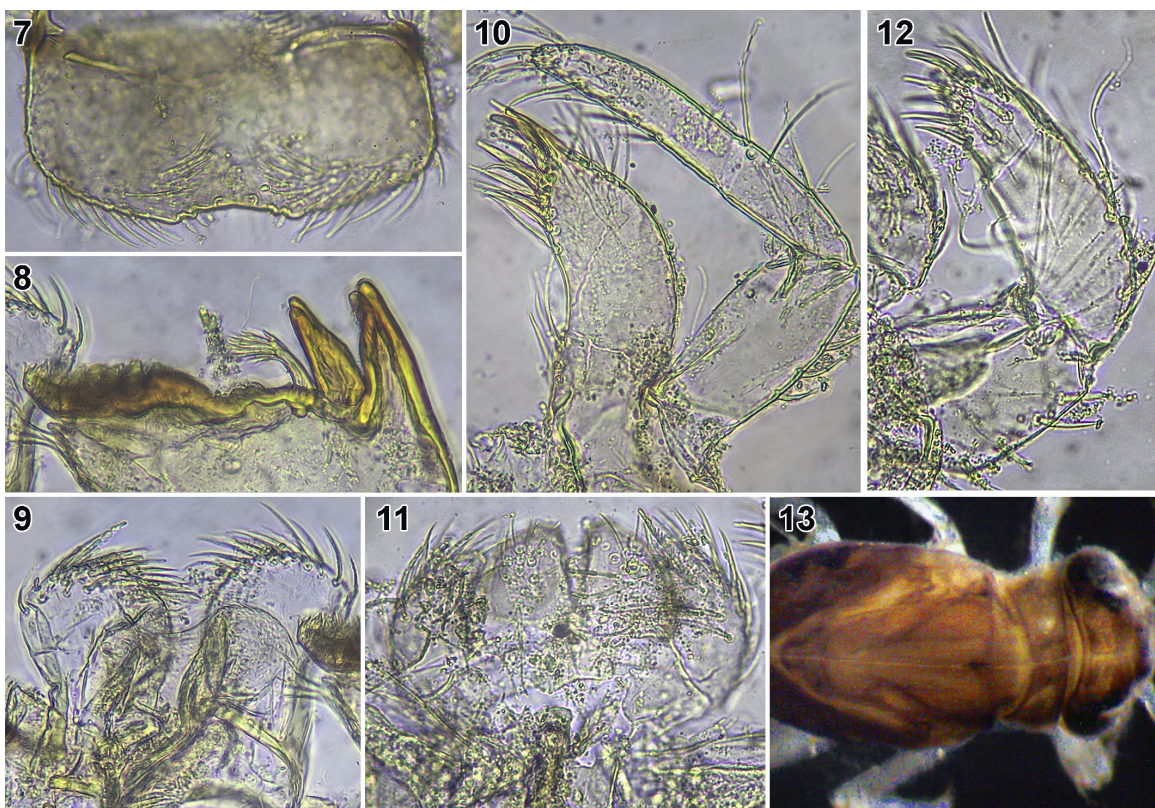
Material examined. One male mature larva (AMC/ZN/279) and two female larvae (AMC/ZN/280), India, Tamil Nadu, Theni district, Anai Pillayar Kovil Dam, 10°03'07"N, 77°34'02"E; 336 m. a.s.l., 23-XII-2020, leg. P. Srinivasan & R. Isack.

Distribution. The species is reported from India (**new record**), Java (Malzacher, 2015), Sumatra (Malzacher, 2015), Thailand (Malzacher, 2015; Malzacher & Sangpradub, 2021), Myanmar (Malzacher, 2023) and Philippines (Malzacher, 2023) (Fig. 28).

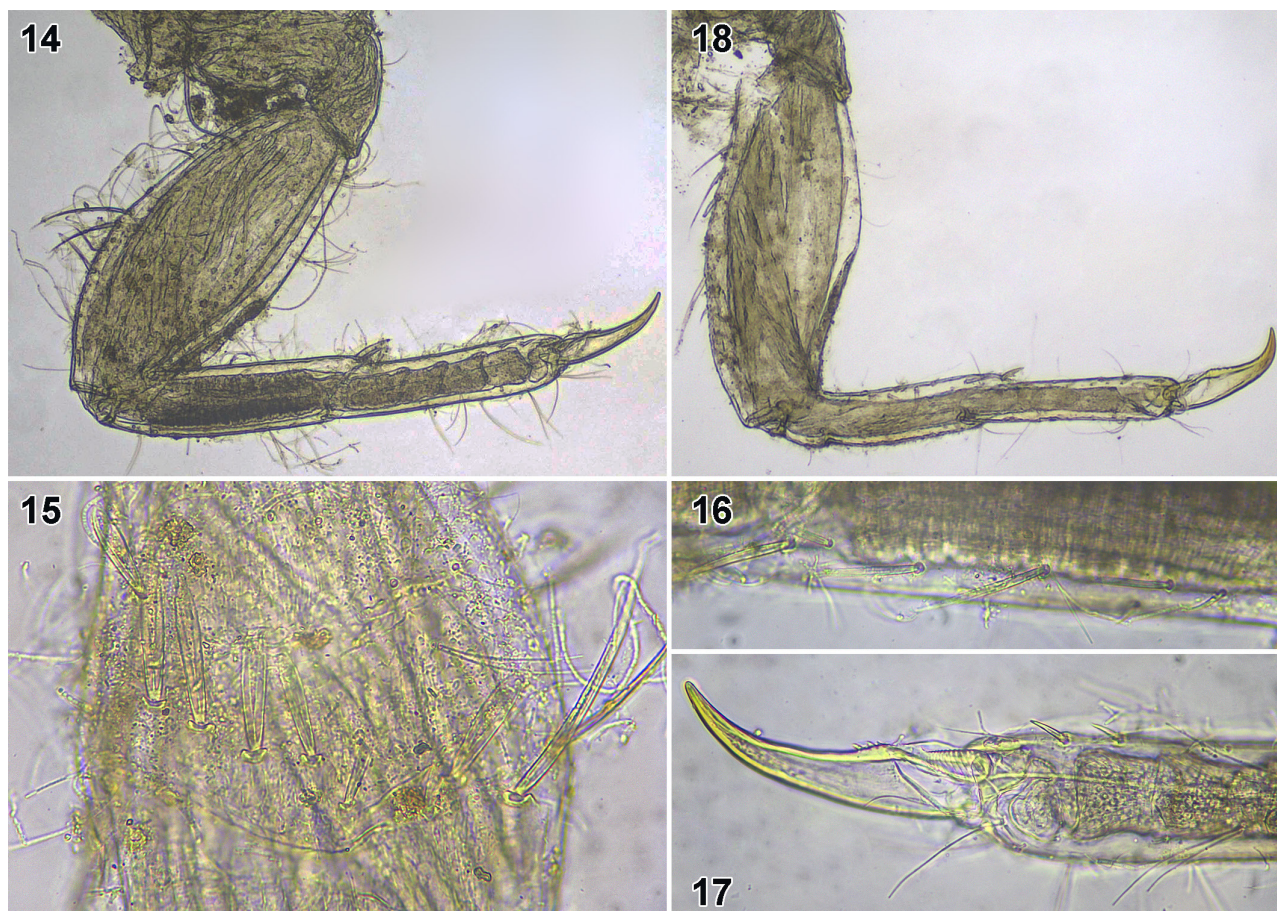
Diagnostic characters. *Caenis ulmeriana* can be distinguished from all other *Caenis* species by the following combination of characters: Imago (Imaginal characters extracted from the male last instar larva): base of antennal flagellum not dilated (Fig. 2); prosternal triangle forming cone-shaped structure (Fig. 3); foretarsus segments 2–4 each with a lateral and median projections (Fig. 4); penis broad and rounded, ventral fold forming a semicircular or semielliptical process (Fig. 5); forcipes moderate, straight, sides apically converging with a rigid elongated spine or a moderate spine equipped with an apical tuft of long spines (Fig. 6).



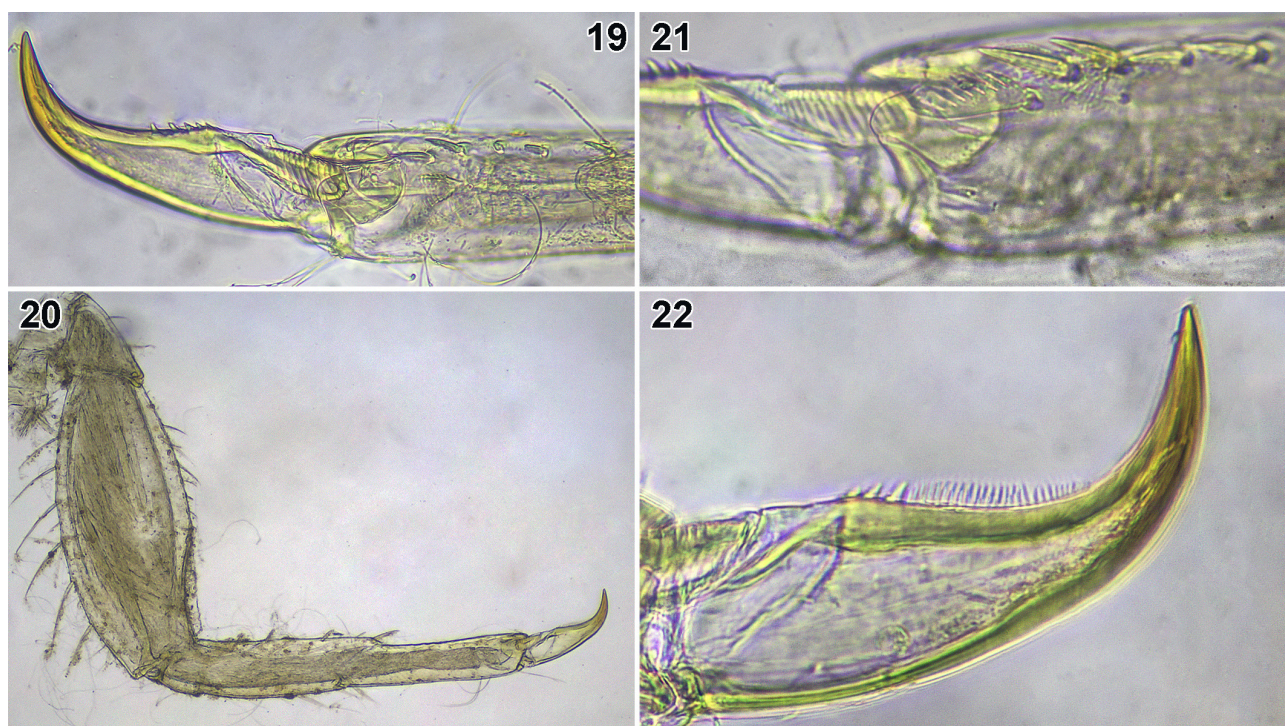
Figures 1–6. *Caenis ulmeriana* Malzacher, 2015. **1.** Male mature larva, dorsal view; **2.** Antenna; **3.** Prosternal triangle; **4.** Fore tarsomeres; **5, 6.** Visible subimaginal genitalia.



Figures 7–13. Larva of *Caenis ulmeriana* Malzacher, 2015. **7.** Labrum; **8.** Right mandible; **9.** Hypopharynx; **10.** Maxilla; **11.** Glossa and paraglossa; **12.** Labial palp; **13.** Head and thorax



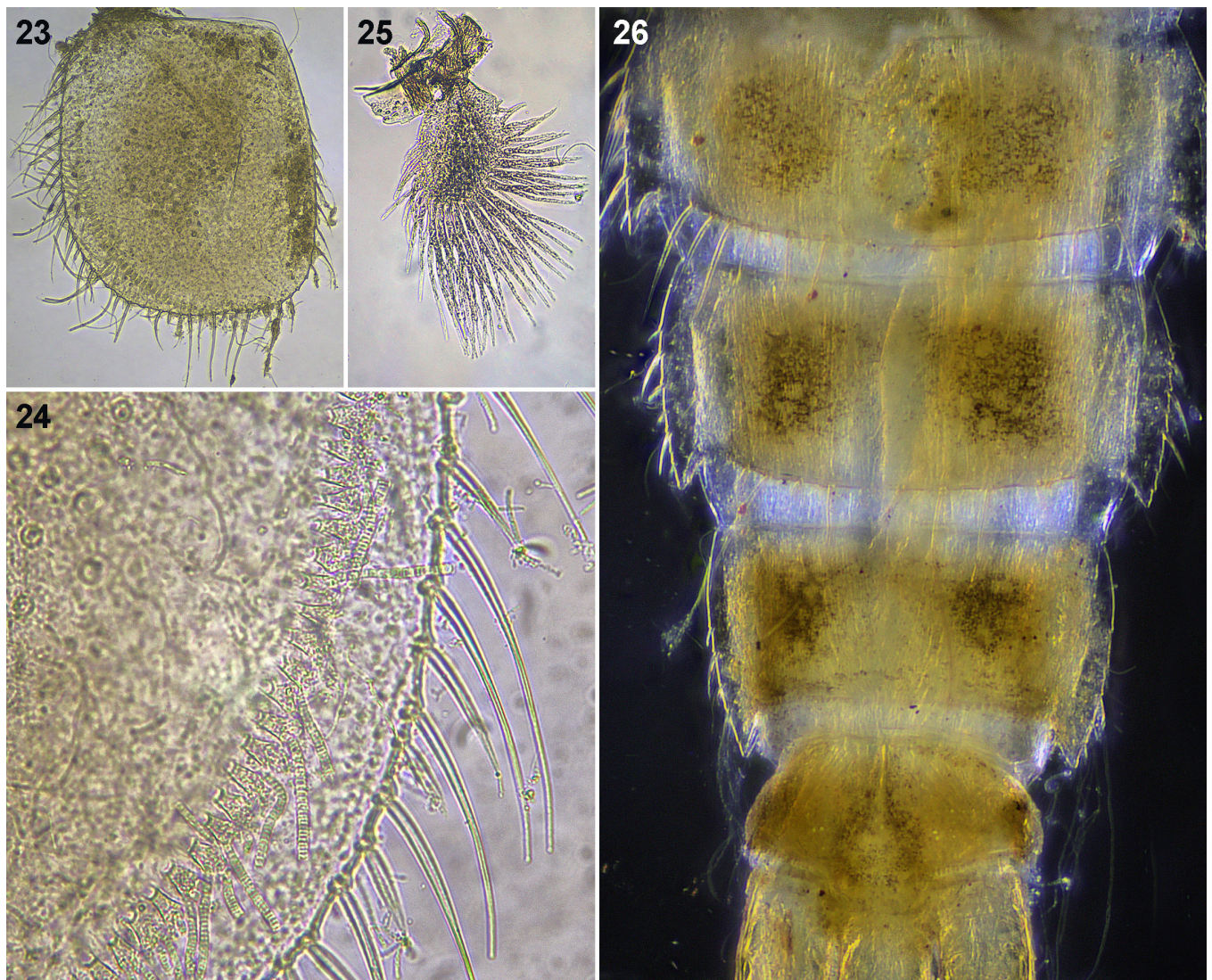
Figures 14–18. Larva of *Caenis ulmeriana* Malzacher, 2015. **14.** Foreleg; **15.** Closer view of transverse row of setation in forefemur; **16.** Closer view of setation in foretibia; **17.** Foreclaw; **18.** Midleg.



Figures 19–22. Larva of *Caenis ulmeriana* Malzacher, 2015. **19.** Midclaw; **20.** Hindleg; **21.** Closer view of setation in hindtarsus; **22.** Hindclaw.

Larva. Genae slightly bulged; pronotum and mesonotum denticulate without any nose-shaped projection (Fig. 13); maxillary palp segment III clearly longer than segment II (Fig. 10); ratio of labial palp segments 2 and 3 greater than 2 (Fig. 12); forefemur with a transverse row of 8–10 conspicuous spatulate setae (Fig. 15); foreclaw slender with 2–3 small basal denticles (Fig. 17); midclaw bowed with 3–5 small basal denticles (Fig. 19); hindclaw strongly bent with 2–3 basal denticles, and a dense row of microdenticles (Fig. 22); dorsal surface of tergalium II with numerous scales and 2–5 spatulate setae on the apical 2/3rd of Y-shaped ridge (Fig. 23); hind margin of tergum VII and VIII with long, simple setae, and hind margin of tergum IX and X with small denticles (Fig. 26).

Ecology. The larvae of *Caenis ulmeriana* were collected in Anaipillayar dam of the southern Western Ghats (3–5 m wide, 0.5–1 cm depth). The water temperature ranges between 24–26°C; pH 7–7.2. Substratum is mainly made of rock, cobbles, gravel and leaf litter (Fig. 27).



Figures 23–26. Larva of *Caenis ulmeriana* Malzacher, 2015. **23.** Tergalium II; **24.** Detail of microtrichia in tergalium II; **25.** Tergalium III; **26.** Hind margin of the abdominal terga.

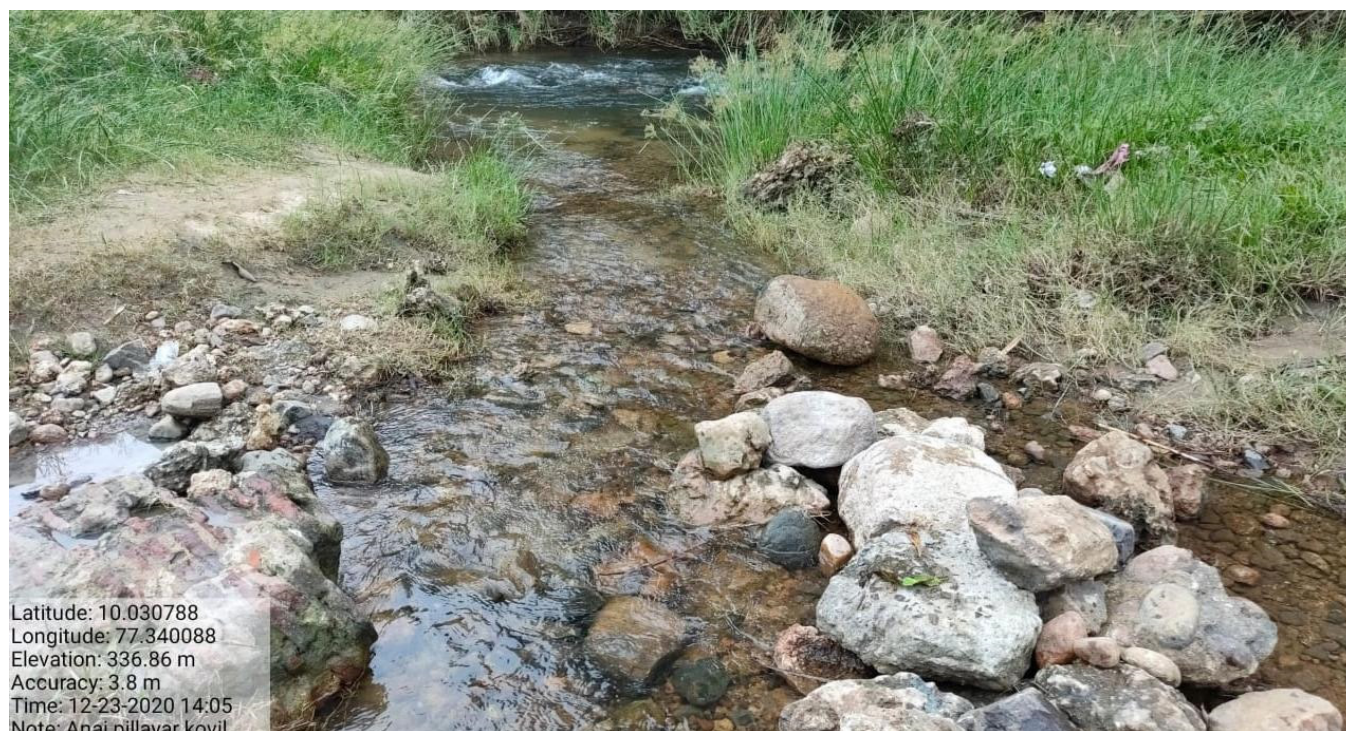


Figure 27. Habitat of *Caenis ulmeriana* Malzacher, 2015. Anai Pillayar Kovil Dam, Theni district, Tamil Nadu, India.

DISCUSSION

Caenis ulmeriana was discovered initially by Malzacher in 2015 from Java, Sumatra, and Thailand based on male imaginal characters. Malzacher & Sangpradub (2021) identified the *C. ulmeriana* group larvae from Thailand with slight variations in the male subimaginal characters. Subsequently, Malzacher (2023) recorded the larva of *C. ulmeriana* group from Myanmar and the Philippines. In continuation of this trend, the larvae of *C. ulmeriana* are now documented for the first time within one of the world's biodiversity hotspots—the Western Ghats, extending its distribution by over 1000 kilometers from previous records. The widespread presence of *C. ulmeriana* across the Western Ghats of India, Myanmar, Thailand, the Philippines, Java, and Sumatra (Fig. 28) indicates a broad habitat preference and adaptability to diverse ecological conditions. This species serves as an exemplary case for Pleistocene refugia theory. The Western Ghats with its diverse habitats and a relatively stable climate, likely acted as a refuge for *C. ulmeriana*. From this stronghold, the species potentially dispersed to other Southeast Asian regions during shifts in ecological and climatic conditions.

The larvae of *C. ulmeriana* from India exhibit slight variations in the shape of forceps, increased denticulation in the mid claw, a reduced number of setae in the Y-ridge of tergite II, and differing shape of sternum IX compared to other continental and island populations. Similar variations have been observed in continental populations of *C. ulmeriana* in Thailand, Myanmar, and the Philippines (Malzacher & Sangpradub, 2021; Malzacher, 2023). These variations in larval and adult characters of *C. ulmeriana* may be attributed to phenotypic plasticity (Peckarsky et al., 2001). However, it is also possible that these variations could indicate the presence of different species or subspecies within the set of observed differences. Further taxonomic investigation, including genetic analysis and morphological comparisons, would be necessary to determine whether these variations represent intraspecific variation or the presence of distinct taxa within the *C. ulmeriana* group. Further research based on the historical biogeography of the genus *Caenis* could provide more insights into its evolutionary history and dispersal patterns.

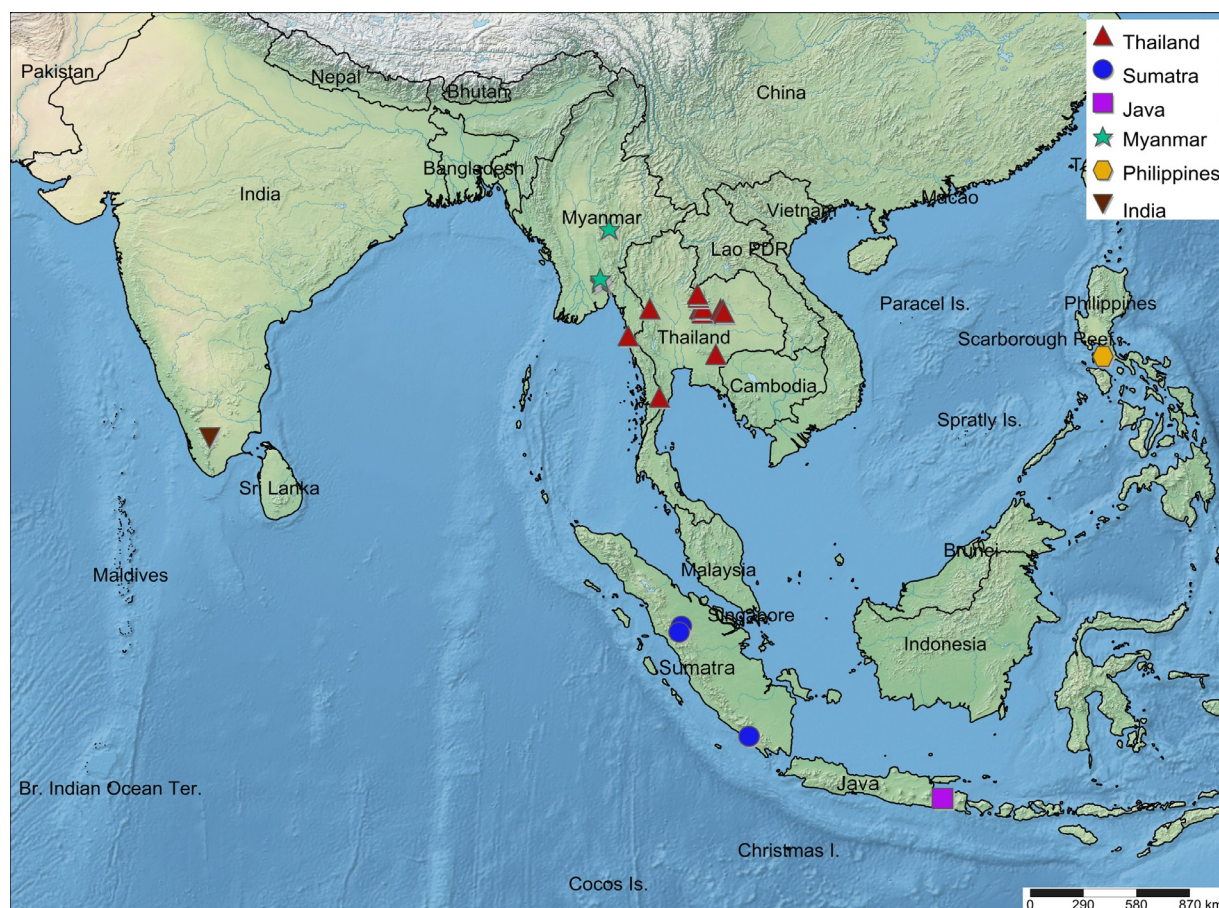


Figure 28. Distribution map of *Caenis ulmeriana* Malzacher, 2015 in the Oriental region.

AUTHOR'S CONTRIBUTION

The authors confirm their contribution in the paper as follows: P. Srinivasan: Manuscript preparation, collecting the specimens in the field, taxonomic identification and revising the manuscript; T. Sivaruban: Manuscript preparation, taxonomical expertise and correspondence; S. Barathy: Conceptualization of work and technical review of manuscript; R. Isack: Taxonomic identification and collecting the specimens in the field. The authors read and approved the final version of the manuscript.

FUNDING

This research received no specific grant from any funding agencies.

AVAILABILITY OF DATA AND MATERIAL

The specimens listed in this study are deposited in the American College Museum (AMC), Madurai, Tamil Nadu, India and are available from the curator, upon request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study only included plants and arthropod material, and all required ethical guidelines for the treatment and use of animals were strictly adhered to in accordance with international, national, and institutional regulations. No human participants were involved in any studies conducted by the authors for this article.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGMENTS

We are grateful to Dr Davamani Christofer (Principal and Secretary of The American College, Madurai) for providing facilities to carry out this research work. We express gratitude to the Subject Editor, Dr N.J. Kluge (St. Petersburg University, Russia) for the evaluation of the manuscript. We also extend our sincere thanks to the anonymous reviewers for providing valuable suggestions to enhance the quality of our manuscript.

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یافته‌های جدید از گروه گونه *Caenis ulmeriana* (Ephemeroptera: Caenidae) در گهات غربی، هند

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| تاریخ دریافت: ۲۱ دی ۱۴۰۲ | تاریخ پذیرش: ۰۷ فروردین ۱۴۰۳ | تاریخ انتشار: ۱۳ تیر ۱۴۰۳ |

چکیده: نمونه‌های از *Caenis ulmeriana* Malzacher, 2015 برای اولین بار از منطقه گهات غربی، هند گزارش شد. حضور این گونه، پیش از این، در مناطق دیگر شامل جاوا، سوماترا، تایلند، میانمار و فیلیپین ثبت شده است. نمونه‌ها *C. ulmeriana* جمع‌آوری شده از هند، تنوع ریخت‌شناسی قابل توجهی را نشان می‌دهند. این اختلافات، شامل تغییرات جزئی در شکل قلاب‌ها در نرهای نابالغ، افزایش تعداد دندان‌ها در پنجه میانی، تعداد کمتر موهای روی شکاف ترزیت دوم و شکل متفاوت بند نهم سینه‌ای لاروها در مقایسه با جمعیت‌های قاره‌ای و جزیره‌ای می‌باشد. تعداد گونه‌های جنس *Caenis* Stephens, 1835 در هند اکنون به دوازده افزایش یافته است. نقشه محدوده انتشار گونه *C. ulmeriana* در منطقه خاورزمین نیز ارائه شد.

واژگان کلیدی: *Caenis*، یک‌روزه‌ها، تنوع ریختی، گزارش جدید، تامیل نادو.