



Diversity and distribution of mayflies (Insecta: Ephemeroptera) in the “sky islands” of Palni Hills, Western Ghats, India

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ABSTRACT. The Palni Hills, part of the Western Ghats Mountain range in southern India, constitute a biodiversity hotspot, and their high elevation creates unique ecological conditions. Despite global recognition of the region as a biodiversity hotspot, many taxonomic groups remain poorly studied, including mayflies. We conducted a survey of mayflies in the Palni Hills to document the current diversity profile and analyse their altitudinal distribution patterns, ranging from 346 to 1685 m asl. Our sampling from April to October 2023 covered eleven sites, resulting in the collection of 788 individuals, representing 24 species, 16 genera, and six families. Four species are reported for the first time from Palni Hills. Notably, the families Baetidae, Heptageniidae, and Leptophlebiidae were the most species-rich, although individual population densities remained low. We have provided the updated taxonomic hierarchy, current diversity profile, and abundance of mayflies of Palni Hills. We have also highlighted the knowledge gaps in the taxonomy and distribution of Ephemeroptera within this study area.

Keywords: aquatic insects, biodiversity hotspot, conservation, elevation, richness

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INTRODUCTION

Present-day patterns of montane diversity, be it aquatic or terrestrial, are broadly structured by geological, eco-climatic, hydrological and human-impacted historical events, which can shape species coexistence at different spatio-temporal scales (Gaston, 2000; Benton et al., 2009; Baker et al., 2014). The genetic consequences of these historical events are manifested in phylogeographic patterns, especially for lentic and lotic macroinvertebrates in “sky islands”, which are montane regions isolated from one another by intervening valleys with dramatically different environmental conditions in a similar way to

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how the sea separates oceanic islands (Mc Cormack et al., 2009). Species restricted to “sky islands”, aquatic taxa in particular, often show unique patterns of population genetic structure influenced by historical climate-induced distributional shifts (Pan et al., 2019). In other words, “sky islands” are critical ‘natural laboratories’ for understanding the ecological and evolutionary consequences of geographical isolation, range shifts and genetic diversity distribution under climate change scenarios (Taubmann et al., 2011).

Despite the ecological and evolutionary importance of “sky islands”, many taxonomic groups remain poorly studied, including mayflies. Gaps in taxonomic knowledge of mayflies, particularly the undescribed species (Linnean shortfalls), and the lack of comprehensive data on species’ geographical distribution (Wallacean shortfall) hinder our understanding of biodiversity, speciation, and conservation, especially in isolated ecosystems like “sky islands” (Hortal et al., 2015; Gueuning et al., 2017; Love et al., 2023). Mayflies (Ephemeroptera) are primitive and ancient extant insect groups. They are considered as efficient biological indicators and model organisms for integrated phylogenetic, biogeographic, and phylogeographic studies (Selvakumar et al., 2016a). 3,700 species, 465 genera, and 42 families are reported globally, except for Antarctica (Jacobus et al., 2019). Ephemeroptera fauna of India is represented by four suborders, 15 families, 63 genera, and 247 species, including 182 endemic species (Subramanian et al., 2024). The Western Ghats, being a biodiversity hotspot region, harbours 13 families, encompassing 42 genera and 82 species, and of these, seven genera and 60 species are endemic. Tamil Nadu, which is part of the Western Ghats, has more species diversity than other parts and has 44 species that belong to 29 genera and 10 families (Sivaramakrishnan et al., 2020).

In tropical biodiversity hotspots, such as the Western Ghats, aquatic ecosystems have been increasingly threatened, directly or indirectly, by human activities (Sundar et al., 2020). In addition to the challenges posed by land-use change, environmental pollution, and water diversion, aquatic systems experience the added stress of climate change and global warming (Sundar et al., 2021). Despite previous studies (Sivaramakrishnan & Job, 1981; Sivaramakrishnan et al., 1990; Selvakumar et al., 2014a; Barathy et al., 2020, 2021a), there is limited information on the diversity and distribution of mayflies in the “sky islands” of the Western Ghats in general and Palni Hills in particular (Sivaramakrishnan & Venkataraman, 1990; Barathy et al., 2021a, 2021b). Hence, the present study aims to contribute to the current diversity profile and abundance of mayfly communities across the “sky islands” of southern and northern Palni Hills and an altitudinal gradient in the Palni Hills of the Western Ghats. This documentation will serve as a foundation for further research and conservation efforts in the region.

MATERIAL AND METHODS

Study area. The Palni Hills in the Dindigul District of Tamil Nadu form an eastward extension of the Western Ghats of India. They span a maximum east-west length of 65 km and a north-south width of 40 km, situated between latitudes 10.12° N and 10.15° N, and longitudes 77.26° E and 77.33° E, covering an area of 2068². The peaks rise to over 2500 m asl, marking the region as one of the significant global biodiversity hotspots known for its high endemism. The Palni Hills are divided into two different mountains, namely southern and northern Palni Hills. Sampling was conducted at eleven sites: Kumbakkarai Falls I, Kumbakkarai Falls II, Moolaiyaru River, a stream near Munishwararkovil, Adukkam Falls, Perumalmalai Stream, Varaiyaru Falls, Umaiyaru River, Thaliyuthu Falls, Thalakuthu Main Falls, and Nallathangal Streams (Fig. 1). The first six study sites were selected from the southern Palni Hills, and the remaining five from the northern Palni Hills (Table 1). This study underscores the significance of selecting diverse habitats based on factors such as altitude, accessibility, and the presence of suitable habitats to get representative samples of the mayfly population in the region.

Specimen collection, preservation and identification. Nymphs or larvae were collected from April to October, 2023 using an aquatic D-frame net, hand picking with a brush or forceps, and kick net method (mesh size; 0.5 to 1.0 mm) at the study sites. The kick net was placed in the opposite direction to the water current to collect organic debris and insects. At each site, the substratum, bed rocks, boulders, and cobbles were vigorously disturbed. The collected specimens were preserved in 70–80% ethyl alcohol and

brought to the laboratory. The specimens were examined under a Leica® S-APO stereo-zoom microscope. Photos were processed, and plates were made using Adobe® Photoshop version CS5. The mayfly larvae were classified up to the genus level using a handbook on morphological and molecular identification of southern Indian mayflies by Selvakumar et al. (2019) and further identified up to the species level through relevant published mayfly taxonomic articles. Linear regression was done using the Microsoft Office tool and analysed to evaluate the relationship between species abundance and elevation.

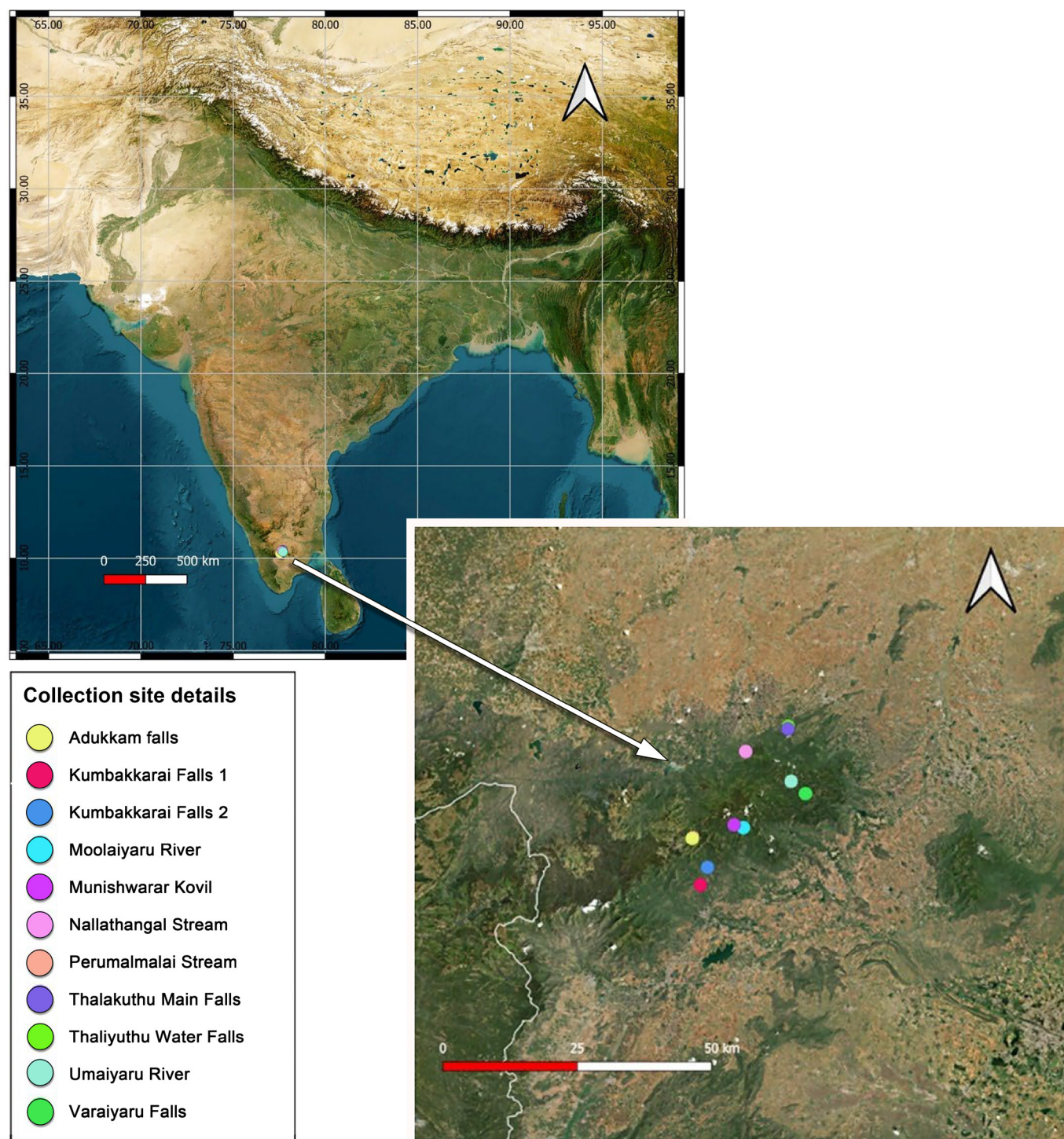


Figure 1. Geographic locations of the sampling sites in the Palni Hills, Western Ghats of India.

Table 1. Details of the collection sites in Palni Hills, Western Ghats of India.

SITE NAME	DATE OF COLLECTION	LATITUDE	LONGITUDE	ALTITUDE
Southern Hills				
Kumbakkarai Falls 1	14 October 2023	10°10'24" N	77°32'13" E	353 m
Kumbakkarai Falls 2	14 October 2023	10°12'11" N	77°32'56" E	448 m
Moolaiyar River	27 April 2023	10°16'13" N	77°36'34" E	1217 m
Munishwarar kovil	27 April 2023	10°16'30" N	77°35'38" E	1271 m
Perumalmalai stream	27 April 2023	10°15'13" N	77°31'26" E	1670 m
Adukkam falls	27 April 2023	10°15'08" N	77°31'22" E	1685 m
Northern Hills				
Thaliyuthu WaterFalls	02 July 2023	10°26'33" N	77°41'09" E	346 m
Thalakuthu Main falls	02 July 2023	10°26'16" N	77°41'07" E	450 m
Nallathangal Stream	02 July 2023	10°23'58" N	77°36'49" E	586 m
Varaiyar Falls	01 July 2023	10°19'41" N	77°42'54" E	1172 m
Umaiya River	01 July 2023	10°20'56" N	77°41'27" E	1236 m

RESULTS

A total of 788 individuals were collected from 11 sampling sites, classified into 24 species, 16 genera, and six families (Tables 2 & 3). The family Leptophlebiidae is represented by seven species belonging to 5 genera, each genus with a single species, except the genus *Choroterpes* Eaton, 1881, which includes three species. The family Baetidae is represented by eight species from 6 genera, with each genus containing a single species, except for the genus *Baetis* Leach, 1815 and *Labiobaetis* Novikova & Kluge, 1987, each of which is represented by two species. The family Heptageniidae includes two genera and four subgenera, each subgenus with a single species. The families Teloganodidae and Caenidae are represented by a single genus with two species. The family Ephemeridae consisted of 1 genus with a single species.

Taxonomic hierarchy

Class Insecta Linnaeus, 1758

Order Ephemeroptera Hyatt & Arms, 1891

Family Leptophlebiidae Banks, 1900

Genus *Choroterpes* Eaton, 1881

Subgenus *Euthraulus* Barnard, 1932

***Choroterpes (Euthraulus) alagarensis* Dinakaran, Balachandran & Anbalagan, 2009 (Fig. 2A)**

Choroterpes (Euthraulus) alagarensis Dinakaran, Balachandran & Anbalagan, 2009, 2064:22, Holotype ♂ imago, Nuburagangai stream, Tamil Nadu, India.

Material examined. 1 larva, Kumbakkarai Falls II, 10°12'11" N, 77°32'56" E, 448 m, 14-x-2023; 3 larvae, Moolaiyar River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 6 larvae, Munishwarar Kovil, 10°16'30" N, 77°35'38" E, 1271 m, 27-iv-2023; 7 larvae, Thaliyuthu Water Falls, 10°26'33" N, 77°41'09" E, 346 m, 02-vii-2023; 3 larvae, Thalakuthu Main Falls, 10°26'16" N, 77°41'07" E, 450 m, 02-vii-2023; 10 larvae, Nallathangal Stream, 10°23'58" N, 77°36'49" E, 586 m, 02-vii-2023; 1 larva, Varaiyar Falls, 10°19'41" N, 77°42'54" E, 1172 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. India: Karnataka, Kerala & Tamil Nadu (Dinakaran et al., 2009; Kluge et al., 2022a).

Table 2. List of mayflies collected from Southern Palni Hills.

Family	Genus	Subgenus	Species	Kumbakkarai Falls 1	Kumbakkarai Falls 2	Moolaiyar River	Munishwarar Kovil	Perumalmalai Stream	Adukkam Falls
Leptophlebiidae	<i>Choroterpes</i>	<i>Euthraulus</i>	<i>alagarensis</i>	-	1	3	6	-	-
	<i>Choroterpes</i>	<i>Euthraulus</i>	<i>atelobranchis</i>	-	-	-	-	-	-
	<i>Choroterpes</i>	<i>Euthraulus</i>	<i>nambiyarensis</i>	50	11	63	-	-	-
	<i>Isca</i>		sp.	2	-	1	-	-	3
	<i>Megaglana</i>		<i>agasthiya</i>	-	-	-	-	8	10
	<i>Nathanella</i>		<i>indica</i>	-	-	-	-	1	42
	<i>Petersulla</i>		<i>courtallensis</i>	-	-	-	1	-	-
Heptogeniidae	<i>Ecdyonurus</i>	<i>Afronurus</i>	<i>kumbakkaraiensis</i>	28	7	3	-	-	-
	<i>Ecdyonurus</i>	<i>Rhithrogeniella</i>	<i>ornatus</i>	-	-	13	-	-	-
	<i>Ecdyonurus</i>	<i>Thalerosphyrus</i>	<i>flowersi</i>	8	7	-	-	-	-
	<i>Epeorus</i>	<i>Epeorus</i>	<i>gilliesi</i>	28	5	1	-	-	-
Ephemeraidae	<i>Ephemera</i>	<i>Aethephemera</i>	<i>nadinae</i>	-	-	-	8	-	-
Caenidae	<i>Caenis</i>		<i>americani</i>	-	-	1	8	-	-
	<i>Caenis</i>		<i>maduraiensis</i>	-	-	-	-	-	-
Teloganodidae	<i>Teloganodes</i>	<i>Dudgeodes</i>	<i>palnius</i>	14	9	10	-	15	1
	<i>Teloganodes</i>	<i>Teloganodes</i>	<i>kodai</i>	-	-	1	-	2	-
Baetidae	<i>Acentrella</i>	<i>Liebiella</i>	<i>vera</i>	55	10	-	-	-	-
	<i>Baetis</i>	<i>Tenuibaetis</i>	<i>frequentus</i>	-	-	-	-	-	-
	<i>Baetis</i>		<i>venkataramani</i>	2	1	-	-	-	-
	<i>Centroptella</i>	<i>Chopralla</i>	<i>ceylonensis</i>	2	27	-	-	-	-
	<i>Labiobaetis</i>		<i>jacobusi</i>	4	-	17	-	-	4
	<i>Labiobaetis</i>		<i>pulchellus</i>	-	-	-	-	-	-
	<i>Nigrobaetis</i>		<i>klugei</i>	3	-	-	-	-	-
	<i>Proclleon</i>	<i>Proclleon</i>	<i>kottagudiensis</i>	-	-	3	-	-	-
No of species				11	9	11	4	4	5
Total No of individuals				196	78	116	23	26	60

***Choroterpes (Euthraulus) atelobranchis* Kluge, Srinivasan, Vasanth, Sivaruban, Barathy, & Isack, 2022 (Fig. 2B)**

Choroterpes (Euthraulus) atelobranchis Kluge, Srinivasan, Vasanth, Sivaruban, Barathy, & Isack, 2022, 5181:13, Holotype L-S-I♂ Veerapandi River, Theni district, Tamil Nadu, India.

Material examined. 29 larvae, Thaliyuthu Water Falls, 10°26'33" N, 77°41'09" E, 346 m, 02-vii-2023; 3 larvae, Thalakuthu Main Falls, 10°26'16" N, 77°41'07" E, 450 m, 02-vii-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (Kluge et al., 2022a).

***Choroterpes (Euthraulus) nambiyarensis* Selvakumar, Arunachalam & Sivaramakrishnan, 2013 (Fig. 2C)**

Choroterpes (Euthraulus) nambiyarensis Selvakumar, Arunachalam & Sivaramakrishnan 2013, 47:71, Holotype, mature nymph – Nambiyar River, Tamil Nadu, India.

Material examined. 50 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 11 larvae, Kumbakkarai Falls II, 10°12'11" N, 7°32'56" E, 448 m, 14-x-2023; 63 larvae, Moolaiyar River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 11 larvae, Umaiyyar River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (Selvakumar et al., 2013; Kluge et al., 2022a), Karnataka, and Kerala (Kluge et al., 2022a).

Table 3. List of mayflies collected from Northern Palni Hills.

Family	Genus	Sub Genus	Species	Thaliyuthu Water Falls	Thalakuthu Main Falls	Nalla Thangal Stream	Varaiyaru Falls	Umaiyaaru River
Leptophlebiidae	<i>Choroterpes</i>	<i>Euthraulus</i>	<i>alagarensis</i>	7	3	10	1	-
	<i>Choroterpes</i>	<i>Euthraulus</i>	<i>atelobranchis</i>	29	3	-	-	-
	<i>Choroterpes</i>	<i>Euthraulus</i>	<i>nambiyarensis</i>	-	-	-	-	11
	<i>Isca</i>		sp.	-	-	-	-	-
	<i>Megaglena</i>		<i>agasthiya</i>	-	-	-	-	-
	<i>Nathanella</i>		<i>indica</i>	-	-	-	-	-
	<i>Petersula</i>		<i>courtallensis</i>	-	1	-	-	1
Heptageniidae	<i>Ecdyonurus</i>	<i>Afronurus</i>	<i>kumbakkaraiensis</i>	-	-	-	-	6
	<i>Ecdyonurus</i>	<i>Rhithrogeniella</i>	<i>ornatus</i>	-	-	-	-	5
	<i>Ecdyonurus</i>	<i>Thalerosphyrus</i>	<i>flowersi</i>	-	-	11	-	3
	<i>Epeorus</i>	<i>Epeorus</i>	<i>gilliesi</i>	-	-	-	-	3
Ephemeridae	<i>Ephemera</i>	<i>Aethephemera</i>	<i>nadinae</i>	-	-	-	-	-
Caenidae	<i>Caenis</i>		<i>american</i>	-	-	-	-	-
	<i>Caenis</i>		<i>maduraiensis</i>	-	2	1	-	-
Teloganodidae	<i>Teloganodes</i>	<i>Dudgeodes</i>	<i>palnius</i>	-	-	-	1	16
	<i>Teloganodes</i>	<i>Teloganodes</i>	<i>kodai</i>	-	-	-	-	14
Baetidae	<i>Acentrella</i>	<i>Liebebiella</i>	<i>vera</i>	-	31	2	6	11
	<i>Baetis</i>	<i>Tenuibaetis</i>	<i>frequentus</i>	-	6	-	15	13
	<i>Baetis</i>		<i>venkataramani</i>	-	2	-	1	-
	<i>Centroptella</i>	<i>Chopralla</i>	<i>ceylonensis</i>	-	1	3	-	6
	<i>Labiobaetis</i>		<i>jacobusi</i>	-	-	-	4	14
	<i>Labiobaetis</i>		<i>pulchellus</i>	3	3	-	-	-
	<i>Nigrobaetis</i>		<i>klugei</i>	-	1	-	-	-
	<i>Procloeon</i>	<i>Procloeon</i>	<i>kottagudiensis</i>	4	-	3	17	15
No of species				4	10	6	7	13
Total No of individuals				43	50	30	45	118

Genus *Isca* Gillies, 1951***Isca* sp. (Fig. 2D)**

Material examined. 2 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 1 larva, Moolaiyaru River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 3 larvae, Adukkam Falls, 10°15'08" N, 77°31'22" E, 1685 m, 27-iv-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (Sivaramakrishnan & Venkataraman, 1990).

Genus *Megaglena* Peters & Edmunds, 1970***Megaglena agasthiya* Vasanth, Subramnian & Selvakumar, 2021 (Fig. 2E)**

Megaglena agasthiya Vasanth, Subramnian & Selvakumar, 2021, 5076:64, Holotype ♂ larva, Pandipath stream, Peppara Wildlife Sanctuary, Trivandrum district, Kerala, India.

Material examined. 8 larvae, Perumalmalai Stream, 10°15'13" N, 77°31'26" E, 1670 m, 27-iv-2023; 10 larvae, Adukkam Falls, 10°15'08" N, 77°31'22" E, 1685 m, 27-iv-2023, Coll. C. Selvakumar & party.

Distribution. India: Kerala (Vasanth et al., 2021b), Tamil Nadu (New report).

***Nathanella indica* Demoulin, 1955 (Fig. 2F)**

Nathanella indica Demoulin, 1955, 31:2, Holotype ♂ imago – Kodaikanal, Tamil Nadu, India.

Material examined. 1 larva, Perumalmalai Stream, 10°15'13" N, 77°31'26" E, 1670 m, 27-iv-2023; 42 larvae, Adukkam Falls, 10°15'08" N, 77°31'22" E, 1685 m, 27-iv-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (Demoulin, 1955).

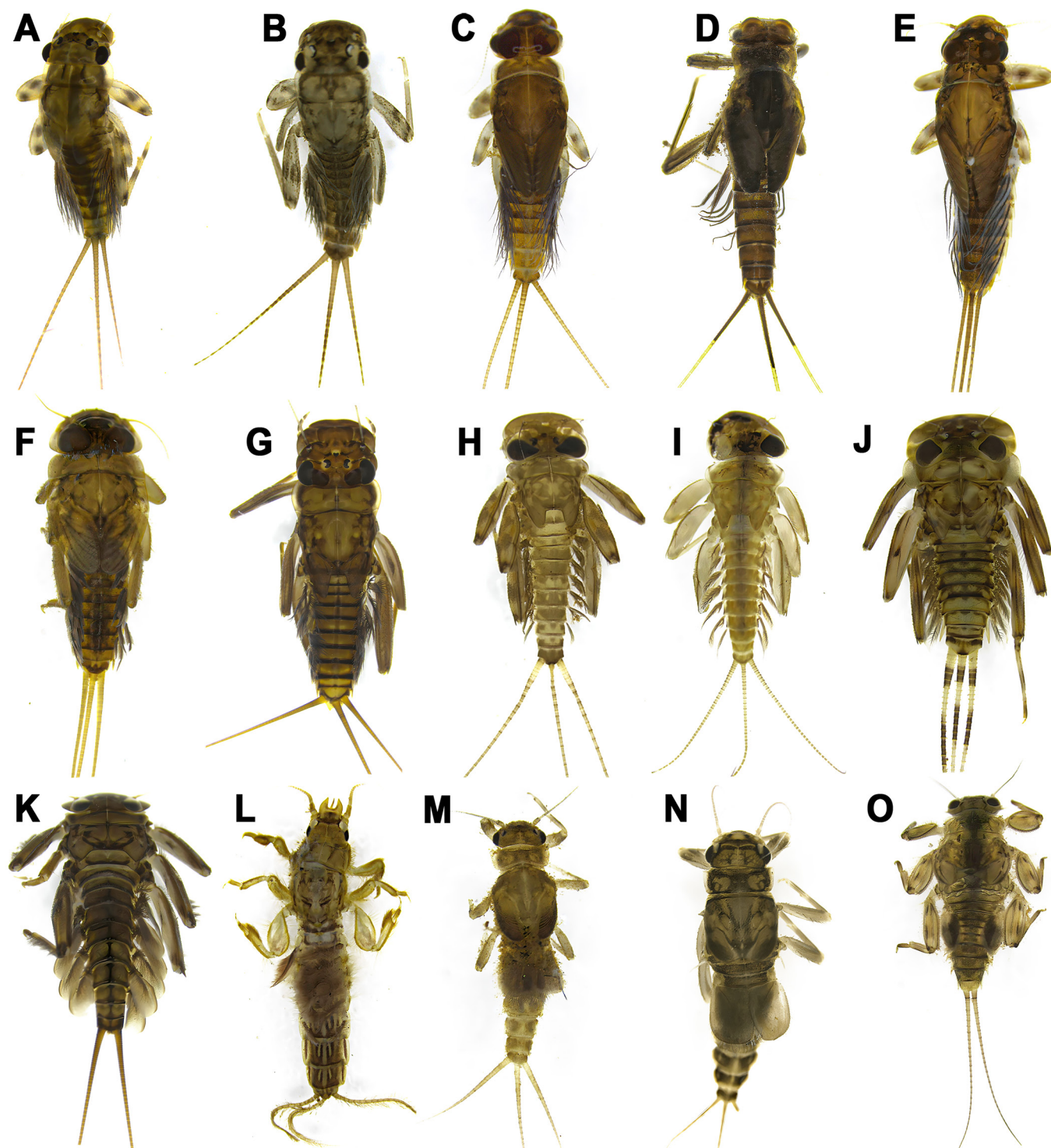


Figure 2. The mayfly larvae from the Sky Islands of Palni Hills, Western Ghats. **A.** *Choroterpes* (*Euthraulus*) *alagarensis* Dinakaran, Balachandran & Anbalagan, 2009; **B.** *Choroterpes* (*Euthraulus*) *atelobranhis* Kluge, Srinivasan, Vasanth, Sivaruban, Barathy, & Isack, 2022; **C.** *Choroterpes* (*Euthraulus*) *nambiyarensis* Selvakumar, Arunachalam & Sivaramakrishnan, 2013; **D.** *Isca* sp.; **E.** *Megaglena agasthiya* Vasanth et al., 2021, 1985; **F.** *Nathanella indica* Demoulin, 1955; **G.** *Petersulla courtallensis* Sivaramakrishnan, 1984; **H.** *Ecdyonurus* (*Afronurus*) *kumbakkariensis* (Venkataraman & Sivaramakrishnan, 1989); **I.** *Ecdyonurus* (*Rhithrogeniella*) *ornatus* (Ulmer, 1939); **J.** *Ecdyonurus* (*Thalerosphyrus*) *flowersi* Venkataraman & Sivaramakrishnan, 1987; **K.** *Epeorus* (*Epeorus*) *gilliesi* Braasch, 1981; **L.** *Ephemera* (*Aethephemera*) *nadinae* McCafferty & Edmunds, 1973; **M.** *Caenis american*i Srinivasan, Sivaruban, Barathy, Malzacher & Isack, 2021; **N.** *Caenis maduraiensis* Balasubramanian & Muthukatturaja, 2021; **O.** *Teloganodes* (*Dudgeodes*) *palnius* Selvakumar, Sivaramakrishnan & Jacobus, 2014.

Genus *Petersula* Sivaramakrishnan, 1984

Petersula courtallensis Sivaramakrishnan, 1984 (Fig. 2G)

Petersula courtallensis Sivaramakrishnan, 1984, 26:199, Holotype ♂ imago – Courtrallam main falls, Tamil Nadu, India.

Material examined. 1 larva, Munishwarar Kovil, 10°16'30" N, 77°35'38" E, 1271 m, 27-iv-2023; 1 larva, Thalakkuthu Main Falls, 10°26'16" N, 77°41'07" E, 450 m, 02-vii-2023; 1 larva, Umaiyaaru River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. **India:** Tamil Nadu (Sivaramakrishnan, 1984), Karnataka (Selvakumar et al., 2018a), and Kerala (Kluge et al., 2022b).

Family Heptageniidae Needham, 1901

Genus *Ecdyonurus* Eaton, 1868

Subgenus *Afronurus* Lestage, 1924

Ecdyonurus (*Afronurus*) *kumbakkariensis* (Venkataraman & Sivaramakrishnan, 1989) (Fig. 2H)

Cinygmmina kumbakkariensis Venkataraman & Sivaramakrishnan, 1989, 1:117, Holotype ♂ imago, Kumbakkarai, Tamil Nadu, India.

Material examined. 28 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 7 larvae, Kumbakkarai Falls II, 10°12'11" N, 77°32'56" E, 448 m, 14-x-2023; 3 larvae, Moolaiyaaru River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 6 larvae, Umaiyaaru River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023; Coll. C. Selvakumar & party.

Distribution. **India:** Tamil Nadu (Venkataraman & Sivaramakrishnan, 1989).

Subgenus *Rhithrogeniella* Ulmer, 1939

Ecdyonurus (*Rhithrogeniella*) *ornatus* (Ulmer, 1939) (Fig. 2I)

Rhithrogeniella ornata Ulmer, 1939, 16:576, Holotype ♂ imago, Sunda Islands.

Material examined. 13 larvae, Moolaiyaaru River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 5 larvae, Umaiyaaru River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. **India:** Karnataka and Tamil Nadu (Kluge et al., 2023b). **Elsewhere:** Indochina and the great Sunda Islands (Kluge et al., 2023b).

Subgenus *Thalerosphyrus* Eaton, 1881

Ecdyonurus (*Thalerosphyrus*) *flowersi* Venkataraman & Sivaramakrishnan, 1987 (Fig. 2J)

Thalerosphyrus flowersi Venkataraman & Sivaramakrishnan, 1987, 56:1126, Holotype ♂ imago, Kumbakkarai, Tamil Nadu, India.

Material examined. 8 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 7 larvae, Kumbakkarai Falls II, 10°12'11" N, 77°32'56" E, 448 m, 14-x-2023; 11 larvae, Nalla Thangal Stream, 10°23'58" N, 77°36'49" E, 586 m, 02-vii-2023; 3 larvae, Umaiyaaru River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. **India:** Tamil Nadu (Venkataraman & Sivaramakrishnan, 1987).

Genus *Epeorus* Eaton, 1881

Subgenus *Epeorus* Eaton, 1881

Epeorus (*Epeorus*) *gilliesi* Braasch, 1981 (Fig. 2K)

Epeorus gilliesi Braasch, 1981, 19 (20), 117, Holotype larva, Khandala River, Maharashtra.

Material examined. 28 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 5 larvae, Kumbakkarai Falls II, 10°12'11" N, 77°32'56" E, 448 m, 14-x-2023; 1 larva, Moolaiyaaru River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 3 larvae, Umaiyaaru River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. **India:** Maharashtra (Braasch, 1981), Karnataka & Goa (Vasanth et al., 2021a), Tamil Nadu (Sivaruban et al., 2013).

Family Ephemeridae Latreille, 1810**Genus *Ephemera* Linnaeus, 1758****Subgenus *Aethephamera* McCafferty & Edmunds, 1973*****Ephemera (Aethephamera) nadinae* McCafferty & Edmunds, 1973 (Fig. 2L)**

Ephemera (Aethephamera) nadinae McCafferty & Edmunds, 1973, 49:306, Holotype mature larva – Kodaikanal, Tamil Nadu, India.

Material examined. 8 larvae, Munishwarar Kovil, 10°16'30" N, 77°35'38" E, 1271 m, 27-iv-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (McCafferty & Edmunds, 1973).

Family Caenidae Newman, 1853**Genus *Caenis* Stephens, 1835*****Caenis americani* Srinivasan, Sivaruban, Barathy, Malzacher & Isack, 2021 (Fig. 2M)**

Caenis americani Srinivasan, Sivaruban, Barathy, Malzacher & Isack, 2021, 4926:106, Holotype ♀ imago, Kodaikanal, Tamil Nadu, India.

Material examined. 1 larva, Moolaiyar River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 8 larvae, Munishwarar Kovil, 10°16'30" N, 77°35'38" E, 1271 m, 27-iv-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (Srinivasan et al., 2021).

***Caenis maduraiensis* Balasubramanian & Muthukatturaja, 2021 (Fig. 2N)**

Caenis maduraiensis Balasubramanian & Muthukatturaja, 2021, 4980:367, Holotype ♂ imago, Vandiyur pond, Madurai district, Tamil Nadu state, India.

Material examined. 2 larvae, Thalakuthu Main Falls, 10°26'16" N, 77°41'07" E, 450 m, 02-vii-2023; 1 larva, Nalla Thangal Stream, 10°23'58" N, 77°36'49" E, 586 m, 02-vii-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (Muthukatturaja & Balasubramanian, 2021; Srinivasan et al., 2023).

Family Teloganodidae Allen, 1965**Genus *Teloganodes* Eaton, 1882****Subgenus *Dudgeodes* Sartori, 2008*****Teloganodes (Dudgeodes) palnius* Selvakumar, Sivaramakrishnan & Jacobus, 2014 (Fig. 2O)**

Dudgeodes palnius Selvakumar, Sivaramakrishnan & Jacobus, 2014, 3846:95, Holotype ♂ larva, Palni hills, Tamil Nadu, India.

Material examined. 14 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 9 larvae, Kumbakkarai Falls II, 10°12'11" N, 77°32'56" E, 448 m, 14-x-2023; 10 larvae, Moolaiyar River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 15 larvae, Perumalmai Stream, 10°15'13" N, 77°31'26" E, 1670 m, 27-iv-2023; 1 larva, Adukkam Falls, 10°15'08" N, 77°31'22" E, 1685 m, 27-iv-2023; 1 larva, Varaiyar Falls, 10°19'41" N, 77°42'54" E, 1172 m, 01-vii-2023; 16 larvae, Umaiya River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (Selvakumar et al., 2014b) and Karnataka (Kluge et al., 2023a).

Subgenus *Teloganodes* Eaton 1882***Teloganodes (Teloganodes) kodai* Sartori, 2008 (Fig. 3A)**

Teloganodes kodai Sartori, 2008, 1957:15, Holotype larva, Kodaikanal, Tamil Nadu, India.

Material examined. 1 larva, Moolaiyar River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 2 larvae, Perumalmai Stream, 10°15'13" N, 77°31'26" E, 1670 m, 27-iv-2023; 14 larvae, Umaiya River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (Sartori et al., 2008; Selvakumar et al., 2018b).



Figure 3. The mayfly larvae from the Palni Hills of the Western Ghats. **A.** *Teloganodes (Teloganodes) kodai* Sartori, 2008; **B.** *Acentrella (Liebebiella) vera* (Müller-Liebenau, 1982); **C.** *Baetis (Tenuibaetis) frequentus* (Müller-Liebenau & Hubbard, 1985); **D.** *Baetis venkataramani* Sivaruban, Srinivasan, Barathy & Isack, 2023; **E.** *Centroptella (Chopralla) ceylonensis* (Müller-Liebenau, 1984); **F.** *Labiobaetis jacobusi* Kubendran & Balasubramanian, 2015; **G.** *Labiobaetis pulchellus* (Müller-Liebenau & Hubbard, 1985); **H.** *Nigrobaetis klugei* Sivaruban, Srinivasan, Barathy & Isack, 2022; **I.** *Procloeon (Procloeon) kottagudiensis* Muthukatturaja & Balasubramanian, 2022.

Family Baetidae Leech, 1815**Genus Acentrella Bengtsson, 1912****Subgenus Liebebiella Waltz & McCafferty, 1987*****Acentrella (Liebebiella) vera* (Müller-Liebenau, 1982) (Fig. 3B)**

Pseudocloeon verum Müller-Liebenau, 1982, 95:285, Holotype mature nymph, Gombak River, Malaysia.

Material examined. 55 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 10 larvae, Kumbakkarai Falls II, 10°12'11" N, 77°32'56" E, 448 m, 14-x-2023; 31 larvae, Thalakuthu Main Falls, 10°26'16" N, 77°41'07" E, 450 m, 02-vii-2023; 2 larvae, Nalla Thangal Stream, 10°23'58" N, 77°36'49" E, 586 m, 02-vii-2023; 6 larvae, Varaiyaru Falls, 10°19'41" N, 77°42'54" E, 1172 m, 01-vii-2023; 11 larvae, Umaiya River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. **India:** Karnataka and Tamil Nadu (Kluge et al., 2013). **Elsewhere:** Malaysia (Müller-Liebenau, 1982), Sri Lanka and Indonesia (Kluge et al., 2013), Java, Lombok and Thailand (Kluge & Novikova, 2011).

Genus Baetis Leach, 1815**Subgenus Tenuibaetis Kang & Yang, 1994*****Baetis (Tenuibaetis) frequentus* (Müller-Liebenau & Hubbard, 1985) (Fig. 3C)**

Baetis frequentus Müller-Liebenau & Hubbard, 1985, 68:537, Holotype nymph, Sri Lanka.

Material examined. 4 larvae, Thalakuthu Main Falls, 10°26'16" N, 77°41'07" E, 450 m, 02-vii-2023; 15 larvae, Varaiyaru Falls, 10°19'41" N, 77°42'54" E, 1172 m, 01-vii-2023; 13 larvae, Umaiya River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar.

Distribution. **India:** Tamil Nadu (Kluge et al., 2023c). **Elsewhere:** Sri Lanka (Müller-Liebenau & Hubbard, 1985, Kluge et al., 2023c).

***Baetis venkataramani* Sivaruban, Srinivasan, Barathy & Isack, 2023 (Fig. 3D)**

Baetis venkataramani Sivaruban, Srinivasan, Barathy & Isack, 2023, 24:150, Holotype ♀ mature nymph, Puliyuthu Falls, Theni, Tamil Nadu, India.

Material examined. 2 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 1 larva, Kumbakkarai Falls II, 10°12'11" N, 77°32'56" E, 448 m, 14-x-2023; 2 larvae, Thalakuthu Main Falls, 10°26'16" N, 77°41'07" E, 450 m, 02-vii-2023; 1 larva, Varaiyaru Falls, 10°19'41" N, 77°42'54" E, 1172 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. **India:** Tamil Nadu (Sivaruban et al., 2023).

Genus Centroptella Braasch & Soldán, 1980**Subgenus Chopralla Waltz & McCafferty, 1987*****Centroptella (Chopralla) ceylonensis* Müller-Liebenau, 1983 (Fig. 3E)**

Centroptella ceylonensis Müller-Liebenau 1983, 97:486, Holotype mature nymph, Sri Lanka.

Material examined. 2 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 27 larvae, Kumbakkarai Falls II, 10°12'11" N, 77°32'56" E, 448 m, 14-x-2023; 1 larva, Thalakuthu Main Falls, 10°26'16" N, 77°41'07" E, 450 m, 02-vii-2023; 3 larvae, Nalla Thangal Stream, 10°23'58" N, 77°36'49" E, 586 m, 02-vii-2023; 6 larvae, Varaiyaru Falls, 10°19'41" N, 77°42'54" E, 1172 m, 01-vii-2023, Coll. C. Selvakumar.

Distribution. **India:** Tamil Nadu (Selvakumar et al., 2017), Kerala and Karnataka (Kluge, 2021). **Elsewhere:** Sri Lanka (Müller-Liebenau, 1983).

Genus Labiobaetis Novikova & Kluge, 1987***Labiobaetis jacobusi* Kubendran & Balasubramanian, 2015 (Fig. 3F)**

Labiobaetis jacobusi Kubendran & Balasubramanian, 2015, 3957:195, Holotype ♂ larva, Vaigai River, Madurai, Tamil Nadu, India.

Material examined. 4 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 17 larvae, Moolaiyaru River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 4 larvae, Adukkam Falls, 10°15'08" N, 77°31'22" E, 1685 m, 27-iv-2023; 4 larvae, Varaiyaru Falls, 10°19'41" N, 77°42'54" E, 1172 m, 01-vii-2023; 14 larvae, Umaiylaru River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (Kubendran et al., 2015).

Labioaetis pulchellus (Müller-Liebenau & Hubbard, 1985) (Fig. 3G)

Baetis pulchellus Müller-Liebenau & Hubbard, 1985, 68:544, Holotype ♂ nymph, Sri Lanka.

Material examined. 3 larvae, Thaliyuthu Water Falls, 10°26'33" N, 77°41'09" E, 346 m, 02-vii-2023; 3 larvae, Thalakuthu Main Falls, 10°26'16" N, 77°41'07" E, 450 m, 02-vii-2023, Coll. C. Selvakumar & party.

Distribution. India: Karnataka, Kerala and Tamil Nadu (Kluge et al., 2023d). **Elsewhere:** Sri Lanka (Müller-Liebenau & Hubbard, 1985; Kluge et al., 2023d).

Genus *Nigrobaetis* Novikova & Kluge, 1987

Nigrobaetis klugei Sivaruban, Srinivasan, Barathy & Isack, 2022 (Fig. 3H)

Nigrobaetis klugei Sivaruban, Srinivasan, Barathy & Isack, 2022, 5091:183, Holotype ♀ mature nymph, Sastha falls, Rajapalayam district, Tamil Nadu, India.

Material examined. 3 larvae, Kumbakkarai Falls I, 10°10'24" N, 77°32'13" E, 353 m, 14-x-2023; 1 larva, Thalakuthu Main Falls, 10°26'16" N, 77°41'07" E, 450 m, 02-vii-2023, Coll. C. Selvakumar & party.

Distribution. India: Tamil Nadu (Sivaruban et al., 2022).

Genus *Procloeon* Bengtsson, 1915

Subgenus *Procloeon* Bengtsson, 1915

Procloeon (*Procloeon*) *kottagudiensis* Balasubramanian & Muthukatturaja, 2022 (Fig. 3I)

Procloeon (*Procloeon*) *kottagudiensis* Balasubramanian & Muthukatturaja, 2022, 5094:322, Holotype ♂ imago, Kottagudi stream, Tamil Nadu, India.

Material examined. 3 larvae, Moolaiyaru River, 10°16'13" N, 77°36'34" E, 1217 m, 27-iv-2023; 4 larvae, Thaliyuthu Water Falls, 10°26'33" N, 77°41'09" E, 346 m, 02-vii-2023; 3 larvae, Nalla Thangal Stream, 10°23'58" N, 77°36'49" E, 586 m, 02-vii-2023; 17 larvae, Varaiyaru Falls, 10°19'41" N, 77°42'54" E, 1172 m, 01-vii-2023; 15 larvae, Umaiylaru River, 10°20'56" N, 77°41'27" E, 1236 m, 01-vii-2023, Coll. C. Selvakumar & party.

Distribution. India: Kerala and Tamil Nadu (Muthukatturaja & Balasubramanian, 2022).

The following four mayfly species: *Megaglena agasthiya*, *Choroterpes* (*Euthraulus*) *atelobranchis*, *Caenis maduraiensis* and *Nigrobaetis klugei* are reported for the first time from the Palni Hills. The endemic species *Megaglena agasthiya* and *Nathanella indica* were found only in the high elevation sites (above 1670 m), whereas *Isca* sp. and *Teloganodes* (*Dudgeodes*) *palnius* were found in low elevation sites (353 m) as well as high elevation site (1685 m). The oriental species, *Ecdyonurus* (*Rhithrogeniella*) *ornatus* occurs in the moderate high elevation ranges between 1217 m and 1236 m. *Ephemera* (*Aethephemera*) *nadinae* is found at only one high elevation site (1271 m), which is characterised by slower water current and sandy bottom. In contrast, other mayflies exhibit overlapping distributions across different altitudes (Table 2). Out of 24 species distributed throughout Palni Hills, 12 occur in the low to moderate elevation study sites. *Megaglena agasthiya*, *Isca* sp., and *Nathanella indica* are distributed only in the southern Palni Hills, whereas *Baetis* (*Tenuibaetis*) *frequentus* is only distributed in the northern Palni Hills. *Caenis american*i occurs only in the southern Palni Hills, whereas *Caenis maduraiensis* is only found in the northern Palni Hills. The number of individuals and richness of species is decreasing with the increasing elevation, while the abundance of species and elevation are negatively correlated ($r=0.26$) (Fig. 4).

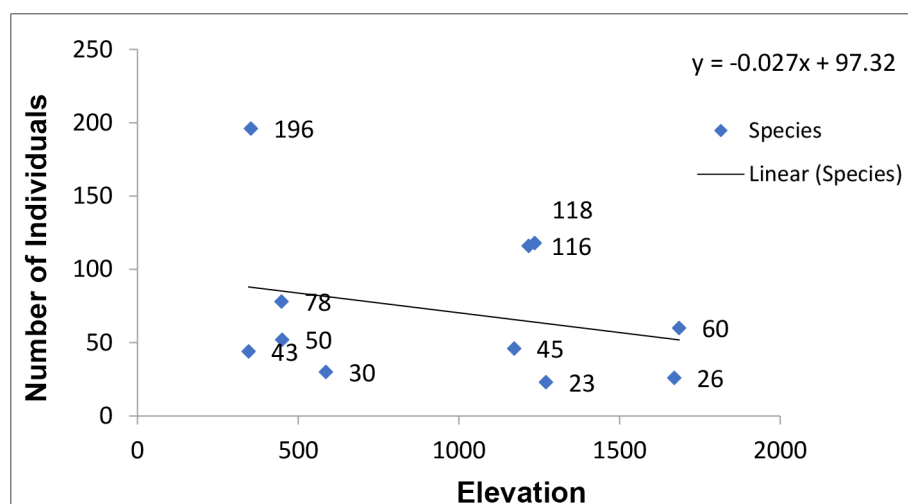


Figure 4. Simple linear regression analysis of elevation and number of individuals.

DISCUSSION

The present study reports 24 species of mayflies from the Palni Hills of the Western Ghats. The families Baetidae, Heptageniidae, and Leptophlebiidae are the most species-rich families, however their abundance was found to be low in freshwater ecosystems of the Western Gath hotspot as previously found in Palni Hills by Sivaramakrishnan and Venkataraman (1990) and in Courtallam Hills by Sivaramakrshnan and Job (1981). Most genera of Leptophlebiidae are widely distributed in different habitats, but the genera *Megaglena* Peters & Edmunds, 1970, and *Nathanella* were only found in the pristine stream habitat. Sivaramakrishnan & Venkataraman (1990) have reported the following three leptophlebiid genera, namely *Edmundsula* Sivaramakrishnan, 1985, *Notophlebia* Peters & Edmunds, 1970 and *Klugephlebia* Selvakumar, Subramanian & Sivaramakrishnan, 2016 in the Palni Hills. However, we were unable to find these three genera during this investigation, including the same sites from where they were reported before. *Edmundsula* and *Notophlebia* occur in other parts of the Western Ghats (Selvakumar et al., 2018a), while *Klugephlebia* was described and reported only from the Pillar Rock of Kodaikkanal, Palni Hills by Selvakumar et al. (2016b) and also reported as a new genus by Sivaramakrishnan and Venkataraman (1990). In our rigorous attempt to collect samples from the type locality of *Klugephlebia* at Pillar Rock in Kodaikanal, we were unable to find any mayfly larvae. This absence raises a concerning possibility: the species may be facing local extinction or may have already vanished due to habitat degradation and anthropogenic impacts. This situation necessitates further intensive field collections across the Palni Hills to confirm its actual distribution and occurrence. Furthermore, this finding highlights the urgent need for conservation measures to protect these ecologically significant aquatic insects and their habitats. Previously, *Choroterpes* (*Euthraulus*) sp. was the only species reported from the Palni Hills by Sivaramakrishnan and Venkataraman (1990). However, the current study identifies three species belonging to the subgenus *Euthraulus*, reflecting advancements in taxonomic knowledge of mayflies and detailed observations of their morphological features. Many baetid species were previously misidentified due to a lack of taxonomic expertise, the absence of molecular techniques, and the inherent complexity of the group (Sivaramakrishnan & Venkataraman, 1990; Barathy et al., 2021a).

Significant discoveries of new mayfly species, including new genera, have been made in the Western Ghats over the past two decades (Selvakumar et al., 2014b, 2016b; Kluge et al., 2022a, 2022b). Additionally, species delimitation has been further refined through DNA barcoding techniques, as demonstrated by Selvakumar et al. (2016a). Table 4 provides a comparison of mayfly diversity in the Palni Hills between 1990 and 2023. Further intensive field studies are required to comprehensively understand the distribution and evolutionary dynamics of mayflies in the streams and rivers of the Palni Hills.

Table 4. Comparison of mayfly diversity in Palni Hills between the years 1990 and 2023.

Family	Reported by Sivaramakrishnan & Venkataraman in 1990	Reported by current study (2023)
Leptophlebiidae	<i>Choroterpes (Euthraulus)</i> sp.	<i>Choroterpes (Euthraulus) alagarensis</i>
		<i>Choroterpes (Euthraulus) atelobranchis</i>
		<i>Choroterpes (Euthraulus) nambiyarensis</i>
	<i>Edmundsula lotica</i>	-----
	<i>Isca</i> sp.	<i>Isca</i> sp.
	-----	<i>Megaglena agasthiya</i>
	<i>Nathanella indica</i>	<i>Nathanella indica</i>
	<i>Notophlebia jobi</i>	-----
	<i>Petersula courtallensis</i>	<i>Petersula courtallensis</i>
Heptageniidae	<i>Cinigmina</i> sp.	<i>Afronurus kumbakkaraiensis</i>
	----	<i>Ecdyonurus (Rhithrogeniella) ornatus</i>
	<i>Epeorus</i> sp.	<i>Epeorus gilliesi</i>
	<i>Thalerosphyrus</i> sp.	<i>Thalerosphyrus flowersi</i>
Ephemeridae	<i>Ephemera (Aethephemera) nadinae</i>	<i>Ephemera (Aethephemera) nadinae</i>
Caenidae	<i>Caenis</i> sp.	<i>Caenis americani</i>
		<i>Caenis maduraiensis</i>
Teloganodidae	<i>Teloganodes</i> sp.	<i>Teloganodes (Dudgeodes) palnius</i>
		<i>Teloganodes (Teloganodes) kodai</i>
Baetidae	----	<i>Acentrella (Liebebiella) vera</i>
	<i>Baetis frequentus</i>	<i>Baetis (Tenuibaetis) frequentus</i>
	<i>Baetis acceptus</i>	<i>Baetis venkatramani</i>
	<i>Baetis conservatus</i>	----
	<i>Centroptella similis</i>	<i>Centroptella (Chopralla) ceylonensis</i>
	<i>Baetis geminatus</i>	<i>Labiobaetis jacobusi</i>
		<i>Labiobaetis pulchellus</i>
		<i>Nigrobaetis klugei</i>
	<i>Procloeon regularum</i>	<i>Procloeon (Procloeon) kottagudiensis</i>
Tricorythidae	<i>Neurocaenis</i> sp.	----

Our study revealed a weak relationship between mayfly species richness and abundance and the elevational gradient. Generally, species richness showed a decline at higher elevations (Sivaramakrishnan & Venkataraman, 1990; Selvakumar et al., 2014a). The distribution of mayflies in the Palni Hills of southern India appears to be primarily influenced by factors such as pristine waters, perennial flow, substratum characteristics, the availability of allochthonous organic matter, temperature, and riparian forest cover. Given that many mayfly species are highly sensitive to anthropogenic impacts, as well as to temperature, riparian land use, and water velocity gradients that often covary with elevation, it is likely that these factors partially explain our findings (Selvakumar et al., 2014a, 2014c). However, streams in this region experience pronounced seasonal fluctuations in environmental factors (e.g., water level, turbidity, and velocity) and are subject to significant hydrological disturbances during monsoons. Therefore, future studies should investigate the role of these drivers in shaping mayfly species richness and abundance.

AUTHOR'S CONTRIBUTION

The authors confirm their contribution to the paper as follows: C. Selvakumar, C. Ashokkumar, S. Sundar and M. Gunasekaran: Field studies and specimen samplings; C. Selvakumar and C. Ashokkumar: Identification of the specimens; C. Selvakumar, S. Sundar and F.O. Roque: drafting, editing and proofreading the manuscript. All authors read and approved the final version of the manuscript.

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AVAILABILITY OF DATA AND MATERIAL

The specimens listed in this study are deposited in the Centre for Research in Aquatic Entomology, Department of Zoology, The Madura College (Autonomous), Madurai, and are available from the first author upon request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study only included 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.

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تنوع زیستی و انتشار یکروزه‌ها (Insecta: Ephemeroptera) در "جزایر آسمانی" تپه‌های پالنی گهات غربی، هند

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چکیده: تپه‌های پالنی که بخشی از رشته‌کوه گهات غربی در جنوب هند هستند، به عنوان یک نقطه داغ تنوع زیستی شناخته می‌شوند و ارتفاع بالای آن‌ها شرایط اکولوژیک منحصر به فردی را ایجاد می‌کند. با وجود شناخت جهانی از این منطقه به عنوان یک نقطه داغ تنوع زیستی، بسیاری از گروه‌های تاکسونومیک از یکروزه‌ها هنوز به خوبی مطالعه نشده‌اند. در این تحقیق، یکروزه‌ها در تپه‌های پالنی را بررسی کردیم تا پروفایل کنونی تنوع زیستی آنها را مستندسازی کرده و تغییرات الگوهای توزیع آنها در ارتفاعات بین ۳۴۶ تا ۱۶۸۵ متر بالاتر از سطح دریا را تحلیل کردیم. نمونه‌برداری ما از آوریل تا اکتبر ۲۰۲۳ شامل یازده منطقه بود و طی آن ۷۸۸ نمونه جمع‌آوری شد. این نمونه‌ها شامل ۲۴ گونه، ۱۶ جنس و شش خانواده است از یکروزه‌ها بود که چهار گونه برای اولین بار از تپه‌های پالنی گزارش شدند. خانواده‌های Baetidae، Heptageniidae و Leptophlebiidae به طور قابل توجهی از نظر تنوع گونه‌ای غنی‌ترین بودند، اگرچه تراکم جمعیت هر گونه همچنان پایین بود. سلسله‌مراتب تاکسونومیک به‌روز شده، پروفایل تنوع زیستی و فراوانی یکروزه‌ها در تپه‌های پالنی ارائه شد. همچنین شکاف دانش تاکسونومیک و توزیع یکروزه‌ها در این منطقه مورد تاکید قرار گرفت.

واژگان کلیدی: حشرات آب‌زی، منطقه غنی، تنوع زیستی، حفاظت، ارتفاع، غنای زیستی