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ZOOLOGICAL SURVEY
OF INDIA
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Faunal Diversity of Biogeographic Zones of India: Western Ghats

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Cover Photo: Endemic shrub, Neelakurunji *Strobilanthes kunthiana* (Nees) T. Anderson ex Benth, in Western Ghats, which blossoms once in 12 years. Photo: Dr. Jommy Augustine

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Chapter 19

Insecta: Ephemeroptera

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Updated data of the Ephemeroptera (mayflies) of the Western Ghats is presented with current nomenclature, taxonomic and diversity profiles. The fauna of the region is represented by 13 families, 42 genera and 82 species. The families Baetidae, Leptophlebiidae and Teloganodidae are the richest ones in terms of generic richness. The mayfly fauna of the region is threatened by habitat destruction, pollution and agriculture runoff.

Keywords: Western Ghats, mayflies, species, diversity, conservation.

INTRODUCTION

Ephemeroptera or mayflies have fascinated humans from the days of Aristotle (384-322 B.C.), who recorded briefly about their life cycle. This small order of insects is geologically an ancient taxon (more than 300 million years ago) and encompasses around 3,700 described species within 43 families and more than 400 genera, with worldwide distribution except Antarctica (Barber-James *et al.*, 2008; Bauernfeind and Soldan, 2012). The order's name has reference to the brevity of adult life span of a few hours to a couple of days. Their larval life span is three to four weeks in the tropics to around a couple of years in colder temperate zones, with greater diversity in clear well oxygenated running waters (rivers, fast-flowing rocky streams) than in lentic waters like lakes and ponds.

Mayflies are unique among insects in having a preadult subimaginal alate (winged) stage between larval and imaginal stages. The subimago (dun) is a stage of sexual maturation in which the wings are semiopaque and covered in minute hairs (microtrichia) with longer setae on the margins (Williams and Feltmate, 1992). Primitive features of mayflies include inability of the paleopterous adult to fold the wings flat when at rest but to position it straight above the body like butterflies. Male imagos have relatively long forelegs to hold the female during nuptial flight. The eyes are usually sexually dimorphic, those of the male being larger and turbinate in Baetidae and Leptophlebidae). The adult life is focused on reproduction and dispersal. They do not even feed, with vestigial mouthparts, deriving nourishment from the nutritional build up from their nymphal stages. They adopt sexual and parthenogenetic reproductive strategies, some being ovoviviparous. Larval mayflies, being microhabitat specialists exhibit a variety of morphologies: the body of active swimmers are streamlined and those inhabiting in riffles of streams exhibit several rheotactic responses. Many burrowing mayflies have cylindrical bodies with mandibular tusks and broad forelimbs for digging. Some sprawl on muddy bottom, others cling to water plants or dislodgable stones and pebbles in montane streams. Larvae moult several times, the number varying in accordance with their food availability and thermal ranges of their respective habitats. Respiration of larval mayflies is hydropneustic and involves usually seven pairs of abdominal gills with varied, sizes and lamellar vibration speed adapted to the differential water flow and dissolved oxygen content of their respective habitats and niches. They also exhibit trophic diversity. Collector-gatherer, scraper feeding

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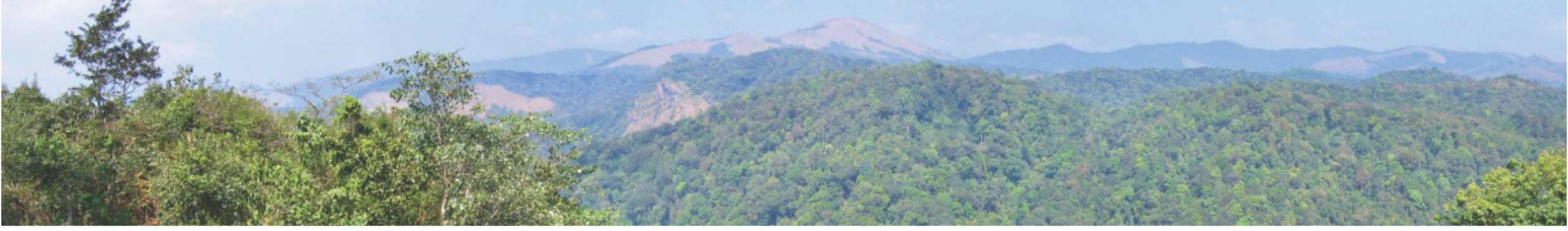


guilds are common in this order (Dudgeon, 1999). Larval and adult mayflies are sensitive indicators of environmental health in freshwater and adjoining terrestrial riparian areas respectively. Mayfly life cycles show a distinct trend from the tropics to the Arctic. In the tropics, non-seasonal multivoltine cycles with asynchronous emergence and bivoltine cycles are common, with seasonality becoming distinct in montane areas. Univoltine cycles with larval lifespan extending to a year or two dominate in mayflies inhabiting upper temperate and Arctic regions (Brittain and Sartori, 2003; Sartori and Brittain, 2015).

Besides being charismatic, mayfly larvae collect FPOM (fine particulate organic matter) and transfers energy contained therein to higher trophic levels in the aquatic community. Subimagos emerge from water and they along with their imagos are avidly consumed by many riparian birds, bats, spiders and lizards. Thus, mayflies play a crucial role in the cycling and transfer of nutrients and carbon between aquatic and terrestrial riparian habitats (Jacobus *et al.*, 2019). Ephemeroptera studies gain added significance due to a plethora of ecosystem services disproportionate to their size in terms of their richness and abundance in their habitats (Jacobus *et al.*, 2019), notwithstanding their intriguing phylogenetic and biogeographic history impacted by tectonic and paleoclimatic activities over several geologic eras spatially and temporally.

With this background, it appears a challenging task to unravel the phylogenetic riddles and biogeographic enigmas behind the latitudinal and altitudinal gradients of distribution of ephemeropteran fauna, of the river basins of the Western Ghats of peninsular India, being dissected by three gaps, of which the middle Palghat gap and southern Shenkottah gap are conspicuous geographical barriers, with a few "sky islands" harbouring "clade evolution in isolation" (Robin *et al.*, 2010), and with southern Western Ghats serving as "refugia for its endemic biota during Cretaceous volcanism" (Joshi and Karanth, 2013) and presently harbouring Afrotropical, Palearctic and east Asian lineages besides Gondwanan ones (Sivaramakrishnan and Subramanian, 2016), the Western Ghats being a chip of original east Gondwana, geologically older than the Himalayas. Added to these, current monsoonal climate with all its vicissitudes and the negative impacts of anthropogenic climate change and habitat destruction especially the riparian zones of shola and evergreen forests have made the globally significant phylogenetic relicts and locally valuable endemic and native of mayflies vulnerable to reduction in abundance and species richness paving the way for rapid extinction even before they are scientifically explored.

The aim of the present chapter on Ephemeroptera is to present the checklist, with updated nomenclature, taxonomic overview, diversity profile, endemism and species assemblages patterns in different river basins and associated lentic bodies, unique to this peninsular Indian biogeographic subzone of the Orient, gaps in the context of existing knowledge and conservation shortfalls and remedial measures relevant to the western Ghats, one of the world's eight "Hottest biodiversity hotspots" (Molur *et al.*, 2008; Subramanian, 2010) with southern Western Ghats falling under the critically Endangered Category of the Global 200 priority ecoregions of the World Wide Fund for Nature (http://wordwildlife.org).

HISTORICAL RESUME

Sporadic observations and brief descriptive accounts were made on some adult mayflies of the Western Ghats during the British colonial period by Navas (1931) and others. However, it was the pioneering studies of the two military officers during that period, D. E. Kimmins, the British Museum expert and M. T. Gillies (Gillies, 2000), the British doctor of Indian Military hospital that initiated serious taxonomic investigations on the mayflies of the Western Ghats (Kimmins, 1947; Gillies, 1949; 1951). Field explorations of the American Ephemeropterist, W. L. Peters and his wife Janice Peters and the Canadian Trichopterist, Fernand Schmid, in the sixties of the twentieth Century in several riverbasins of the Western Ghats along with global investigations by Edmunds Jr., Traver, McCafferty and of Ulmer (1939) on Sunda Islands or Malayan archipelago stabilized Ephemeroptera Systematics of the Oriental region on a solid base, and was immediately followed by crucial contributions very relevant to Western Ghats mayflies (Peters, 1967; 1975; Peters and Edmunds 1970). With the patronage and guidance of Professor W. L. Peters and his colleague, Dr. W. Flowers of A&M University, Florida, USA, Sivaramakrishnan (1984, 1985a,b) and Venkataraman (Venkataraman and Sivaramakrishnan 1987; 1989) and their students, Balasubramanian (1991, 1992, 2019a,b), Selvakumar (2012, 2013, 2014a, 2015a,b, 2016a, 2017; 2018a,b,c), Subramanian (2009, 2017) and Kubendran (2014, 2015) both presently in ZSI, and a few ephemeropterists of the subsequent generation (Sivaruban *et al.*, 2013; Anbalagan *et al.*, 2015; Balachandran *et al.*, 2016, Ramya-Roopa *et al.*, 2017, Rekha *et al.*, 2019, Vasanth *et al.*, 2019; Muthukatturaja *et*

al., 2020) intensively surveyed the streams of southern Western Ghats and contributed substantially establishing new genera, and describing new species and new records at the family, generic and species levels along with significant contributions on eco-evolutionary studies (Sivaramakrishnan and Subramanian, 2016) in Western Ghats mayflies. Selvakumar *et al.* (2016b; 2019) added a molecular dimension to the systematics and phylogeny of around 40 species of Western Ghats mayflies. As part of global studies of several families of mayflies, Kluge continues to contribute substantially to the knowledge of mayflies of the Western Ghats (Kluge *et al.*, 2013, 2015; Kluge, 2014; Kluge and Novikova 2014; Kluge, 2020; Kluge and Suttinun, 2020; Kluge *et al.*, 2020). Notable publications on studies of diversity and biogeographic patterns of mayflies of the West Ghats include Sivaramakrishnan and Subramanian (2016), Subramanian *et al.*, (2017) and Selvakumar *et al.*, (2020). 'State of art" mayfly studies in India were updated periodically till 2015 (Sivaramakrishnan, 2016) requiring further updation. Hubbard and Srivastava (1984) listed the available and missing types of Ephemeroptera in the Zoological Survey of India, Calcutta.

DIVERSITY

Global distribution of extant families is basically the result of the continental drift since the break off of Pangea more than 200 mys. In India we have 4 suborders, 15 families, 59 genera and 172 species (Table 1). Western Ghats, being a biodiverse region of peninsular Indian subregion of the Orient, harbours 13 families of mayflies encompassing 42 genera and 82 species of which Baetidae (12), Leptophlebiidae (9) and Teloganodidae (5) are the three richest ones in terms of generic richness (Table 1). Present ephemeropteran generic and species assemblages along the latitudinal and altitudinal gradients of the inland waters of the river basins of the Western Ghats are structured by the interplay of the following past geological and evolutionary events: 1. Mesozoic tectonic event of drifting Indian plate from Gondwanaland, transporting original gondwanan elements; 2. Post-quaternary volcanic scenario resulting in arrival of Afrotropical elements "into - India"; 3. Arrival of Palearctic elements as per "Eurasian route theory" after post-Indian plate – Eurasia collision and 4. *in situ* evolution in "sky islands" of the Western Ghats and overall north-south dispersal within segments of the Western Ghats impacted by geographical barriers of the Palghat and Shenkotta gaps and periodic climate fluctuations (Karanth, 2015). Local species assemblages within river basins are fine tuned by respective microhabitat diversity, spatio-temporal food availability (Burton and Sivaramakrishnan, 1993), eco-climatic changes, especially monsoonal vicissitudes, also impacted by several land use changes (Selvakumar *et al.*, 2014b) and anthropogenic impacts (Dinakaran and Anbalagan, 2007) resulting in reduction of abundance of individual species populations and attenuation of species richness. Unfortunately however, even publications from reputed Institutions suffer from major taxonomic errors. Instances of such erroneous taxonomic misplacements and distributional anamolies include recording species/genera, not belonging to the Western Ghats Biogeographic Region, for instance recording occurrence of the genus *Leptophlebia* belonging to the subfamily, Leptophlebiinae in Balachandran *et al.* (2014), including *Thraulus* sp. in the family, Neoephemeridae (Table 2 in Barathy *et al.* (2020) and reporting ecological data on species not yet formally described and supported by deposition of type materials in approved national depositories like Zoological Survey of India, for instance ecological data on a species of *Caenis* and a species of *Labiobaetis* of Alagar hills (Balachandran *et al.*, 2017). Such 'misinformation' considerably erodes the value of the published work for posterity to depend on as a reliable database. Significant contributions on aspects of feeding behaviour (Sivaramakrishnan and Venkataraman, 1987), trophic guilds (Anbalagan *et al.*, 2004) emergence, swarming oviposition (Sivaramakrishnan and Venkataraman, 1985), fecundity (Sridhar and Venkataraman, 1989), parthenogenesis (Sivaramakrishnan *et al.*, 1991), commensalism (Subramanian and Sivaramakrishnan, 2009) and biomonitoring potential (Sivaramakrishnan *et al.* 1996) of the mayflies of the Western Ghats are increasing since last decade of the previous century to impress the stakeholders and conservationists regarding the crucial ecosystem services (cultural, provisioning, regulatory and supporting) silently being rendered in lentic and lotic inland waters by mayfly larval communities and by the emerging mayfly sub imagos and imagos in adjoining riparian terrestrial zones (Jacobus *et al.*, 2019).

ENDEMISM

Endemism in mayflies is a function of the history of the lineage under study and the ecological requirements of their larvae. The lineages that have evolved because of vicariant processes are composed of endemic genera like *Petersula*, *Edmundsula*, *Klugephlebia, Nathanella* and *Notophlebia* coming under the category,

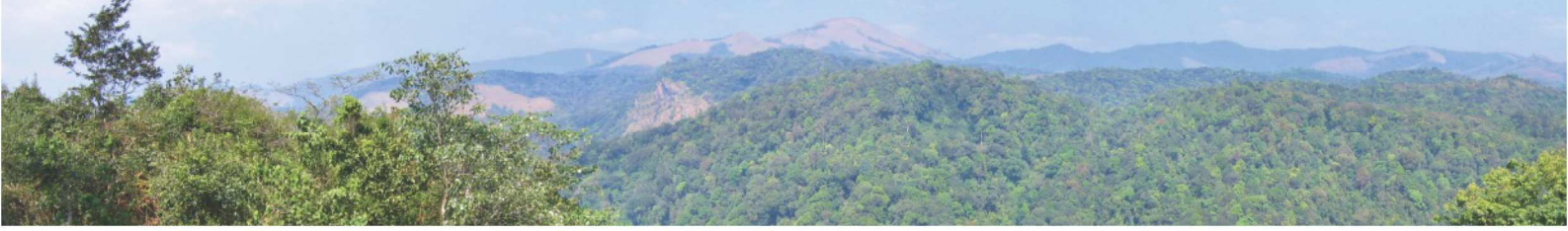


Table. 1. Comparative Analysis of the Ephemeroptera species

Sl. No.	Suborder/Family	India		Western Ghats		Endemic species to India (No.)	Endemic species to Western Ghats (No.)
		No. of Genera	No. of Species	No. of Genera	No. of Species		
	Carapacea						
1	Prosopistomatidae	1	3	1	3	3	3
	Furcatergalia						
2	Leptophlebiidae	12	28	9	21	24	17
3	Ephemeridae	3	16	3	11	11	7
4	Polymitarcyidae	3	5	1	2	3	1
5	Potamanthidae	2	3	2	3	2	2
6	Caenidae	2	11	2	6	8	5
7	Neoephemeridae	1	2	1	1	1	0
8	Ephemerellidae	3	10	1	2	3	0
9	Teloganodidae	5	8	5	7	8	7
10	Tricorythidae	1	1	1	1	1	1
11	Vietnamellidae	1	1	0	0	0	0
	Setisura						
12	Heptageniidae	10	26	3	5	23	5
13	Isonychidae	1	1	1	1	1	1
	Pisciforma						
14	Ameletidae	1	2	0	0	2	0
15	Baetidae	13	55	12	19	38	11
	Total	**59**	**172**	**42**	**82**	**128**	**60**

Table. 2. Ephemeroptera species diversity in different provinces and States of Western Ghats

Taxa	Province		Kerala	Tamil Nadu	Karnataka	Goa	Maharashtra
	Malabar Plains (5A)	Western Ghats (5B)					
Order: **Ephemeroptera**							
Family (No.)	2	13	9	10	8	-	9
Genera (No.)	2	40	18	29	24	-	13
Species (No.)	5	77	24	44	31	-	17

paleoendemism. Paleoendemic species were formerly widespread but are now restricted to a smaller area. Species that have recently evolved through divergence and reproductive isolation are neoendemics belonging to cosmopolitan or tropical genera. The genus *Cloeon* for example probably includes several neoendemics in Western Ghats streams needing exploration adopting integrative taxonomic approach as is done outside India (Benhadji *et al.,* 2020). Totally, 6 genera and 60 species of mayflies are endemic to the river basins of the Western Ghats (Table 1) out of which, 5 genera and 17 species of Leptophlebiid mayflies (Selvakumar *et al.,* 2018a) and the genus *Indoganodes* and 6 of teloganodid mayflies described from the Western Ghats are presently endemic to the region (Selvakumar *et al.,* 2018b). It is obvious that species endemism is rather high in Western Ghats mayflies in peninsular Indian context and on a smaller scale, endemism appears conspicuous in and within individual ranges as in "sky islands" and this needs intensive exploration for prioritization of species conservation along with their specific microhabitats.

SYSTEMATIC LIST

Order EPHEMEROPTERA
Suborder CARAPACEA
Family PROSOPISTOMATIDAE Lameer, 1917
Genus ***Prosopistoma*** Laterille, 1833
1. *P. coorgum* Balachandran & Anbalagan, 2016: 5B
2. *P. indicum* Peters, 1967: 5B
3. *P. someshwarensis* Ramya-Roopa, Selvakumar & Subramanian, 2017: 5B

Suborder FURCATERGALIA
Family LEPTOPHLEBIIDAE Banks, 1900
Subfamily Atalophlebiinae
Genus ***Choroterpes*** Eaton, 1881
4. *C.* (*Choroterpes*) *petersi* Tong & Dudgeon, 2003: 5B
5. *C.* (*Euthraulus*) *alagarensis* Dinakaran, Balachandran & Anbalagan, 2009: 5B
6. *C.* (*Euthraulus*) *kalladaensis* Rekha *et al.* 2019: 5B
7. *C.* (*Euthraulus*) *nambiyarensis* Selvakumar, Arunachalam & Sivaramakrishanan, 2012: 5B
8. *C.* (*Monochoroterpes*) *nandini* Selvakumar & Sivaramakrishnan, 2015: 5B

Genus ***Edmundsula*** Sivaramakrishnan, 1985
9. *E. lotica* Sivaramakrishnan, 1985: 5B

Genus ***Indialis*** Peters & Edmunds, 1970
10. *I. badia* Peters and Edmunds, 1970: 5B
11. *I. rossi* Peters, 1975: 5B

Genus ***Isca*** Gillies, 1951
12. *I.* (*Isca*) *purpurea* Gillies, 1951: 5B

Genus ***Klugephlebia*** Selvakumar, Subramanian & Sivaramakrishnan, 2016
13. *K. kodai* Selvakumar, Subramanian & Sivaramakrishnan, 2016: 5B

Genus ***Nathanella*** Demoulin, 1955
14. *N. indica* Demoulin, 1955: 5B
15. *N. saraswathiae* Sivaramakrishnan, Venkataraman & Balasubramanian, 1996: 5B

Genus ***Notophlebia*** Peters & Edmunds, 1970
16. *N. ganeshi* Kluge, 2014: 5B
17. *N. hyalina* Peters and Edmunds, 1970: 5B
18. *N. jobi* Sivaramakrishnan and Peters, 1984: 5B

Genus ***Petersula*** Sivaramakrishnan, 1984
19. *P. courtallensis* Sivaramakrishnan, 1984: 5B
20. *P. nathani* Sivaramakrishnan and Hubbard, 1984: 5B

Genus ***Thraulus*** Eaton, 1881
21. *T. gopalani* Grant & Sivaramakrishnan, 1985: 5B
22. *T. mudumalaiensis* Arumuga-Soman, 1991: 5B
23. *T. semicastaneus* (Gillies, 1951): 5B
24. *T. thiagarajani* Balasubramanian & Muthukatturaja, 2019: 5B

Superfamily: EPHEMEROIDEA
Family EPHEMERIDAE Latreille, 1810
Subfamily: Ephemerinae
Genus: ***Ephemera*** Linnaeus, 1758
25. *E.* (*Ephemera*) *annandalei* Chopra, 1937: 5B
26. *E.* (*Ephemera*) *diffusa* Chopra, 1937: 5B
27. *E.* (*Ephemera*) *distincta* Hubbard, 1982: 5B
28. *E.* (*Ephemera*) *exspectans* (Walker, 1860): 5B
29. *E.* (*Ephemera*) *fulvata* Navas, 1935: 5B
30. *E.* (*Ephemera*) *immaculata* Eaton, 1871: 5B
31. *E. nathani* Hubbard, 1982: 5B
32. *E.* (*E.*) *supposita* Eaton, 1883: 5B
33. *E.* (*Aethephemera*) *nadinae* McCafferty and Edmunds, 1973: 5B

Subfamily Hexageniinae
Genus: ***Eatonigenia*** Ulmer, 1939
34. *E. trirama* McCafferty, 1973: 5B

Subfamily Palingeniinae
Genus ***Anagenesia*** Eaton, 1883
35. *A. minor* (Eaton, 1892): 5B

Family POLYMITARCYIDAE Banks, 1900
Subfamily: Polymitarcyinae
Genus: ***Ephoron*** Williamson, 1802
36. *E. indicus* (Pictet, 1843): 5B
37. *E. punensis* Dubey, 1970: 5B

Family POTAMANTHIDAEAlbarda, 1888
Genus: ***Potamanthus*** Pictet, 1843
38. *P. subcostalis* Navas, 1931: 5B

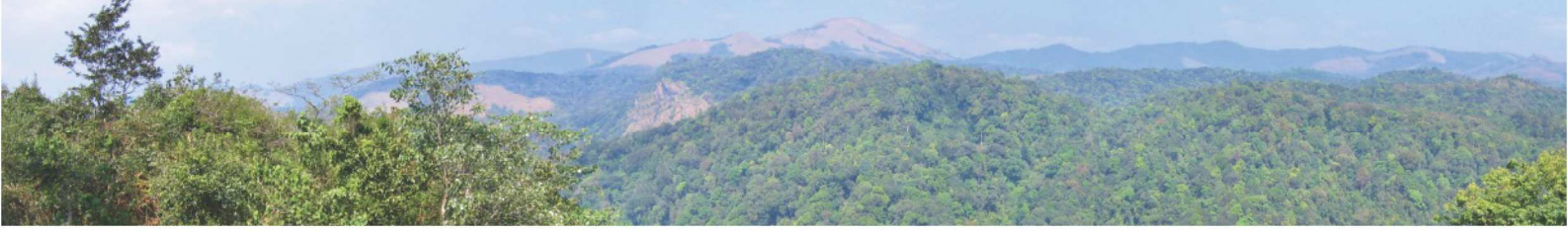
Genus: ***Rhoenanthus*** Eaton, 1881
39. *R. distafurcatus* Bae and McCafferty, 1991: 5B
40. *R.* (*R.*) *tungaiensis* Balasubramanian and Muthukatturaja, 2019: 5B

Family CAENIDAE Newman, 1853
Subfamily: Caeninae
Genus: ***Caenis*** Stephens, l835
41. *C. maratha* Malzacher, 2015: 5A
42. *C. nigrostriata* Navas, 1932: 5A

Genus: ***Clypeocaenis*** Soldan, 1978
43. *C. bisetosa* Soldan, 1978: 5B
44. *C. gayathri* Balasubramanian & Muthukatturaja, 2020: 5B
45. *C. multisetosa* Soldan, 1978: 5B
46. *C. sharadhae* Balasubramanian & Muthukatturaja, 2020: 5B

Family NEOEPHEMERIDAE Traver, 1935
Genus: ***Potamanthellus*** Lestage, 1931
47. *P. caenoides*Ulmer, 1939 : 5B

Superfamily EPHEMERELLOIDEA
Family EPHEMERELLIDAE Klapalek, 1909
Genus ***Torleya*** Lestage, 1917



48. *T. lacuna* Jacobus, McCafferty and Sites, 2007: 5B
49. *T. nepalica* Allen and Edmunds, 1963: 5B

Family TELOGANODIDAE Allen, 1965
Genus ***Derlethina*** Sartori, 2008
50. *D. tamiraparaniae* Selvakumar, Jacobus & Sivaramakrishnan, 2014: 5B

Genus ***Dudgeodes*** Sartori, 2008
51. *D. bharathidasani* Anbalagan, 2015: 5B
52. *D. palnius* Selvakumar, Jacobus & Sivaramakrishnan, 2014: 5B

Genus ***Indoganodes*** Selvakumar, Sivaramakrishnan & Jacobus, 2014
53. *I. jobini* Selvakumar, Sivaramakrishnan & Jacobus, 2014: 5B

Genus ***Teloganella*** Ulmer, 1939
54. *T. indica* Selvakumar, Jacobus & Sivaramakrishnan, 2014: 5B

Genus ***Teloganodes*** Eaton, 1882
55. *T. dentatus* Navas, 1931: 5B
56. *T. kodai* Sartori, 2008: 5B

Family TRICORYTHIDAE Lestage, 1942
Genus ***Sparsorythus*** Sroka & Soldan, 2008
57. *S. gracilis* Sroka and Soldan, 2008: 5B

Suborder: SETISURA
Family HEPTAGENIIDAE Needham, 1901
Subfamily: Heptageniinae
Genus ***Afronurus*** Lestage, 1924
58. *A. keralensis* (Braasch & Soldan, 1987): 5B
59. *A. kumbakkaraiensis* Venkataraman and Sivaramakrishnan, 1989: 5B

Genus ***Thalerosphyrus*** Eaton, 1881
60. *T. flowersi* Venkataraman and Sivaramakrishnan, 1987: 5B

Subfamily Rhithrogeninae
Genus ***Epeorus*** Eaton, 1881
61. *E. gilliesi* Braasch, 1981: 5B
62. *E. petersi* Sivaruban, Venkataraman and Sivaramakrishnan, 2013: 5B

Family ISONYCHIIDAE Burks, 1953
Genus ***Isonychia*** Eaton, 1871
63. *I. moyarensis* Vasanth, Selvakumar and Subramanian, 2019: 5B

Suborder: PISCIFORMA
Family BAETIDAE Leach, 1815
Subfamily Baetinae
Genus ***Acentrella*** Bengtsson, 1912
64. *A. (L.) vera* (Müller-Libenau, 1982): 5B

Genus ***Baetis*** Leach, 1815
65. *B. fluitans* Gillies, 1949: 5B
66. *B. michaelohubbardi* (Selva-Kumar, Sundar and Sivaramakrishanan, 2012): 5B

Genus ***Centroptella*** Braasch and Soldán, 1980
67. *C. (Centroptella) soldani* (Müller-Liebenau, 1983): 5B
68. *C. (Chopralla) pusilla* (Müller-Liebenau, 1984): 5B

Genus ***Indobaetis*** Muller-Liebenau & Morihara, 1982
69. *I. microfolius* Kluge & Novikova, 2014: 5B

Genus ***Indocloeon*** Müller-Liebenau 1982
70. *I. (Hindocloeon) continentale* Kluge &Suttinun, 2020: 5B

Genus ***Labiobaetis*** McCafferty and Waltz, 1995
71. *L. jacobusi* Kubendran & Balasubramanian, 2015: 5B
72. *L. soldani* Kubendran *et al.*, 2014: 5B

Genus ***Nigrobaetis*** Novikova and Kluge, 1987
73. *N. paramakalyani* Kubendran & Balasubramanian, 2015: 5B

Genus ***Tenuibaetis*** Kang and Yang, 1994
74. *T. frequentus* (Müller-Liebenau and Hubbard, 1985): 5B

Subfamily Cloeoninae
Genus ***Cloeon*** Leach, 1815
75. *C. bicolor* Kimmins, 1947: 5A
76. *C. bimaculatum* (Eaton, 1885): 5A
77. *C. harveyi* (Kimmins, 1947): 5A

Genus ***Procloeon*** Bengtsson, 1914
78. *P. dipsicum* (Gillies, 1949): 5B
79. *P. (Oculogaster) malabarensis* Kluge, 2020: 5B
80. *P. palmyrae* (Gillies, 1949): 5B
81. *P. rubellum* (Navas, 1931): 5B

Genus ***Symbiocloeon*** Müller-Liebenau & Heard, 1979
82. *S. madhyasthai* Subramanian & Sivaramakrishanan, 2009: 5B

GAP AREAS

Inland water ecosystems with rich larval ephemeropteran fauna of the Western Ghats, as is elsewhere are part of a larger catchment and intensive survey on all the catchment upstream with adjoining riparian zones for adult mayflies alone can render justice for effective conservation. In this context, unfortunately no protected areas were created exclusively for freshwater biodiversity conservation without a utilitarian value such as a dam and reservoir for drinking water supply or irrigation or power generation (Molur *et al.,* 2011). Headwater streams and lentic aquatics in upper stretches of the larger rivers that originate in the Western Ghats viz., Godavari, Krishna and Cauvery need to be explored for mayfly larvae intensively besides the following significant gap areas in the eight riverine basins (Subramanian, 2010) of the Western Ghats viz., forests of Agasthyamalai, Pandalam hills, Idukky and the Cardamom hills, High Range and Idamala- Pooyankutty valleys, Nelliampathis and forests of Palghat hills, Nilgiri western and eastern slopes and the Brahmagiris in addition to the streams crisscrossing the mature rainforests with dense canopy cover still remaining in the Periar Tiger Reserve (Kerala) and the adjoining Meghamalai and High Wavy Mountains (Tamil Nadu), a major area of them still outside the control of Protected areas, but harbouring rich mayfly species assemblages of conservation value (Sathish Chandran Nair, 1991; 1994 Ranjit Daniels and Jayshree Vencatesan, 2008) .

THREATS

Globally escalating and mutually interacting major threats to survival of mayflies includeglobal warming and climate change, destruction or degradation of habitat, water pollution, flow modification and invasion

of alien inland water taxa preying on mayfly larvae (Dudgeon *et al.*, 2006; Strayer and Dudgeon, 2010).

In the context of a rapidly increasing human population and economic bloom due to globalization with consequent anthropogenic impacts have imperilled the entomofauna of inland waters and mayflies are no exception. Sensitive Western Ghats habitats of *Myristica* swamps, peat bogs, laterite rock pools and phytotelma microcosms are critically threatened habitats of mayfly larvae.

Deforestation

Replacement of polyculture and natural riparian forests by coffee and tea plantations in Anamalais and southern segment of the Western Ghats have resulted in attenuated diversity of pollution sensitive, flow sensitive microhabitat specialists taxa of aquatic insects like mayflies due toincreased sediment loads, erosion, flash floods due to vicissitudes of monsoonal climate, loss of niche habitats such as stagnant pools, inconsistent flow and disappearance of perennial and intermittent streams (Molur *et al.*, 2008).

Construction of megadams and other regional threats

Impacts of mega dams in rhithronic segments of Godavari, Krishna and Cauveri rivers have considerably mayfly species diversity and abundance due to changes in flow regimes, increased sedimentation within reservoirs and impacts of mining like for instance like the ore mine in Kudramukh and bauxite mining in the state of Goa pose major problem for survival of aquatic insects like mayflies in the upper catchments of riers in the region. Other threats to mayflies of montane streams of the Western Ghats include pollution from industry, agriculture, urbanization introduction of exotic ornamental fishes, expanding tourism industry, lack of baseline data on species distributions and abundance and their specific ecological requirements by encouraging longterm monitoring of mayfly communities in different river basins of the Western Ghats.

CONSERVATION STRATEGIES

At the outset, it should be brought to the attention of stakeholders and committed entomologists that conservation of larval and alate stages of mayflies will be effective not only by prioritisation exercise of taxa and habitats in a waterscape and adjoining riparian landscape but by thoughtful holistic conservation of theentire pristine forests segments in protected and unprotected montane regions of the Western Ghats. There is an awakening at the global level to identify the shortfalls of conservation (Cardoso *et al.*, 2011) of every order of aquatic insects including mayflies and a team of global experts are working intensively on protocols for a longterm monitoring system (Cardoso and Leather, 2019) which can be fed to a central repository, that allows real time tracking of changes as they happen in specific areas of riverscapes in a country. If such a globally significant database emerges in our country by the coordinated effeorts of acclaimed research institutions and universities and Colleges committed to our valuable heritage of aquatic entomofauna like the Ephemeroptera with their manifold ecosystem services that takes of the welfare of human society as well not only in the present but also for posterity, our efforts will pay rich dividents for averting an "Ecological armagedden" (Leather, 2018) due to global and regional "insect apocalypse" 2019 including those of the Ephemeroptera.

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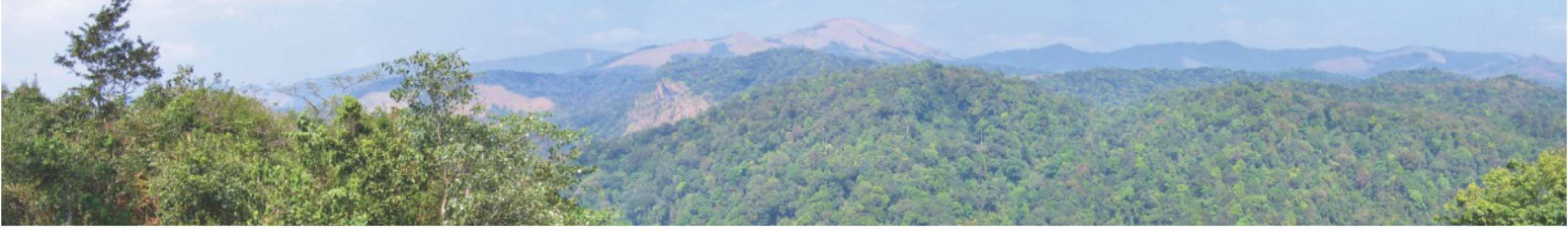

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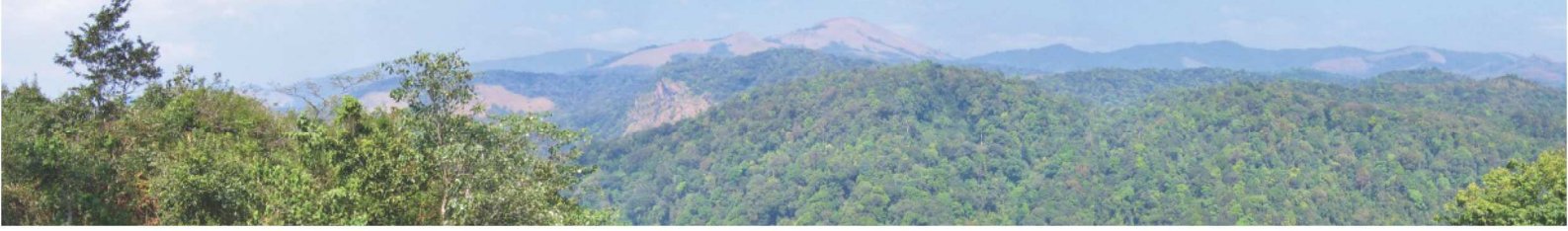

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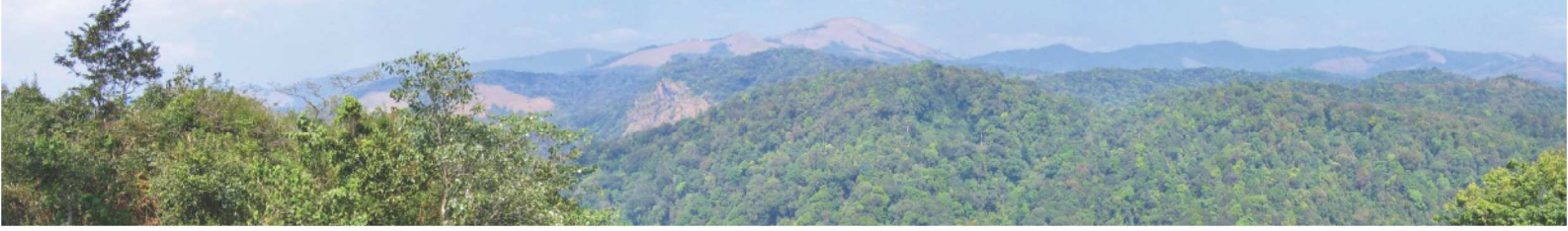
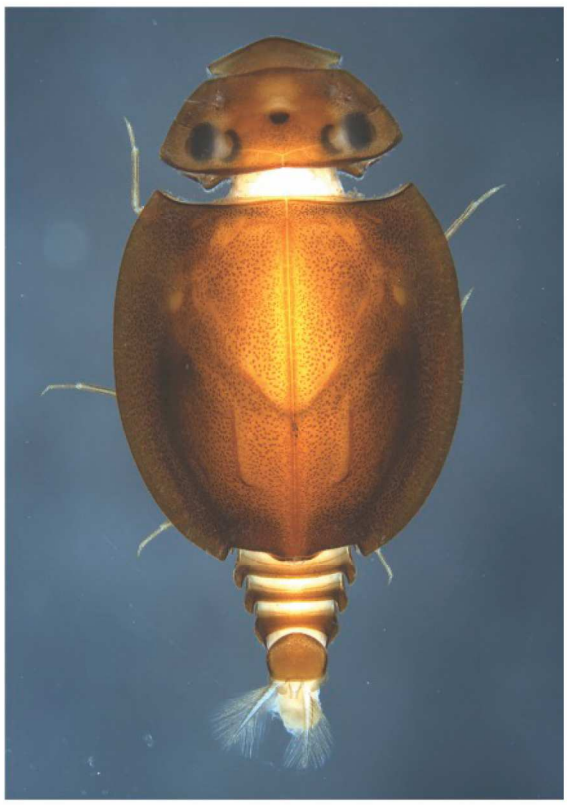


Family PROSOPISTOMATIDAE

Prosopistoma indicum Peters, 1967



Prosopistoma someshwarensis Ramya-Roopa, Selvakumar & Subramanian, 2017

Family LEPTOPHLEBIIDAE

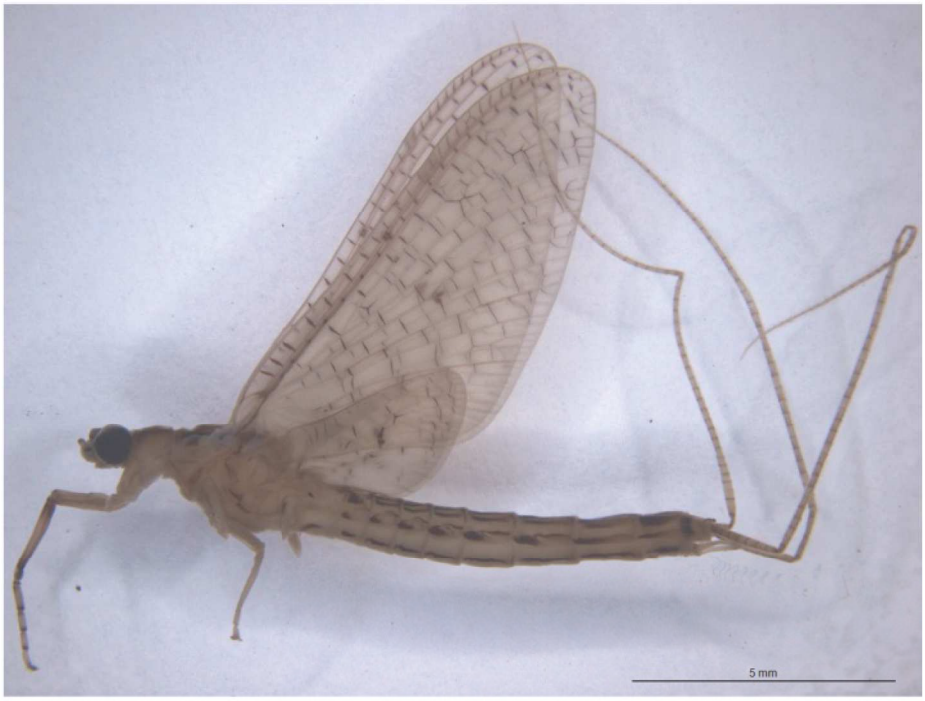
Larva

Adult

Klugephlebia kodai Selvakumar, Subramanian & Sivaramakrishnan, 2016

Family EPHEMERIDAE

Ephemera (Aethephemera) nadinae McCafferty and Edmunds, 1973



Ephemera (Ephemera) annandalei Chopra, 1937

Family POLYMITARCYIDAE

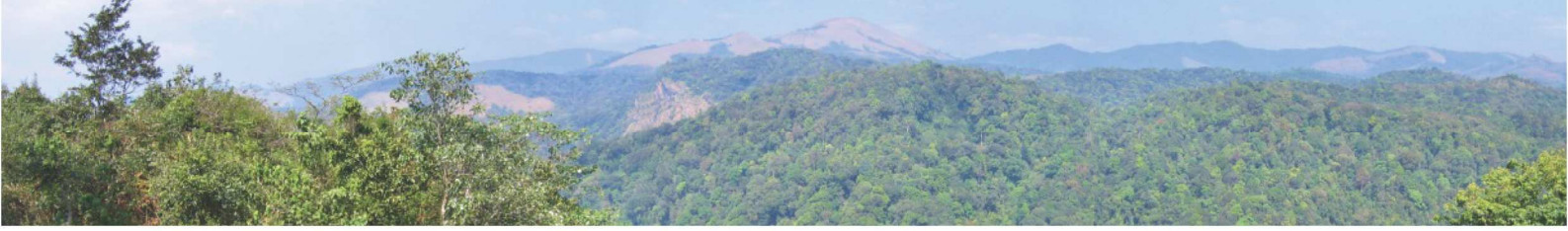
Languidipes sp.

Family POTAMANTHIDAE

Rhoenanthus sp.

Family CAENIDAE

Clypeocaenis bisetosa Soldan, 1978



NEOEPHEMERIDAE

Potamanthellus caenoides
Ulmer, 1939

EPHEMERELLIDAE

Torleya nepalica
Allen and Edmunds, 1963

TELOGANODIDAE

Derlethina tamiraparaniae
Selvakumar, Jacobus &
Sivaramakrishnan, 2014

TRICORYTHIDAE

Sparsorythus gracilis
Sroka & Solan, 2008

HEPTAGENIIDAE

Epeorus petersi
Sivaruban, Venkataraman &
Sivaramakrishnan, 2013

Thalerosphyrus flowersi
Venkataraman &
Sivaramakrishnan, 1987

ISONYCHIIDAE

Isonychia moyarensis
Vasanth, Selvakumar
& Subramanian, 2019

BAETIDAE

Baetis michaelohubbardi (Selva-Kumar, Sundar & Sivaramakrishanan, 2012)

Centroptella (C.) pusilla (Müller-Liebenau,1984)

Labiobaetis jacobusi Kubendran & Balasubramanian, 2015

Tenuibaetis frequentus (Müller-Liebenau & Hubbard, 1985).

Cloeon sp.

Cloeon bicolor Kimmins, 1947