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Inventory of Small Minnow Mayflies (Ephemeroptera: Baetidae) of the Western Ghats with Records of Endemic Taxa

C. Selvakumar, T. Kubendran and K.G. Sivaramakrishnan

Abstract

Baetidae is one of the most specious families of Ephemeroptera in India and also using as biological indicators of water quality. The present study deals with checklist, diagnostic characters, diversity, distribution and status of 19 species belonging to 10 genera under 2 subfamilies of Baetidae from the Western Ghats of India based on the materials collected and identified and published materials. Ten species are endemic to the Western Ghats and 1 species endemic to India. Images of baetid mayflies are also provided based on the collected materials.

Keywords: Mayfly, Baetidae, key characters, endemic taxa, Western Ghats.

Introduction

The homogenous family Baetidae commonly known as minnow mayflies and its encompasses around 100 genera and 900 species constituting one-quarter of the global Ephemeroptera diversity with a cosmopolitan distribution except for Antarctica and New Zealand (Gattolliat & Neito 2009). They are one of the major components freshwater zoo-benthos less diversified in standing water and mainly diversified in unimpacted lotic water, especially in the tropical belt. It is an excellent bioindicators of water quality (Buss & Salles, 2007; Kubendran *et al.* 2017). Baetidae are distinguished by the presence of turbinate eyes in the male imago, detached MA_1 and MA_2 forewing veins, the presence of single or double free intercalary vein in the forewing, hind wings reduced or absent, 3 segmented mid and hind tarsi and membranous penis (Edmands *et al.* 1976). Larvae are pisciform, generally with long antennae and simple or double ovaid gills on segment I-VII or II-VII. They are unique in having the lateral branches of the epicranial suture anterior to the lateral ocellia ventral orientation of the dorsal lobe at the apex of femora (Wang & McCafferty 1996). Kazlauskas (1972) proposed dividing the family Baetidae into 2

subfamily viz., Baetinae and Cloeoninae. This is primarily based on the diversity of the Palaearctic representation of the Baetidae. Furthermore, two confecting concepts have been proposed the division of the Baetidae into different subfamilies (Gillies 1991) or the gathering of genera in several complexes (Waltz *et al.* 1994; Lugo-Ortiz & McCafferty 1996b; 1998a; 1998b). Generic delimitation in Baetidae is being fine-tuned by taking into account larval characters rather than only imaginal ones and secondly by the use of phylogenetic methods and the splitting of paraphyletic and polyphyletic genera. Recent molecular reconstruction should that the division in subfamily is too simplistic and most of the complexes are not monophyletic (Gattolliat *et al.* 2008).

The pioneering investigations on Baetidae of Oriental realm were carried out by Hagen (1985) and Eaton (1883-1888). The more mutual work of Ulmer (1939) on the mayflies of the Sunda Islands provided an exhaustive account of Baetidae of that region. In India, 45 species belonging to 12 genera were described so for (Kimmins 1947; Gillies 1949; Traver 1939; Kapur & Kripalani 1963; Kaul & Dubey, 1970; Dubey 1970, 1971; Müller-Liebenau 1982; Subramanian & Sivaramakrishnan 2009; Selvakumar *et al.* 2012; Kluge & Novikova 2014; Kubendran *et al.* 2014, 2015). Most of the previous descriptions are incomplete and parts of the drawings are somewhat sketchy. Mukherjee *et al.* (2012) reassigned *Procloeon harveyi* to *Cloeon* with the new combination *Cloeon harveyi* Kimmins 1947. The present study deals with checklist, diagnostic characters, diversity, distribution and status of 19 species belonging to 10 genera under 2 subfamilies of Baetidae from the Western Ghats, India based on the materials collected and identified and published materials.

Materials and Methods

Collections were made in streams and river basins of the Western Ghats of India during 2009-2015. This area is mountainous with waterfalls and streams, and holds promise as harboring taxa. Collecting was conducted with an aquatic D-frame insect net. In streams, the substrate was kick-sampled allowing the current to carry organic debris, including insects, into the net. Waterfalls were sampled by scouring the rock surfaces by hand, allowing the current to carry insects into the net. Along stream margins and in ponds vegetation was swept with aquatic D-frame insect net. All insects were preserved into 80% ethyl alcohol. Mayfly nymphs are particularly fragile because the gills and terminal filaments detach from the body very easily. Therefore, when possible, series of specimens were collected to maximize

the likelihood of obtaining intact specimens and accurate determinations. To minimize damage to specimens, mayflies were collected in containers separate from other aquatic insects. Collected samples were brought to laboratory and were examined using a Leica M205A microscope and identified using published taxonomic literature and type specimens in the Zoological Survey of India.

Results

Checklist: The genera and species are presented alphabetically for convenience. This order should in no way be regarded indicating phylogeny.

Order: Ephemeroptera

Suborder: Pisciforma

Family: Baetidae Leach, 1815

Subfamily: Baetinae

Genus: *Acentrella* Waltz & McCafferty, 1987

1. *Acentrella* (*Liebebiella*) *vera* (Müller-Libenau, 1982)

Genus: *Baetis* Leach, 1815

2. *Baetis fluitans* Gillies, 1949
3. *Baetis michaelohubbardi* (Selvakumar, Sundar & Sivaramakrishanan, 2012)

Genus: *Bungona* Harker, 1957

4. *Bungona* (*Centroptella*) *soldani* (Müller-Liebenau, 1983)
5. *Bungona* (*Chopralla*) *pusilla* (Müller-Liebenau, 1984)

Genus: *Indobaetis* Müller-Liebenau, 1982

6. *Indobaetis microfolius* Kluge & Novikova, 2014

Genus: *Labiobaetis* McCafferty & Waltz, 1995

7. *Labiobaetis jacobusi* Kubendran & Balasubramanian, 2015
8. *Labiobaetis soldani* Kubendran, Rathinakumar, Balasubramanian, Selvakumar & Sivaramakrishnan, 2014

Genus: *Nigrobaetis* Novikova & Kluge, 1987

9. *Nigrobaetis paramakalyani* Kubendran & Balasubramanian, 2015

Genus: *Tenuibaetis* Kang & Yang, 1994

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

Subfamily: Cloeoninae

Genus: *Cloeon* Leach, 1815

11. *Cloeon bicolor* Kimmins, 1947
12. *Cloeon bimaculatum* (Eaton, 1885)
13. *Cloeon harveyi* (Kimmins, 1947)
14. *Cloeon kimminsi* Hubbard, 1974
15. *Cloeon marginale* (Hagen, 1858)

Genus: *Procloeon* Bengtsson 1915

16. *Procloeon dipsicum* (Gillies, 1949)
17. *Procloeon palmyrae* (Gillies, 1949)
18. *Procloeon rubellum* Navás, 1931

Genus: *Symbiocloeon* Müller-Liebenau & Heard, 1979

19. *Symbiocloeon madhyasthai* Subramanian & Sivaramakrishanan, 2009

Baetidae Leach, 1815

Subfamily: Baetinae

Diagnosis: The subfamily Baetinae can be distinguished by the following combination of characters: In the larvae (i) tuft of setae absent on the inner side of the prostheca of the right mandible; and in the adult (ii) the presence of double free intercalary vein in the forewing.

Genus: *Acentrella* Bengtsson 1912

Type Species: *Acentrella lapponica* Bengtsson 1912

Diagnosis: The genus *Acentrella* can be distinguished by the following combination of characters: In larvae (i) one or few segments of median terminal filament, never longer than 1/2 of cerci or vestigial, many times shorter than cerci; (ii) presence of a regular setal row on tibia and (iii) tarsi of all legs bear single subapical bristles. In adults: (i) anteronotal protuberance often conic and sharply projected upward and (ii) 2nd segment of gonostylus usually inner-apical convexity.

Distribution: Holarctic, Oriental and Ethiopian Regions.

Status: Wide distribution.

Remarks: The genus *Acentrella* comprises five subgenera viz.

Acentrella, *Tanzaniops*, *Liebebiella*, *Jubabaetis* and *Platybaetis*.

Subgenus *Liebebiella* Waltz & McCafferty, 1987

Diagnosis: The subgenus *Liebebiella* can be distinguished by the following combination of characters: In larvae (i) larval terga lack median hooks, either smooth, or with small tubercles; and (ii) apex of each glossa without 2 very thick, short, stout and blunt setae.

Distribution: Oriental Region.

1. ***Acentrella* (*Liebebiella*) *vera* (Müller-Libenau, 1982)**

Fig 1: *Acentrella* (*Liebebiella*) *vera* (Muller-Libenau, 1982)

Materials Examined: Tamil Nadu, Tirunelveli, Ramanathi stream, 08°84′80″ N, 77°31′40″ E, 237 m, 11.vii.2009; Shengottai, Adavinayinar Dam river, 09°04′55.93″ N, 77°13′58.16″ E, 273 m, 03.xi.2013; Theni, Kurangani stream, 10°05′01″ N, 77°14′55″ E, 1744 m, 21.01.2010; Kodaikanal, Moolaiyar, 10°05′01″ N, 77°14′55″ E, 28.09.2013; Kerala, Silent Valley, Bhavani river, 11°03′56″ N, 76°32′14″ E, 550 m, 10.v.2014; Karnataka, Srimanae falls, 13°23′14″ N, 75°10′46″ E, 716 m, 03.v.2013; Nandini hole, 13°23′23″ N, 77°10′47″ E, 640 m, 3.v.2013.

Diagnosis: *Acentrella* (*Liebebiella*) *vera* can be identified by the following combination of characters: In larvae (i) terminal filament reduced with 10–14 segments; (ii) femora with single dorsal row of multilaterally ciliate bristles and (iii) metatibia with two well developed rows of bristles. In adults (i) reddish maculae on the abdominal terga 3 and 4; (ii) distal half of the fore femur reddish and (iii) unusual curvation in gonovectes.

Distribution: India, Indochina, Java, Lombok, Malay Peninsula, Sri Lanka and Sumatra.

Status: Oriental distribution.

Remarks: This species is distributed over a very wide area within the Oriental Realm.

Genus: *Baetis* Leach, 1815

Type Species: *Ephemera fuscata* Linnaeus 1761

Diagnosis: The genus *Baetis* can be distinguished by the following combination of characters: In larvae (i) two-segmented maxillary palps; (ii) tarsal claws bearing a single row of denticles; (iii) femur, tibia and tarsus lack long bristles; (iv) abdominal terga often patterned; (v) median terminal filament shorter than cerci with lateral hairs; (vi) single, lamellate gills with minutely serrate margins borne on segments 1-7 or 2-7 and (vii) hindwing pads present or absent.

Distribution: Holartic, Oriental and Afrotropical (and probably Australia).

Status: Wide distribution.

Remarks: Twenty three species were listed under this genus from the Indian Subregion, thirteen species from western Malaysia, nine from India and Hong Kong, seven from Sri Lanka, four from the Philippines and three from Java and Sumatra.

2. *Baetis fluitans* Gillies, 1949

Diagnosis: *Baetis fluitans* can be differentiated from other species of this genus by the following combination of characters: In adults (i) abdominal segments 2-6 translucent white, 7-10 dark reddish brown; (ii) stigmatic area of forewing with 5 or 6 simple, slanting veinlets; (iii) hindwing small, rounded with an acute spur and two veins.

Distribution: Maharashtra.

Status: Endemic to the Western Ghats.

Remarks: Diagnostic characters are provided based on original description. Larval stage is unknown.

3. *Baetis michaelohubbardi* (Selvakumar, Sundar and Sivaramakrishnanan, 2012)

Fig 2: *Baetis michaelohubbardi* (selvakumar, Sundar and Sivaramakrishnan, 2012)

Materials Examined: Tamil Nadu, Tirunelveli, Tamiraparani river at Papanasam, 08°42′37″ N, 77°22′03″ E, 108 m, 18.vii.2009; Nambiyar river at Nambikovil, 08°26′01″ N, 77°29′55″ E, 06.vi.2011; Coimbatore, Bhavani river at Sundapatti, 11°03′56″ N, 76°32′14″ E, 1052 m, 9.v.2014.

Diagnosis: *Baetis michaelohubbardi* can be differentiated from other species of this genus by the following combination of characters: In larva (i) abdominal gills 1–7 without tracheal branch; (ii) margin of paraproct with more than three spines; and (iii) spines on posterior margin of abdominal terga segments 1–10 rounded.

Distribution: Tamil Nadu.

Status: Endemic to the Western Ghats.

Remarks: Adult stage is unknown.

Genus: *Bungona* Harker, 1957

Type Species: *Bungona narilla* Harker, 1957

Diagnosis: The genus *Bungona* can be distinguished from the other genera of Baetidae and especially from other genera of the *Cloeodes* complex by the following combination of characters: in larval stage (i) long, sparse setae on the dorsal margin of femora; (ii) spine-like setae between prostheca and mola of right mandible; (iii) right prostheca elongate and bifid; and in imaginal stage: (i) forewings with double marginal intercalary veins; (ii) hindwings absent or vestigial; and (iii) segment III of male genital forceps elongate (Salles *et al.* 2016).

Distribution: Australia, New Guinea, and southern, eastern and southeastern Asia.

Status: Wide distribution.

Remarks: The genus *Bungona* was erected by Harker (1957) to include a single species from Australia, *B. narilla* and it presently encompasses with 3 subgenera viz., *Bungona*, *Chopralla* and *Centroptella*. The original description is concise and the relationship of *Bungona* to other genera such as *Centroptella* and *Chopralla*, was overlooked by Waltz & McCafferty (1987) while reviewing the genus *Cloeodes*. However, the distinction among *Bungona*, *Chopralla* and *Centroptella*, and especially between *Bungona* and *Centroptella* is very subtle, relying on a few unusual characters (Salles *et al.* 2015).

Subgenus: *Bungona* (*Centroptella*) Braasch & Soldán, 1980

Diagnosis: This subgenus can be identified by the following combination of characters: (i) prostheca of right mandible relatively far from

incisors [in comparison with *Bungona* (*Bungona*)], slender and with thin medial process; (ii) distal margin of labial palp segment III straight; (iii) few setae on outer margin of fore femur (around six); (iv) angle of row of long setae on posterior surface of fore tibia around 30°; (v) gills weakly serrate; (vi) gill VII long, reaching caudal filaments.

Distribution: Southern and southeastern Asia.

Remarks: Currently, the subgenus *Centroptella* Braasch & Soldán encompasses three species viz., *Bungona* (*C.*) *longisetosa* (Braasch & Soldán, 1980) from China, *Bungona* (*C*) *soldani* (Müller-Liebenau, 1983) from Sri Lanka and *Bungona* (*C.*) *papilionodes* Gattolliat & Marle, 2016 from Borneo, Indonesia.

4. *Bungona* (*Centroptella*) *soldani* (Müller-Liebenau, 1983)

Fig 3: *Bungona (C.) soldani* (Muller-Liebenua, 1983)

Material Examined: 3 larvae, Tamilnadu, Tirunelveli, Tamiraparani river, Kottumthalam, 08.42.0279 N, 77.21.34 E, 181 m, 26.xii.2013, Coll. C. Selvakumar; 3 larvae, Tamilnadu, Kodaikanal, Moolaiyaru, 10.14.19 N, 77.29.19 E, 1216 m, 28.ix.2013, Colls. C. Selvakumar & T. Kubendran; 2 larvae, Karnataka, Agumbe, 13.30.361 N, 75.05.5314 E, 640 m, 02.v.2013, Colls. C. Selvakumar & T. Kubendran.

Diagnosis: This species can be identified by the following combination of characters: (i) presence of an additional small denticle on the outer margin of the outer incisor; (ii) maxillary palp equal or ½ length of galea-lacinia and (iii) third segment of the labial palp broader (apical width of segment III is 1.6 × base).

Distribution: India (Tamil Nadu and Karnataka) and Sri Lanka.

Status: Narrow distribution.

Remarks: This species was originally described by Müller-Liebenau (1983) from Sri Lanka and recently reported in India by Selvakumar *et al* (2017). Adult stage is unknown.

Subgenus: *Bungona* (*Chopralla* Waltz & Mccafferty, 1987)

Diagnosis: This subgenus can be identified by the following combination of characters: (i) prostheca of right mandible relatively far from incisors [in comparison to *Bungona* (*Bungona*)], slender and with thin medial process (except in *B.* (*Ch.*) *liebenauae* and Genus No. 2 sp 1, *sensu* Müller-Liebenau, 1984); (ii) base of glossa not reaching inner 1/3 of paraglossa; (iii) length of row of long setae on anterior surface of fore tibia extending for about 0.8× length of tibia; (iv) width of row of long setae on posterior surface of fore tibia around 0.7× width of tibia; (v) peculiar denticles on tarsal claws present; (vi) scales on tergal surface lanceolate; (vii) characteristic contrasting body colour pattern; and (viii) gills weakly serrate.

Distribution: Southern and southeastern Asia.

Remarks: Currently, the subgenus *Centroptella* Braasch & Soldán encompasses seven species viz., *Bungona* (*Ch.*) *ceylonensis* (Müller-Liebenau, 1983) and *Bungona* (*Ch.*) *similis* (Müller-Liebenau, 1983) from Sri Lanka, *Bungona* (*Ch.*) *pusilla* (Müller-Liebenau, 1984) from East Malaysia, *Bungona* (*Ch.*) *bintang* Gattolliat & Marle, 2016 from Borneo, Indonesia, *Bungona* (*Ch.*) *colorata* (Soldán, Braasch & Luu, 1987) and *Bungona* (*Ch.*) *liebenauae* (Soldán, Braasch & Muu, 1987) from Vietnam and *Chopralla fusina* (Tong & Dudgeon 2003) from China.

5. *Bungona* (*Chopralla*) *pusilla* (Müller-Liebenau, 1984)

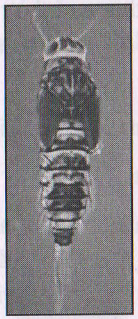

Fig 4: *Bungona (Ch) pusilla* (Muller-Liebenua, 1983)

Material Examined: 6 larvae, Tamilnadu, Tirunelveli, Ramanathi river, 08.50.534 N, 77.18.512 E, 237 m, 18.i.2014, Coll. C. Selvakumar; 1 larva, Tamilnadu, Tirunelveli, Iluppaiyar, 08.47.546 N, 77.19.37 E, 111 m, 05.xi.2013, Coll. C. Selvakumar; 1 larva, Tamilnadu, Kurangani river, 10.05.0197 N, 77.14.5535 E, 1744 m, 26.iii.2014, Coll. C. Selvakumar; 1 larva, Karnataka, Srimane falls, 13.23.149 N, 75.10.4642 E, 715 m, 03.v.2013, Colls. C. Selvakumar & T. Kubendran.

Diagnosis: This species can be identified by following combination of characters: (i) hindwing pad minute; (ii) posterior margin of terga segments IX–X with spines; (iii) prostheca of right mandible bifid, a few short spine like setae between prostheca and mola; (v) paraproct with spines increasing in length and (vi) dorsal margin of femora with 8-10 clavate setae.

Distribution: Borneo and India (Tamil Nadu, Karnataka, Madhya Pradesh, Meghalaya, Nagaland and Odissa).

Status: Wide distribution.

Remarks: This species was originally described from Borneo by Müller-Liebenau (1984) and recently reported in India by Selvakumar *et al.* (2017). Adult stage is unknown.

Genus: *Indobaetis* Müller-Liebenau & Morihara, 1982

Type Species: *Indobaetis costai* Müller-Liebenau & Morihara 1982.

Diagnosis: *Indobaetis* can be distinguished from all other genera of Baetidae by the following combination of characters: In larva (i) gills 2–7; (ii) distal denticle of claw enlarged with at least one strong seta posteriad of it; (iii) hindwings absent; (iv) tibia with a regular row of stout setae on outer margin, different from setae of a regular row on outer margin of femur; (v) head bowed vertically and head and thorax laterally compressed; (vi) mandibular incisors fused together and the right mandibular protheca slender and pointed, not bifurcate; and (vii) 3rd dentiseta of maxilla absent (In other Baetidae three dentisetae).

Distribution: India (Karnataka) and Sri Lanka.

Status: Narrow distribution.

Remarks: Müller-Liebenau & Morihara (1982) established the genus *Indobaetis* for two species viz., *I. costai* and *I.starmuehlneri* from Sri Lanka. Recently, Kluge and Novikova (2014) provided modified generic characters for *Indobaetis* and described a new species of *Indobaetis* from India (Karnataka).

6. *Indobaetis microfolius* Kluge & Novikova, 2014

Diagnosis: *Indobaetis microfolius* can be distinguished from other species of *Indobaetis* by the following combination of characters: In larvae (i) completely fused 2nd and 3rd segments of labial palp; (ii) longitudinal patella-tibial suture and very small gill; (iii) absence of transverse row of setae on glossae; (iv) absence of posterior prolongation of paraproct; and (v) loss of primary swimming setae on cerci and other characters.

Distribution: Karnataka.

Status: Endemic to the Western Ghats.

Remarks: Diagnostic characters are provided based on original description. Adult stage is unknown.

Genus: *Labiobaetis* McCafferty & Waltz, 1995

Type Species: *Baetis atrebatinus* Eaton 1870

Diagnosis: The genus *Labiobaetis* can be distinguished from other species of the genus by the following combination of characters: In larva (i) distolateral notch on the antennal scape present; (ii) right prostheca maniform; (iii) presence of a distomedial concavity on segment 2 of maxillary palps; (iv) width of the paraglossa of labium more than 1.8 times wider than the glossa; (v) apex of labial palp slightly pointed; (vi) second segment of labial palp with a broad thumblike distomedial projection laterally rounded; (vii) femoral villopore absent; (viii) projection at inner distal end of paraproct absent; and (ix) patch of notched scale of paraproct present. In adult (i) anterior margin of frons with medial ridge straight in lateral view; (ii) apical segment of forceps globular; and (iii) forewings with double intercalary vein.

Status: Wide distribution all over the world except in Central and South America.

7. *Labiobaetis jacobusi* Kubendran & Balasubramanian, 2015

Fig 5: *Labiobaetis jacobusi* Kubendran & Balasubramanian, 2015

Material Examined: Tamil Nadu, Theni, Valipparai stream, Vaigai River, 9°43'35.67" N, 77°31'00.24" E, 1300 m, 29.vii.2012; Kodaikanal, Manjalaru river, Mulaiyaru, 10°14'19.99" N, 77°29'19.90" E, 1216 m, 29.vii.2012; Chinnasuruli, Suruli falls, 9°42'35.17" N, 77°25'28.62" E, 605 m, 15.ix.2012, Megamalai, 9°43'38.52"N, 77°21'39.34"E, 1485 m, 20.xii.2012.

Diagnosis: *Labiobaetis jacobusi* can be differentiated from other

species of this genus by the following combination of characters: In larva (i) distolateral notch on antennal scape absent; (ii) a row of 12 spatulate submarginal setae on labrum; (iii) right mandible without tubercle at inner margin between incisor and mola; (iv) broadly concave subapical inner margin present on segment 2 of maxillary palp; (v) segment 2 of labial palp with broad falcate distomedial projection; (vi) hindwing pads absent; and (vii) dorsal margin of tibiae with stout setae. In adult: (i) segment 1 and 2 completely of genital forceps fused; inner margin of segment 1 expanded basally, progressively narrower with 6–8 thin setae, segment 2 with parallel margins, segment 3 globular; and (ii) well developed sclerotized triangular process between forceps, without setae.

Distribution: Tamil Nadu.

Status: Endemic to the Western Ghats.

Remarks: Larva and adult stages are known.

8. *Labiobaetis soldani* Kubendran, Rathinakumar, Balasubramanian, Selvakumar & Sivaramakrishnan, 2014

Fig 6: *Labiobaetis soldani* Kubendran *et al.* 2014

Materials Examined: Tamilnadu, Tirunelveli, Gadana river at Sivasailam, 08°47′17.03″ N, 77°20′49.51″ N, 28.vi.2012.

Diagnosis: *Labiobaetis soldani* can be differentiated from other species of this genus by the following combination of characters: In larva (i) labrum rounded, with an arc and stout setae, long and thin setae medially; distal margin bordered with setae, distolaterally 14 feathered bristles; (ii) inner margin of the 2nd segment of maxillary palp with around 6 hairs and with a shallow subapical excavation leading to a tapering apex; (iii) the paraglossae of labium more than 1.8 times wider than the glossae; (iv) presence of 6 pointed setae on the dorsal femoral margin; (v) absence of hind wing pads; (vi) gills in segment 1–7 with serrated margins and (vi) with scattered notched scales in the middle of the paraproct and without a projection on the posterior end of the inner margin of paraproct. In adults (i) male genitalia with three segmented gonopods; first and second segments almost fused,

third segment globular; well developed sclerotized process between forceps, as broad as distance between forceps, apically flattened without setae.

Distribution: Tamil Nadu.

Status: Endemic to the Western Ghats.

Remarks: Larva and adult stages are known.

Genus: *Nigrobaetis* Novikova & Kluge, 1987

Type Species: *Nigrobaetis Niger* Linnaeus, 1761

Diagnosis: The genus *Nigrobaetis* can be distinguished from other species of the genus by the following combination of characters: In larva (i) body cylindrical, prostheca normal or reduced, glossae with few to many dorsal setae, femoral villopore absent, claws without preapical setae; two kinds of peculiar setae of the distal margin of the labrum, the truncated third segment of labial palp the few stout setae between prostheca and mola on both mandibles and humped posture of the prothorax; () presence or absence of hindwing pads; number of abdominal gills. There are no useful characters for separating *Nigrobaetis* from other related genera at adult stage (Waltz *et al.* 1994)

Distribution: Oriental, Plaearctic and Afrotropical including Madagascar and La Reunion Island.

Status: Wide distribution.

Remarks: The genus *Nigrobaetis* comprises around 30 species, from the Palaearctic (12 species), Oriental (13 species) and Afrotropical (5 species) realms (Barber-James *et al.* 2013).

9. *Nigrobaetis paramakalyani* Kubendran & Balasubramanian, 2015

Fig 7: *Nigrobaetis paramakalanyi* Kubendran & Balasubramanian, 2015

Materials Examined: Tamil Nadu, Tirunelveli, Sivasailam, Gadana river, 08°47'17.03" N, 77°20'49.51" E, 104 m, 28.vi.2012; Tirunelveli, Ramanathi river, 08°50'53.4" N, 77°18'51.2" E, 237 m, 18.i.2014.

Diagnostic Characters: *Nigrobaetis paramakalyani* can be differentiated from the other species of this genus by the following characters: (i) presence of hindwing pads; (ii) seven pairs of gills; (iii) paraproct with a reduced number of spines on distal margin (two large and three small spines); (iv) segment 3 of labial palp truncated or slightly concave; (v) margin between prostheca and mola of both mandibles with reduced number of spines; (vi) contrasted pattern of the abdominal tergites.

Distribution: Tamil Nadu.

Status: Endemic to the Western Ghats.

Remarks: Adult stage is unknown.

Genus: *Tenuibaetis* Kang & Yang, 1994

Type Species: *Tenuibaetis pseudofrequentus* Müller-Liebenau, 1985

Diagnosis: The genus *Tenuibaetis* can be distinguished from other genera of Baetidae by the following combination of characters: In larva (i) mandible with smooth medial margin; (ii) Conical segment 3 of labial palpus; (iii) presence of villopore on femur; and (iv) paraproct with a patch of notched scales.

Distribution: Japan, Taiwan, Hong Kong, Sri Lanka and India.

Status: Wide distribution.

Remarks: The genus *Tenuibaetis* encompasses six species viz., *T. flexifemora* (Gose 1980), *T. frequentus* (Müller-Liebenau and Hubbard, 1985), *T. pseudofrequentus* (Müller-Liebenau 1985), *T. arduus* Kang & Yang 1994, *T. inornatus* Kang & Yang 1994, and *T. parvipterus* Fujitani 2011.

10. *Tenuibaetis frequentus* (Müller-Liebenau and Hubbard, 1985)

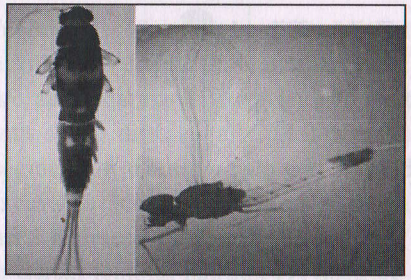

Fig 8: *Tenuibaetis frequentus* (Muller-liebenau and Hubbard, 1985)

Material Examined: Tamil Nadu, Theni, Kurangani stream, tributary of Vaigai River, 10º05'01.97"N, 77º14'55.35"E, 1744 m, 30.vii.2012;

Vaigai river, Valipparai, 9°43'35.67" N, 77o31'00.24" E, 1300 m, 29.vii.2012; Kodaikanal, Manjalaru river, 10°14'19.99" N, 77°29'19.90" E, 1216 m, 29.vii.2012.

Diagnosis: *Tenuibaetis frequentus* can be differentiated from the other species of this genus by the following combination of characters: In larva (i) dark brown tergal color pattern typical of the genus but with a pale yellow transverse band on the posterior half of mesonotum, paired pale yellow maculae on abdominal tergum IV and abdominal terga IX–X pale yellow; (ii) segment 2 of labial palp with a row of 6 long setae; (iii) abdominal gills 1–7 with poorly developed tracheae and with serrated margin; and (iv) number and size of the spines of the distal margin of paraproct. In adult (i) hindwings with an erect costal spur at ¼ length of wing, two longitudinal veins reaching margin, none of them bifurcated; (ii) segment 1 and 2 of genitalia completely fused, segment 3 elongated, apically slightly expanded; and (iii) well-developed sclerotized plate between forceps, as broad as distance between forceps, apically convex without setae.

Distribution: India (Tamil Nadu) and Sri Lanka.

Status: Narrow distribution.

Remarks: The species originally described from Sri Lanka and reported later from India (Balaji *et al.* 1990; Sivaramakrishnan & Venkataraman 1990). Redescription of larva and description of adult stage by Kubendran *et al.* (2015).

Subfamily: Cloeoninae Kazlauskas, 1972

Diagnosis: The subfamily Cloeoninae can be distinguished by the following combination of characters: In the larvae (i) tuft of setae present on the inner side of the prostheca of the right mandible; and in the adult (ii) the presence of single free intercalary vein in the forewing.

Genus: *Cloeon* Leach, 1815

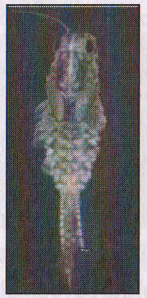

Fig 9: *Cloeon* sp.

Type Species: *Ephemera dipterum* Linnaeus, 1761

Diagnosis: The genus *Cloeon* can be distinguished from other genera of Baetidae by the following combination of characters: In larva (i) additional dorsal lamella of gills 2–6 always present, with anterior-proximal projection (in contrast to all other taxa); (ii) additional dorsal lamella of gill 1 lanceolate, without proximal projection; (iii) labial palp with 3rd segment (truncate) either widened, or non-widened; (iv) cerci and paracercus with long bare last segments (in contrast to *Procloeon*, distal part of cercus without one large spine on each segment (several spines can be present on lateral side of each segment). In adult: (i) male imago unpaired sclerotized projection of penial bridge conical; (ii) female imago usually with more or less expressed coloration of costal and subcostal field; (iii) colour pattern of these fields either speciesspecific, or varies individually; (iv) known species lack hind wings; and (v) viviparous (Kluge, 2016).

Distribution: Dominate in Afrotropical and Oriental Regions; few species in Holarctic and Australia.

Status: Cosmopolitan.

Remarks: The genus *Cloeon* and the genus *Procloeon* several times mainly by the tarso-tibial index and the details of gill morphology which are variable within species and unstable at the genus level, and hence, the subgeneric classification as advocated by Kluge & Novikova (1992) and predicted by Gillies (1997) appear convincing rather than giving *Procloeon* a generic status.

11. *Cloeon bicolor* Kimmins, 1947

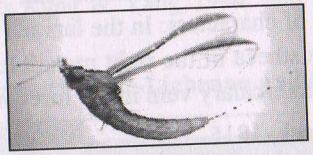

Fig 10: *Cloeon bicolor* Kimmins, 1947

Material Examined: 10 male imago, Tamil Nadu, Madurai, Tiruvedakam, Vaigai River, 10°47'5.8"N, 77°96'0.25"E, 198 m, 11.vi.2015; 8 adults, Tamilnadu, Tirunelveli, Alwarkurichi pond, 08°46'50.73" N, 77°24'04.76" E, 87 m, 20.xii.2015.

Diagnosis: *Cloeon bicolor* can be differentiated from the other species of this genus by the following combination of characters: In adult (i) forewing of female with bicoloured costal streak; (ii) absence of reddish spots on abdominal segments 3 and 6 of male; and (iii) abdominal patterns of females lacking lateral extension on segments 3 and 6.

Distribution: India (Karnataka, Kerala, Madhya Pradesh, Tamil Nadu and West Bengal), Malaysia, Singapore and Thailand.

Status: Wide distribution.

Remarks: Larval stage is unknown.

12. *Cloeon bimaculatum* (Eaton, 1885)

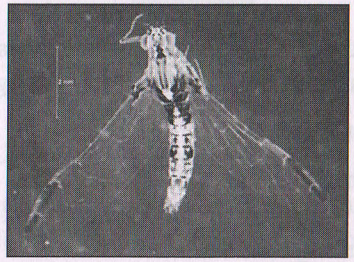

Fig 11: *Cloeon bimaculatum* (Eaton, 1885)

Diagnosis: *Cloeon bimaculatum* can be differentiated from the other species of this genus by the following combination of characters: In adult (i) pterostigma of female forewing brownish with a sub-apical pale spot in costal area; (ii) humeral cross-vein marked with reddish, area between it and pterostigma very faintly yellow-brown; and (iii) tergites 2, 3 and 6 in addition each with a dark reddish brown triangular spot on each side, tergites 8-10 with indefinite fuscous markings.

Distribution: India (West Bengal and Karnataka), Bangladesh, China, Indonesia, Philippines, Sri Lanka, Thailand and Vietnam.

Status: Wide distribution.

Remarks: Diagnostic characters are provided based on original description. Larval stage is unknown.

13. *Cloeon harveyi* (Kimmins, 1947)

Fig 12: *Cloeon harveyi* (Kimmins, 1947)

Diagnosis: *Cloeon harveyi* can be differentiated from the other species of this genus by the following combination of characters: In adult (i)

psterostigma of female forewing brownish with a sub-apical dark-brown spot in costal area; (ii) female abdominal tergites 1, 4, 5, 7 and 8 with minute, feeble and pale brownish, tergites 2, 3 and 6 with broad and very prominent dark reddish brown lateral spots; and (iii) male abdominal tergite 6 with a triangular patch in each apical angle, tergite 7 with a pair of less defined reddish patch, tergites 8 and 9 brightly brick-red, tergite 10 with a patch but not trifid.

Distribution: India (Kerala, Madhya Pradesh, Maharashtra, Tamil Nadu and West Bengal), Thailand, Malaysia and Hong Kong.

Status: Wide distribution.

Remarks: Mukherjee *et al.* (2012) reassigned *Procloeon harveyi* to *Cloeon* with the new combination *Cloeon harveyi* Kimmins 1947 and they redescribed all the life stages.

14. *Cloeon kimminsi* Hubbard, 1974

Diagnosis: *Cloeon kimminsi* can be differentiated from the other species of this genus by the following combination of characters: In female adult (i) broader pale area dividing the head stripes; (ii) apple green body, marked with reddish brown costal stripe yellow green; and (iii) abdominall tergites 2-7 with three pale basal marks much as in *C. bicolor* Kimmins, 1947.

Distribution: Karnataka, Maharashtra, Manipur and West Bengal.

Status: Endemic to India.

Remarks: Diagnostic characters are provided based on original description. Larval and male adult stages are unknown.

15. *Cloeon marginale* (Hagen, 1858)

Diagnosis: *Cloeon marginale* can be differentiated from the other species of this genus by the following combination of characters: In adult (i) female: marginal and submarginal area of forewing with bistre-brown, five straight cross-veinslets in the psterostigmatic area; and (ii) male: reddish brown colour of the dorsum of the posterior abdominal somites of male.

Distribution: India (Maharashtra, Odissa and West Bengal), Bangladesh, China, Indonesia, Philippines, Sri Lanka, Taiwan and Vietnam.

Status: Wide distribution.

Remarks: Diagnostic characters are based on description provided by Chopra (1924). Larval and male adult stages are unknown.

Genus *Procloeon* Bengtsson 1915

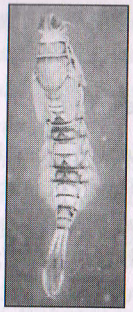

Fig 13: *Procloeon* sp.

Type Species: *Cloeon bifidum* Bengtsson 1912.

Diagnosis: The genus *Procloeon* can be distinguished from other genera of Baetidae by the following combination of characters: In larva (i) lateral side of distal part of cercus each segment bears one greatly enlarged spine (unique autapomorphy, not found in any other taxa); (ii) cerci and paracercus without long bare last segments, same in *Pseudocentroptilum*; (iii) in contrast to *Cloeon*, additional dorsal lamella of gill without anteriorproximal projection, in some species dorsal lamella lost; (iv) labial palp with 3rd segment (truncate) always widened. In adult (i) unpaired sclerotized projection of penial bridge semicircular or truncate; (ii) forewing of female not colored; (ii) hindwings present or absent; and (iii) oviparous or viviparous.

Distribution: Holarctic, Oriental and Afrotropical Regions.

Status: Wide distribution.

Remarks: The genus *Procloeon* divided into several subgenera, among them largest nominative subgenus *Procloeon* s.str. It is a plesiomorphon ancestral to subgenera *Pseudocentroptiloides* Jacob (in Jacob & Glazaczow) 1987, *Oculogaster* Kluge, 2016 and others.

16. *Procloeon dipsicum* (Gillies, 1949)

Diagnosis: *Procloeon dipsicum* can be differentiated from the other species of this genus by the following combination of characters: In adult (i) stigmatic area of forewing with 6–10 simple or very occasionally forked, slanting veinlets; (ii) hindwing small, narrow with rounded end and complete absence of costal spur; and (iii) well-developed sclerotized plate between forceps, as broad as distance between forceps, apically flat without setae.

Distribution: Maharashtra.

Status: Endemic to the Western Ghats.

Remarks: Diagnostic characters are provided based on original description. Larval stage is unknown.

17. *Procloeon palmyrae* (Gillies, 1949)

Diagnosis: *Procloeon palmyrae* can be differentiated from the other species of this genus by the following combination of characters: In adult (i) stigmatic area of forewing with 6–7 incomplete slanting veinlets; (ii) hindwing narrow, spurless with two veins; (iii) well-developed sclerotized plate between forceps, as broad as distance between forceps, apically concave without setae; and (iv) second segment of forceps bent sharply inwards at proximal end.

Distribution: Maharashtra.

Status: Endemic to the Western Ghats.

Remarks: Diagnostic characters are provided based on original description. Larval stage is unknown.

18. *Procloeon rubellum* Navás, 1931

Diagnosis: *Procloeon rubellum* can be differentiated from the other species of this genus by the following combination of characters: In adult (i) stigmatic area of forewing with 6–7 incomplete slanting veinlets; (ii) hindwing narrow, spurless with two veins; (iii) well-developed sclerotized plate between forceps, as broad as distance between forceps, apically concave without setae; and (iv) second segment of forceps bent sharply inwards at proximal end.

Distribution: Maharashtra.

Status: Endemic to the Western Ghats.

Remarks: Diagnostic characters are provided based on original description. Larval stage is unknown.

Genus *Symbiocloeon* Müller-Liebenau & Heard, 1979

Type Species: *Symbiocloeon heardi* Müller-Liebenau, 1979

Diagnosis: *Symbiocloeon* can be distinguished from other genera of Baetidae by the following combination of characters: In larva (i) larva inside the mantle cavity of a bivalve; (ii) 2nd and 3rd segments of labium completely fused together to form one large stout segment, bilobed at apex; and (iii) tarsal claws without teeth, strongly hooked at apex.

Distribution: India (Western Ghats) and Thailand.

Status: Narrow distribution.

Remarks: Interesting associations of *Symbiocloeon* with freshwater clams and mollusks were recorded in Thailand (Müller-Liebenau and Heard, 1979) and India (Subramanian and Sivaramakrishnan, 2009). The former is between the mayfly, *Symbiocloeon heardi* Müller-Liebenau, 1979 and the clam, *Hyriopsis myersiana* (Unionidae), whereas the latter is between the mayfly *Symbiocloeon madhyasthai* Subramanian and Sivaramakrishnan, 2009 and mussel, *Pseudomulleria dalyi* Smith, 1898 (Unionoida: Etheriidae).

19. *Symbiocloeon madhyasthai* Subramanian and Sivaramakrishanan, 2009

Diagnosis: *S. madhyasthai* can be distinguished from *S. heardi* Muller-Liebenau, 1979 by the following combination of characters: In larva (i) margins and dorsum of legs without spines or setae; (ii) tarsal claws sharply hooked at apex without denticles; (iii) thorax of male extends posteriorly as a short blunt process; (iv) tergum of 10th abdominal segment with a dark brown "bird in flight" pattern; (v) abdominal segments are without marginal spines; (vi) caudal filaments and cerci extremely short and equal in length; (vii) mandible without setae in the middle part; (8) maxillary palp equal in length to galealacinia; (viii) 2 and 3 segments of labium fused towards the base; (ix) glossae and praglossae covered densely with inwardly directed long setae towards the apical end; and (ix) smooth paraproct without bristles or pores.

Distribution: Karnataka.

Status: Endemic to the Western Ghats.

Remarks: Diagnostic characters are provided based on original description. Adult stage is unknown.

Discussion

The present study deals with checklist, diagnostic characters, diversity, distribution and status of 19 species belonging to 10 genera under 2 subfamilies of Baetidae from the Western Ghats of India. Ten species are endemic to the Western Ghats and 1 species endemic to India. Larvae of baetid are found at undisturbed habitats with less pollution and good riparian vegetation were specialists with narrow distribution. On the other hand, species of genus *Cloeon* Leach, 1815 recorded at industrial or urban areas with moderately polluted wetlands and disturbed riparian vegetation were generalists with wide habitat preference and distribution. Mayflies are sensitive not only to the quality of the freshwater but also to the major

landscape changes, especially changes in the riparian zone. Therefore, the conservation of biodiversity and their habitats and microhabitats of freshwater ecosystem is very essential.

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