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Distribution and Biology of the Mayflies (Ephemeroptera) of Western Ghats

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Introduction

Insects are perhaps the most successful creatures in the whole of the animal kingdom, considering their prolific numbers of species (of estimated eight million species, over one million species described) and individuals, their extraordinarily adaptations to live in diverse habitats of land, water and air. They are invertebrates (having no backbone), belonging to the Phylum **Arthropods** which are characterised by hard, protective outer shield and three pairs of jointed legs. Insects, which belong to a Class **Insecta**, are different from other arthropods, like spiders and mites, centipedes and millipedes, crabs and shrimps etc. which have more number of legs. Most insects also have wings, which are lacking in other arthropods. Winged insects have wider distributional coverage than their wingless counterparts. Insects play crucial role in ecosystem functions such as decomposition, nutrient cycling, pollination, predation, parasitism and maintenance of community structure wherever they live.

Ephemeroptera is an order of insects, comprising of over 3000 species of insects, popularly referred to as **mayflies**, which are confined to fresh water, at least for part of their life cycles. The name Ephemeroptera (*ephemeros* means "short-lived", *pteron* is "wing") refers to the winged adults, which have lifespans from just 1-2 hours to few days, a maximum of 14 days. Adult mayfly species are terrestrial, the immature called **naiads** (nymph), are aquatic. The early, reproductively immature adults are known as **subimago** and the mature ones as **imago**.

Classification

Much success was not achieved in the classification systems of mayflies, attempted by Linnaeus and other early biologists, since 18th to mid-20th century (Linnaeus, 1758;

Leach, 1815; Pictet, 1843-1845; Eaton, 1871, 1883-1888). Notable contribution was given by Edmunds (1962) who reconstructed the phylogeny of the order. McCafferty and Edmunds (1979) divided the mayflies in two suborders, Pannota and Schistonota. This reconstructed phylogeny was widely used by biologists and constituted the basis for McCafferty's (1991) classification, where the suborder Schistonota being incomplete was replaced by three new suborders, Retracheata, Setisura and Pisciforma. In a later modified system McCafferty and Wang (2000), divided the order into four main suborders: 1) Carapacea; (2) Furcatergalia; 3) Setisura and 4) Pisciforma.

Ephemeroptera consists of 3046 species under 400 genera and 42 families. The members are present worldwide barring Antarctica and some remote oceanic islands (Barber-James et al., 2008). Sivaramakrishnan et al.'s, (2010) checklist of Indian Ephemeroptera has 124 species, under 46 genera and 12 families. This does not include Tricorythidae, a family of a single genus *Sparsorythus*, described from north Western Ghats and Chennai by Sorka & Soldan (2008). Subramanian and Sivaramakrishnan (2010) discovered *Symbiocloeon*, a new genus, having just one species, under Baetidae family raising the total number of species from 124 to 126 under 48 genera and 13 families. From the Western Ghats 52 species of mayflies, under 30 genera and 12 families have been so far reported. All families of Indian mayflies except of Ameletidae are found here. Of these 52 species 15 are endemic to the Western Ghats.

Mayflies: Latitudinal distribution in the Western Ghats and Biology

One of the oldest and most fundamental spatial patterns described in community ecology pertains to the richness of species diversity in the tropics and its gradual decline towards the poles. Based on literature review and our own field observations, we have attempted here to give the picture of the latitudinal distribution of mayflies in the Western Ghats. Based on literature review we have also attempted to give biology of mayfly species. For the convenience of presentation of the mayfly distribution the Western Ghats are divided into latitudinal intervals of 2 degrees each in the south-north direction (8-10°; 10-12° up to 18-20° N) as given in the **Table 1**. The highest generic diversity occurs in 10° to 12°N followed by 8° to 10°N, 12° to 14°N, 18° to 20°N, 14° to 16°N, and 16° to 18°N in that

order (**Figure 4**). The mayfly genera, *Baetis*, *Epeours*, *Caenis*, and *Teloganodes* are distributed throughout except in lat. 16°- 18°N. This discontinuity could be the outcome of no studies carried out in this section. The genera such as *Choroterpes*, *Isca*, *Afronurus* (*Cinygmima*) occur all along from 8° to 16°N. In the latitude between 8° and 12° N were documented genera like *Thraululus* and *Edmensula*. Genera *Procloeon*, and *Sparsorythus* are present in latitude 10° to 12°N and 18° to 20° N. *Prosopistoma* occurs in latitude 8° and 10°N and 14° to 16°N. Present throughout the Western Ghats are genera like *Pseudocloeon*, *Symbiocloeon*, *Indialis*, *Nathanella*, *Eatonigenia*, *Euthyplosia*, *Ephoron*, *Potamanthus*, *Rhoenanthus*, *Potamanthellus*, *Clypeocaeni*, *Cloeon* and *Toyleya*. Diversity of species diversity was highest in the 18° to 20°N, but unfortunately no species level data occurs between 14°N to 18°N latitude (**Figure 5**). This situation has arisen due to the lack of proper taxonomic description and paucity of experts for identification. If we take plant species in general, and tree species in particular, the southern Western Ghats have highest number of them progressively declining towards the north. This is quite evident for many taxa with highest endemism such as amphibians, fishes, reptiles etc. The generic level depression in the distribution of Mayflies between 16°-18° N and species level total absence of data between 14°-18° N clearly indicate that mayflies constitute an understudied group of insects in the Western Ghats, despite this mountain range being a global biodiversity hot spot and the significant ecological role the larvae of these organisms specially in aquatic ecosystems notwithstanding.

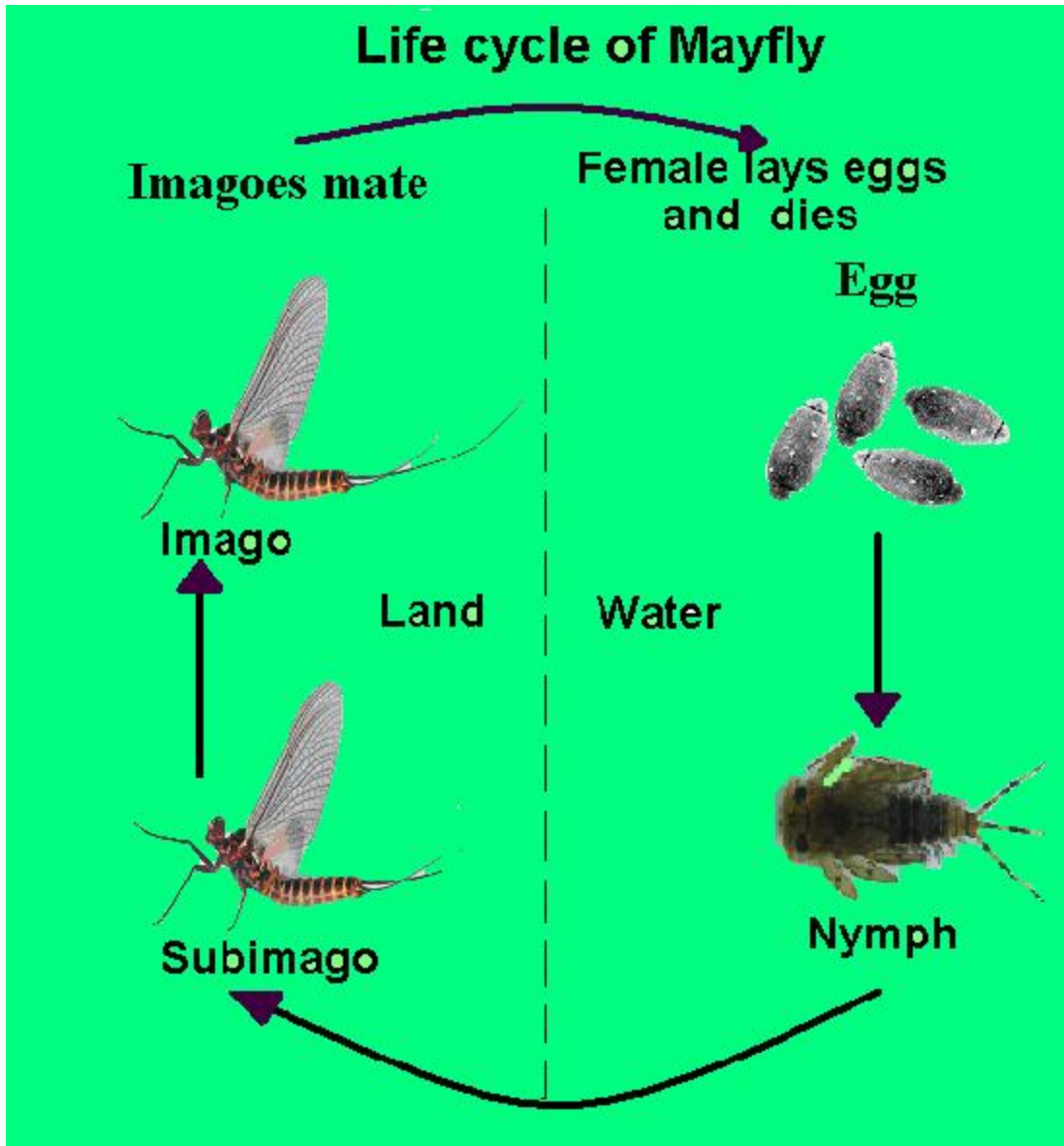
Lifecycle

Mayflies belong to the most primitive order of insects. These soft-bodied and winged insects are nearly cosmopolitan in distribution. Nymphs (the young, wingless stage) of all species are aquatic and occur in variety of freshwater habitats from standing to running. Most nymphs feed by scraping algae from underwater rocks and higher plants or by extracting food particles from mud.

Mayfly demonstrates incomplete metamorphosis in its life cycle (**Figure.1**). Eggs are laid in water and the nymph stage also completed there before the adults move on to the land.

arly part of the life cycle (eggs and nymph stage) is in water and the rest (adult flies) on the land. The adulthood can be divided into two stages; the **subimago** or premature and **imago** or mature adults. The imagoes only mate and the females release their eggs in water. The egg laying mechanism is species-specific and comes under any of the three types viz. 1. Eggs are laid on water surface; 2. Eggs dropped from the air on to the water surface and 3. The adult immerses the body in water and lay eggs. In all these cases the eggs sink to the bottom and the lifecycle begins. Laboratory and field based studies show that the incubation period of eggs varies from several days to several months in different species and is also temperature dependent (Elliott, 1972, Sivaramakrishnan, 1985, 1991, and Gupta et.al., 1993). Generally, the eggs are hatched within 1-2 weeks (Salas and Dudgeon, 1999). Whereas in most species eggs are laid after fertilization in *Cloeon sp* sometimes unfertilized eggs may develop parthenogenetically into nymphs (Sivaramakrishnan, 1991 and Tojo, K. et. al., 2006). Nymph is the term applied to the larva that emerges from the egg. The nymphs live in water for periods from one month to two years in different species which accounts for most part of the lifetime of mayflies. Finally the nymphs are transformed into the subimago or pre-adult stage- winged creatures that fly off to the land. In the course of attaining maturity the nymph undergoes moulting or **ecdyses** up to a maximum of 24 times in different species; during each ecdysis the nymph sheds its body case and it gets a new one. The nymph stage is a period of vigorous feeding and growth as well as development of wings. The last ecdysis in water marks the emergence of the sub-imago stage. Within a matter of 24 to 36 hours, marked by one more shedding of their cases, these sub-imagoes attain reproductive maturity. The adult flies, the imagoes, have lifespan ranging from merely a day to a maximum of two weeks or so, depending on the species. They swarm in the air, males and females together. No one indeed would have missed to note the nuptial dances of mayflies in the nights close to the burning lights. Soon after mating the male flies die and the females a little later after laying of the eggs.

Figure 1: Life cycle of a mayfly



Morphological features

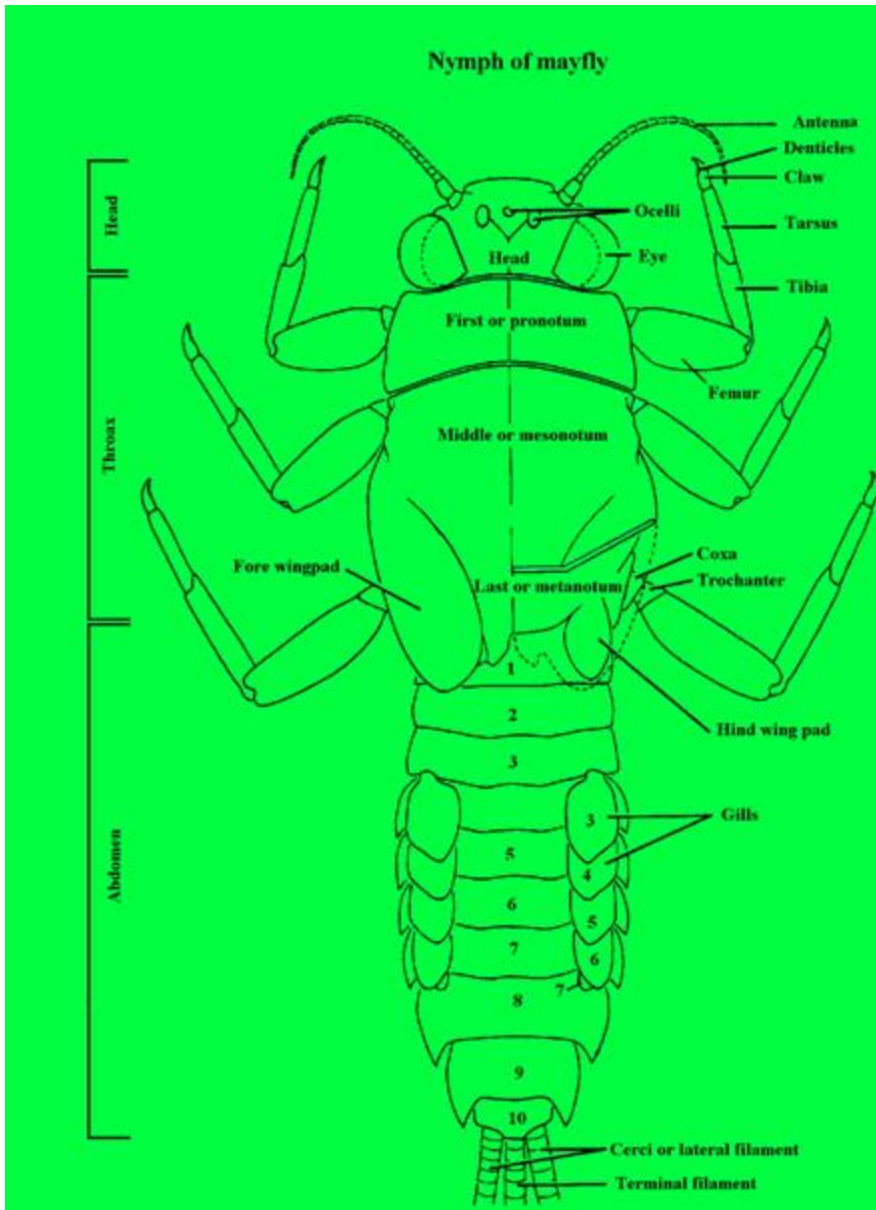
Egg

The eggs are tiny, scarcely visible to naked eyes, ranging from 0.15 mm to 0.22 mm in length. Exceptionally, in some larger sized species, the eggs may measure to about 1 mm (Dudgeon, 1999 and Morse, et.al, 1994). Their shapes vary from ovoid to rectangular. Towards their two ends are tiny caps, the polar caps. The eggs have adhesive surfaces for sticking on to the substratum. The egg morphology is species-specific.

Nymph

Nymphs (**Figure. 2**) are soft and fragile in all the mayflies. They are spindle shaped in Baetids, broad and compressed in Caenids, Heptagenids and Leptophlebiids. Three regions- the **head**, the **thorax** and the **abdomen** can be seen in the nymphs. The head has a pair of eyes, a pair of sensitive hair like structures called **antennae**, and the mouth. The mouth has different parts, their shapes and structures suited for feeding methods like scraping, or collecting tiny food particles from water, or grazing of algae from surfaces or for capturing tiny creatures. The thorax consists of three segments each bearing a pair of legs, a total of six legs. The middle and last segments have a pair of wing pads each, which develop into wings (two pairs) in the subimago. Diverse types of species-specific outgrowths such as ridges, spines or shields characterize the nymphs. The abdominal region has 10 segments. The abdominal segments up to 7th segment, bear paired gills the number and arrangements of which are species-specific. Normally flattened and leaf-shaped these gills may function both as respiratory organs and as a ventilating mechanism. The last abdominal segment bears three filament-like outgrowths, rarely two, helpful in balancing and swimming in water.

Figure 2: Nymph of mayfly



Pre-adult (Subimago):

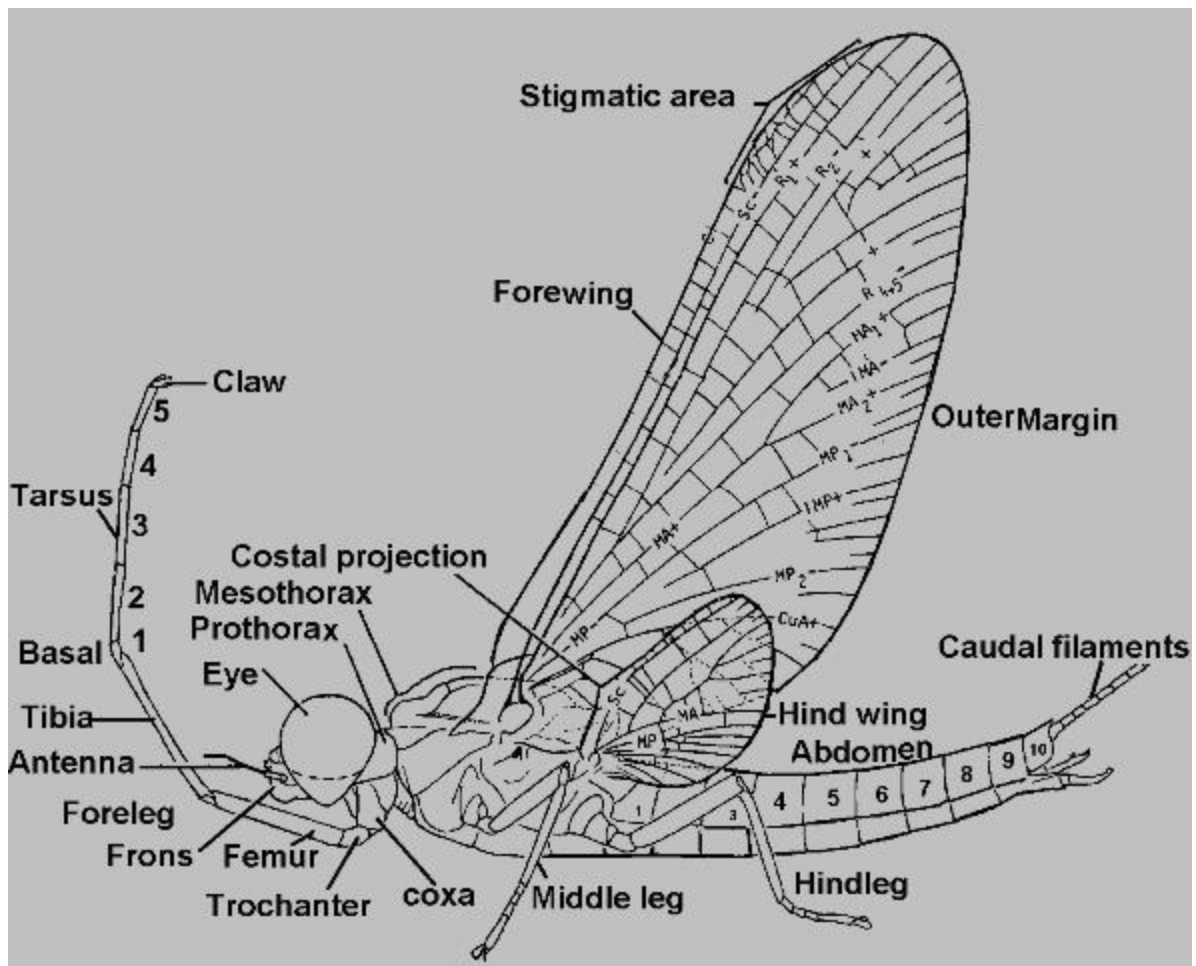
The nymph transforms into the pre-adult or subimago that flies off from water to land. In all features the subimago resembles the adult mayfly except for the immature reproductive system and duller colour compared to the adults. The size of subimago ranges from 2–12 mm. in Baetidae and Caenidae and 1–235 mm. in Ephemeridae, Heptageniidae and Leptophlebiidae. The subimago no more feeds and its mouth parts are non-functional; the same holds good with the adult also. Within 24 to 36 hours of its reaching the land the subimago develops reproductive organs, undergoes a moulting and turns into the adult.

Adult (Figure 3):

Imagoes in size are same as of the subimagoes of the respective species. The **head portion** appears triangular in dorsal view because of the two prominent eyes situated towards the upper lateral sides of the head. Eyes of male are more prominent than in the female. In front of the head, between the eyes, are three sensitive spots or **ocelli** lateral often larger than the middle one. The head has two antennae in front, as long as the head or shorter to it. The **antennae** are sensory organs as in most other insects. **Thorax** region, as in the case of the nymph and subimago has three segments. The **abdomen** that follows has ten segments as in the earlier stages. The dorsal sides of the middle and last thoracic segments have hard bristles called **spiracles**. Wings are somewhat triangular, membranous fragile, both pairs held vertically upwards at rest. Hind wings are smaller than forewings and have lesser venation than the forewings. In Caenidae, Baetidae and some Leptophlebiidae the hind wings are highly reduced or absent. Legs are joined to the thorax by two short segments called **coxa** and **trochanter**. The basal part of the leg or **femur** is attached to the trochanter. The next part of the leg is **tibia** and its distal part is **tarsus**. Tarsus has 4-5 segments and the last segment bears one or two **claws**. Mayflies do not use the legs for walking. The fore legs of the male are much longer and are used for grasping the female during mating which takes place in their flight. As in the early stages the abdomen of the adult has 10 segments. The 10th segment of the abdomen bears three filaments. The lateral ones, the caudal filaments, are longer, often twice or thrice the length of the entire body. The middle one or terminal filament is short or absent. All these

filaments are segmented. From the hind portion of the ninth abdominal segment of the male arises the genitalia from which protrudes a pair of outgrowths called forceps. In between the forceps, in the ninth segment, are present a pair of penes. In the female the forceps are absent and behind the ninth segment are enlarged sub-anal plates.

Figure 3: Adult of mayfly



Collection techniques

There are different techniques for collection of mayflies and their nymphs, based on their habitats. Nymphs of Baetidae inhabiting in the littoral zone amongst rooted vegetation and fallen leaves are collected by a gentle sweep of water using a "D" frame net. When using the net is difficult amidst aquatic plants water from in between plants is scooped out in a tray after agitating the plants. The nymphs that are in the tray are transferred using a fine soft brush to a preservative, usually 70% alcohol. For members of other families, which live attaching to the underside of boulders, pebbles, leaf litter and woody debris, the bottom of the water body is agitated with hands and the organisms trapped in a fine meshed net (200 μm).

Pre-adults and adults though winged are not good fliers and often remain very close to the water body amidst plants and are collected by forceps, soft brush and even by delicately holding them between thumb and forefinger. The adults during their swarming flights for mating are air-borne, but closer to the water body. They are often attracted towards lights during nights and could be collected by hand picking method.

Ecological role of mayflies

- Nymphs are mostly collector-gatherers or scrapers although some are predator-engulfers which capture and swallow tiny creatures from water (Merritt and Cummins 1984; Edmunds 1984). The mayflies play important role in the food chains of aquatic environments.
- They facilitate breakdown and recycling of organic matter that enter the stream/water body from outside sources.
- The mayflies and their nymphs constitute important food resources for many fishes, amphibians, reptiles and birds as well as even for larger insects and various aquatic invertebrates.
- Different species of mayflies, their diversity and abundance are good indicators of water quality. Among them are species that are least tolerant of pollution to species that indicate various levels of pollution.

- Mayfly helps purifying freshwater by filtering large amounts of particulate nutrients from water.
- Sometimes mayflies are of nuisance value, as adults of a few species may swarm towards lights in habitations near lakes, as great swarms of them may provoke allergies in some people.

Diversity in habitats

Nymphs live in different types of freshwater habitats like streams, rivers, brooks, lakes, marshes, and ponds. However, their diversity and abundance are greater in unpolluted mountain streams. The ecological classification of the nymphs is very important, because the morphological-ecological type of the nymph is adapted to ecological conditions (Peters and Campbell, 1991). The nymphs are divided into the following morpho-ecological types, according to their different mode of life and shape:

- Nymphs inhabiting submerged vegetation and leaf litter, with large gills (e.g. Baetidae and some Leptophlebiids)
- Nymphs living in silty bottoms, their gills protected by an operculum (e.g. *Caenis sp.*)
- Nymphs living on sandy bottoms, with long claws and "brushes" on the head (e.g. *Tricorythids sp.*)
- Nymphs inhabiting rapid streams and riffle area, with fine gills, which swim actively (e.g. Leptophlebiids).
- Flat-bodied inhabitants of rapids, with clasping legs in the riffle area (e.g. Heptagenids).
- Bottom-inhabiting, burrowing nymphs with "tusks" (e.g. *Ephemera sp.*)

Conclusion

India, despite being a mega-diversity country, and hosting as well two bio-diversity hotspots, in the Eastern Himalayas and the Western Ghats, it is disconcerting to note that only scanty studies so far are attempted on diversity, distribution and ecology of mayflies. In the Western Ghats, for instance, only 52 species under 30 genera have been reported so far. In general, the species diversity and endemism, of various taxa such as higher plants, reptiles, amphibians and fishes and several other groups have greater diversity and endemism towards southern Western Ghats, exhibiting a gradual decline towards northern latitudes. However, the latitudinal distribution of mayflies, so far known, does not follow this pattern. Between 14°-16° N only 8 genera and between lat. 16°-18° N merely 2 genera have been so far documented. Not even a single species has been identified in these genera. Although mountain perennial streams, the most preferred habitats of the mayflies are more characteristic of the southern and central Western Ghats, which experience 7-10 months of rainfall, only 20 genera and 16 species have been recorded from this region. But the northern Western Ghats (>lat.18°N), which experience barely four months of rainfall account for 14 genera and 17 species, almost rivaling even the southern Ghats which by far have the richest floral and faunal diversity. This irony gets more glaring considering the fact that most of the Maharashtra studies are merely confined to Pune and surroundings, which constitute a fraction of the dry zone of the hilly terrain of the State. We therefore emphasize the need for more concerted studies on mayflies and their ecology all over the Western Ghats, through the involvement of more number of biologists under systematized programmes. Mayfly studies are all the more significant in view of the ever rising human impacts on their habitats, which the 20th century had witnessed on a very large scale, in the form of widespread deforestation, raising of tree monocultures and other commercial plantations such as of coffee, tea, cinchona etc. urbanization, pollution of water courses, construction of dams and bunds, unchecked removal of cobbles, gravel and sand, and draining of marshes and swamps and numerous other activities. Although organized and state sponsored deforestation and habitat degradation are on the decline during the present century, the smaller perennial streams and other water courses continue to vanish or are ravished in many ways by

insidious human impacts. The micro-climatic conditions suitable for mayfly diversity are getting seriously altered everywhere and impact of pesticide, fertilizers and sewage on aquatic ecosystems are also on the rise. Feeling all the more for elephants and tigers and other flagship species and mascots of conservation are justifiable. But here is also a humble plea for the conservation of the lowly mayflies that are towards the bottom of the animal kingdom, yet playing a paramount role in the very functioning of the ecosystems.

Figure 4: Genera of mayfly diversity and distribution through the latitudinal gradients in Western Ghats.

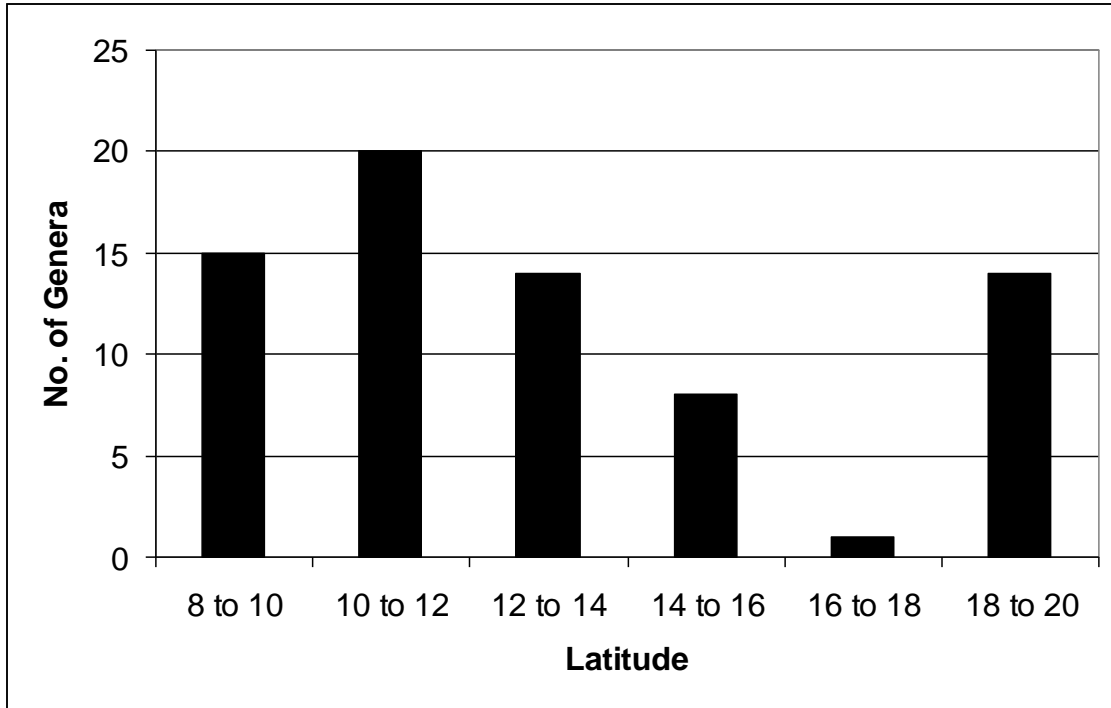


Figure 5: Latitudinal distribution and diversity of mayfly species in Western Ghats.

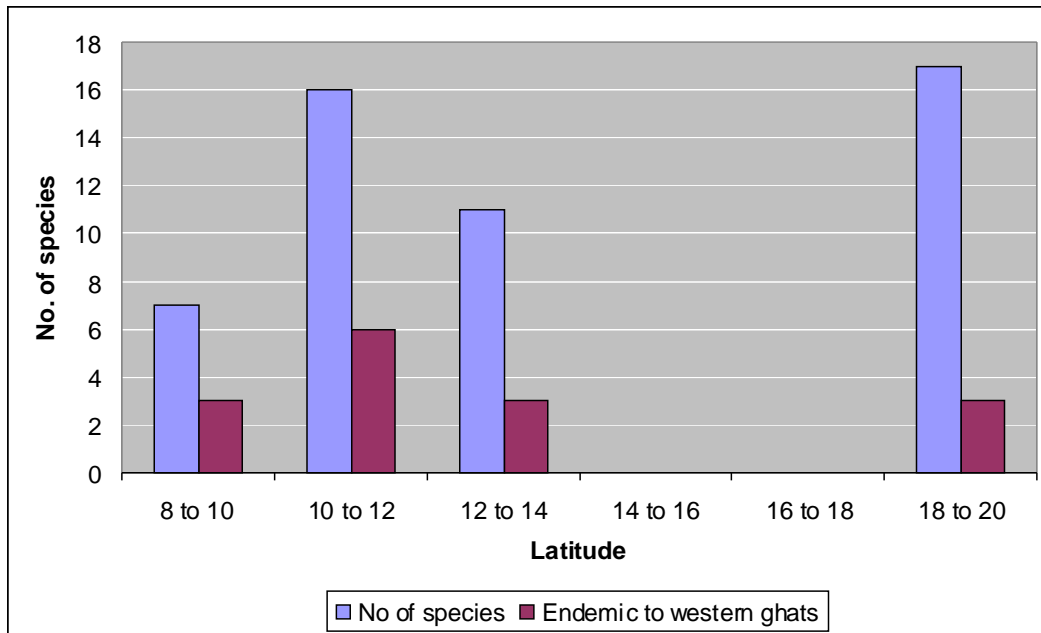


Table 1: Genera of mayfly diversity and distribution of each part of latitudinal gradients in Western Ghats.

suborder	Family	Genera	Latitude Gradients (N)					
			8' to 10'	10' to 12'	12' to 14'	14' to 16'	16' to 18'	18' to 20'
Carapacea	Prosopistomatidae	Prosopistoma	+			+		
Setisura	Heptageniidae	Epeours	+	+	+	+		+
		Ecyonurus	+	+			+	+
		Afronurus	+	+	+	+		
		Thalerosphyrus	+	+	+			
Pisciforma	Baetidae	Baetis	+	+	+	+		+
		Cbeon			+			+
		Procloeon		+				+
		Pseudocloeon						+
		Symbiocloeon			+			
Rectracheata	Leptophlebiidae	Isca	+	+	+	+		
		Choroterpes	+	+	+	+		
		Notophlebia	+	+	+			
		Petersula	+	+	+			
		Thraululus	+	+				
		Edmundsula	+	+				
		Indialis	+					
		Nathanella		+				
	Ephemeridae	Ephemeria		+	+			+
		Eatonigenia		+				
	Polymitarcyidae	Euthyplosia						+
		Ephoron						+
	Potamanthidae	Potamanthus						+
		Rhoe nanthus		+				
	Neophemeridae	<i>Potamanthellus</i>		+				
	Caenidae	Caenis	+	+	+	+		+
		Clypeocaenis						+
	Ephemerellidae	Toyleya			+			
	Telganodidae	Telganodes	+	+	+	+		+
	Tricorythidae	Sparsorythus		+				+

+ indicate presence of genera

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