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Diversity and Distribution of Mayflies (Insecta: Ephemeroptera) in Tamirabarani River of Southern Western Ghats, India

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Diversity and distribution of Ephemeroptera larvae were studied in ten study sites of Tamiraparani river of southern Western Ghats, India. Twenty four species belonging to twenty genera and six families were recorded. Diversity (Simpson and Shannon's index) was governed by the heterogeneity of the substratum which in turn was influenced by catchment disturbances (anthropogenic impact, sewage mixing, inorganic agriculture and sand mining).

Insects /Biodiversity

As the threat to biodiversity increases throughout the world, particularly in developing countries, the need to discover, describe, and determine biogeographic and phylogenetic relationships among species also increases. Simply stated, humankind needs to know as much as possible about the composition, distribution, and evolutionary history of species in order to preserve them. If such information is missing, or inadequate, ecologists lack the necessary database that would allow them to study and understand complex natural systems, and environmental managers would be seriously hindered in developing sound conservation strategies and policies (Lugo-Ortiz and McCafferty, 1999). Unfortunately, the numbers of taxonomists, systematists, and biogeographers have decreased dramatically in recent years, leading some experts to voice their concerns about a "Linnean shortfall" (Barrowclough, 1992) and the certainty that many species (some of which may be crucial to the adequate functioning of ecosystems) will disappear without ever being documented (Wilson, 1992).

Insects comprise the most abundant and diverse class of organisms on earth. When compared to their terrestrial counterparts, insects inhabiting the most fragile montane freshwater ecosystems are relatively depauperate. Thirteen of the insect Orders have representatives in the lentic and lotic systems of the Western Ghats of peninsular India, one of the global biodiversity hotspots, of which only four (Ephemeroptera, Odonata, Plecoptera and Trichoptera) have juvenile stages which are almost always aquatic. However, their contribution to the diversity of aquatic ecosystems is quite significant.

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Freshwater insects, and other aquatic macroinvertebrates, play an important role in ecosystem functioning. As consumers at the intermediate trophic levels, aquatic insects are influenced by both bottom-up and top-down effects. Nutrient cycles, primary production, decomposition and translocation of materials within the ecosystem can all be affected by the activities of aquatic insects. Diverse feeding strategies have evolved to utilize available food resources and these are important in regulating ecosystem processes like, for instance, terrestrial leaf litter degradation that occur within the aquatic environment. At higher trophic levels, aquatic insects can be important as a food source for fish and other larger organisms. Aquatic insects of inland waters comprise some well known groups like mayflies (Ephemeroptera), dragonflies and damselflies (Odonata), and caddisflies (Trichoptera) besides aquatic bugs (Heteroptera) and aquatic beetles (Coleoptera) and aquatic flies (Diptera). The order Ephemeroptera, or mayflies, is a major group of aquatic insects that, except for the United States, Canada, and some western European countries, has significantly lagged behind in its documentation (Lugo-Ortiz and McCafferty, 1999).

Mayflies are very good indicators of conservation importance and of centres of endemicity, and they can be used to identify significant localities at much smaller scale than those identified by studies on vertebrates. The nymphal stage of mayflies is the dominant life history stage, and is always aquatic. The nymphs undergo a series of moults as they grow, the precise number being variable within a species, depending on external factors, such as temperature, food availability and current velocity (Brittain and Sartori, 2003).

Globally, about 3000 species in 400 genera and 42 families are currently known. Of these, 390 species in 84 genera and 20 families occur in the Oriental region. About 49% of the genera (41 genera) are endemic to the region. The Western Ghats-Sri Lanka biodiversity hotspot shows a high degree of endemism (Barber-James *et al.* 2008). The fauna of the Indian subregion is represented by four suborders, fifteen families, sixty genera and 204 species (Sivaramakrishnan et al. 2009a). The Ephemeroptera fauna of India is represented by 4 suborders, 12 families, 46 genera and 125 species (Sivaramakrishnan *et al.* 2009b) and the Western Ghats part of southern India alone constitute 49 species under 28 genera and 13 families (Dinakaran and Anbalagan 2009) though around 41 genera in 14 families were recorded in recent surveys (Sivaramakrishnan and Subramanian, 2011). Without knowledge of current status of diversity it is not possible to answer even the simplest questions posed by conservationists or understand the deficiencies of our existing data. Developing a landscape-level understanding of the distribution and diversity of these species will be the focus of this paper.

Materials and Methods

Study area

Tamiraparani, a major east flowing river with catchment area of 5482 km^2 (CWC, 1987) is a medium sized river basin in India, but a major river system in southern Tamil Nadu. It originates from the Pothigai hills of Kalakad-Mundanthurai Tiger Reserve of Western Ghats (8˚ 42' N and 77.15˚ 24' E) at an altitude of 2074 m (Fig. 1), meanders through a distance of 120 km (24 km in hilly terrain and 96 km in plains) in Tirunelveli and Tuticorin districts and drain into the Bay of Bengal. Major tributaries are the Servalar, Manimuthar, Gadana, Ramanathi, Pachaiyar and Chittar. This river is highly regulated, with three major reservoirs, namely Pabanasam, Manimuthar and Servalar, in the upper reaches and eight check dams or weirs in the middle and lower reaches of the 11 feeder canals. Tamiaraparani river basin benefits from both the north-east and south-west monsoons (Martin et al. 2000).

Samples of mayflies were randomly collected from ten study sites of Tamiraparani river. Sampling sites were selected based on different aquatic habitats and details given in table 1. Sites I and II are reference sites which are upstream of river, site III is outlet of upper Karaiyar Dam and site IV is outlet of lower Dam, sites V, VI, VII and VIII are nearby agricultural, sewage and anthropogenic impacted places and sites IX and X are sand mining sites. Water samples were collected from each site at the time of sampling and different variables such as water temperature, air temperature, pH, conductivity were measured by using Multi meter and other parameters were analyzed using methods following APHA manual (APHA, 1998).

Collecting was conducted with an aquatic D-net. In streams, the substrate was kick-sampled, allowing the current to carry organic debris, including insects, into the net. Along stream/rivers margins and in pools, vegetation was swept with the D-net. All insects were placed into 80% ethyl alcohol. Collected samples were brought to laboratory and were examined under stereomicroscope (ZEISS, Stemi DV4) and identified using standard taxonomic literature. Diversity was estimated using Shannon and Simpson's indices calculations and CCA were by the PAST (Hammer et al. 2001).

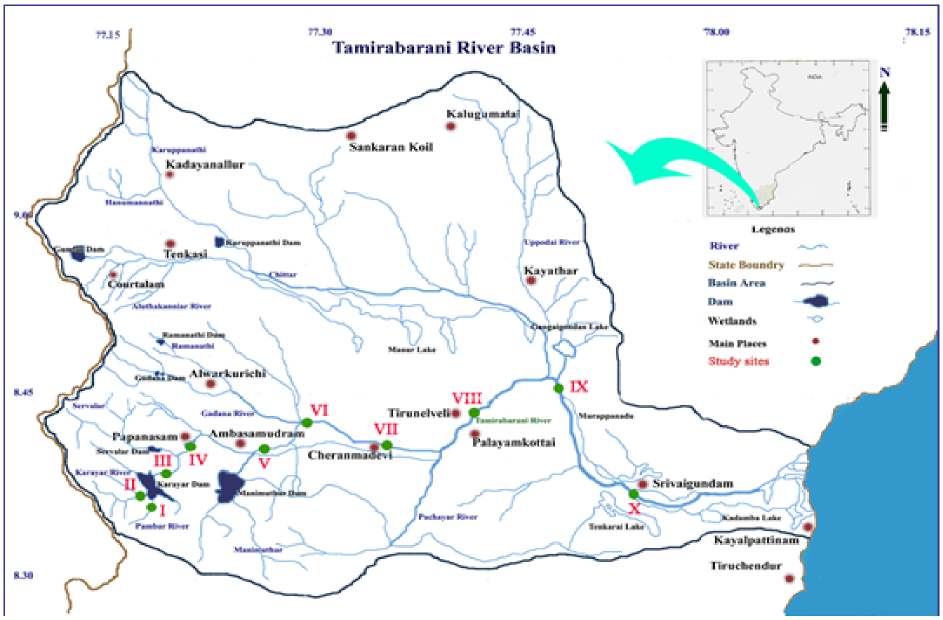

Fig. 1: Study area with localities

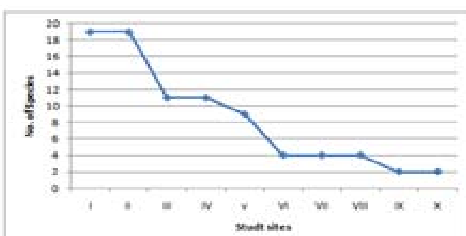

Fig. 2a

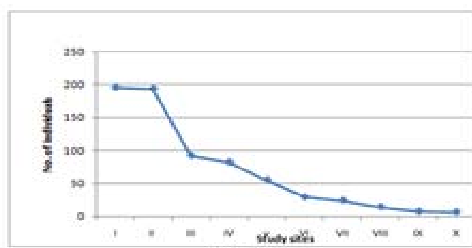

Fig. 2b

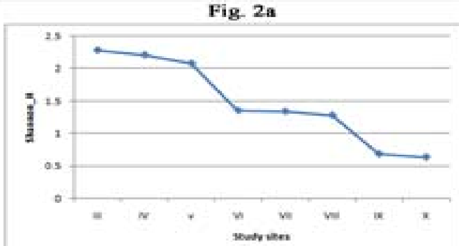

Fig. 2c

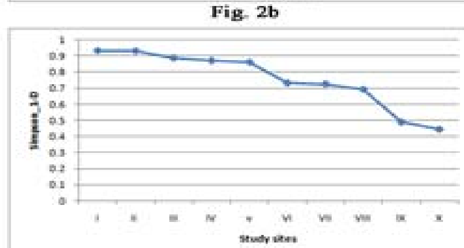

Fig. 2d

Fig. 2: Number of species, individuals, Shannon index and Simpson index values for the ten study sites

Table-1: Study sites details of Tamiraparani river

Site code	Site name	Altitude (m)	Latitude N°	Longitude E°	Surrounding Land use
I	Periyamylar	345	08° 34' 11"	77° 22'17"	Riparian vegetation
II	Vanathertham	263	08° 34' 58"	77° 31'16"	Riparian vegetation
III	Karaiyar	254	08° 39' 39"	77° 31'23"	Riparian vegetation
IV	Papanasam	108	08° 42' 37"	77° 22'03"	Agriculture
V	Kallidaikurichi	105	08° 41' 38"	77° 27'30"	Agriculture
VI	Mukkudal	60	08° 43' 57"	77° 30'48"	Agriculture
VII	Cheranmahadevi	58	08° 42' 04"	77° 33'56"	Agriculture
VIII	Tirunelveli	47	08° 43' 38"	77° 42'49"	Human settlement
IX	Seevalaperi	38	08° 46' 53"	77° 48'36"	Agriculture
X	Srivaigundam	25	08° 37' 35"	77° 54'44"	Agriculture

Results and Discussion

Physical and chemical variables

Air temperature and water temperature varied moderately among sites. Though the higher temperature was recorded in downstream sites upstream sites (reference sites) had lower temperatures. pH, conductivity, alkalinity, total hardness, biological oxygen demand, chemical oxygen demand and total solids values were higher in downstream river sites than undisturbed sites however dissolved oxygen showed a decreased trend in downstream river sites. Temperature fluctuations were due to the variations in the altitude (50 to 300 m above msl). Water quality parameters showed a gradual rise at sites VII, VIII, IX and X (Table 2), due to anthropogenic impact, entry of domestic sewage, inorganic agriculture and sand mining. Stations I and II were not silted and had a heterogeneous mineral substratum. The low substratum heterogeneity and siltation in stations III, IV, V and VI were due to collection of boulders and cobbles from the stream bed and washing-off of sand and denuded slopes. Stations VII, VII, IX and X were silted with only fist-sized pebbles and smaller gravel on their beds.

Species composition and diversity of Ephemeroptera

A total of 20 genera and 24 species were collected across ten sampled sites of Tamiraparani river. Baetidae and Leptophlebiidae were the most numerous and ubiquitous families, comprising six and seven genera and eight species equally (Table- 3). *Baetis acceptus, Baetis conservatus, Choprella similis, Indobaetis* sp., *Labiobaetis geminatus, Labibiella vera, Platybaetis* sp., *Afronurus kumbakkaraiensis, Epeorus* sp., *Choroterpes (Euthraulus)* sp., *Edmundsula lotica, Indialis badia, Isca purpurea, Notophlebia jobi, Petersula courtallensis, Thraulus gopalani, Teloganodes insignis* and *Teloganodes kodai* were the presence at reference sites. There were significant declines of *Baetis acceptus, Indobaetis* sp., *Labiobaetis geminatus, Platybaetis* sp. and *Isca purpurea* at sites III, IV and V. *Choroterpes (Euthraulus) alagarensis* was present at all the sites except reference sites and downstream sites IX and X. *Baetis frequentus* and *Torleya nepalica* were present only at sites III and IV and *Indialis badia* was present at all the sampled sites except sites IX and X. *Caenis kimminsis* and *Clypeocaenis bisetosa* species only present at all the sites except reference sites.

With respect to useful bioindicator taxa for measuring diversity and distribution in river systems of the study catchments, these results suggest that presence of *Caenis kimminsis, Clypeocaenis bisetosa* and *Choroterpes* (*Euthraulus*) *alagarensis* were the best bioindicator of anthropogenic impact, sewage mix, inorganic agriculture activities sites and sand mining. The presence *Baetis conservatus, Choprella similis, Labibiella vera, Afronurus kumbakkaraiensis, Epeorus* sp., *Thalerosphyrus flowersi, Choroterpes* (*Euthraulus*) sp., *Edmundsula lotica, Petersula courtallensis, Thraulus gopalani, Teloganodes insignis* and *Teloganodes kodai* would be good bioindicators of pristine forest conditions with intact riparian vegetation and heterogeneity substratum.

Diversity analysis

The total number of individuals collected at each study sites, the number of species, individuals, Shannon index and Simpson index values are presented in Table 4 and also all the values were gradually decreases. Taxa richness and individuals were highest at reference sites, uniform in sites III and IV and gradually decreases at all the study sites (Fig.2a & b). Shanaon and Simpson diversity indices were higher at reference sites and lower at other sites (Fig.2c & d).

Table -2: Physico-chemical values for the sites studied along the Tamiraparani river

Parameters	Study sites									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Air temperature (°C)	29	29	30.8	31.2	32.4	32.2	31.8	32.5	32.7	31.9
Water temperature (°C)	22.4	22.5	23.1	25.5	25.1	25.5	25.1	25.4	25.8	26.3
pH	6.3	6.4	6.2	6.5	7.3	7.0	7.5	7.9	8.0	8.0
Conductivity (µS/cm)	11	10	12.5	20.7	30.5	40	45.5	50	55	60
Alkalinity (mg/l)	20	20	30	40	40	50	40	50	50	60
Total hardness (mg/l)	20	20	40	40	50	60	50	60	60	60
Dissolved Oxygen (mg/l)	8	8	8.4	6.0	6.4	6.0	5.4	5.5	5.7	5.1
BOD (mg/l)	1.1	1.9	2.3	2.4	2.7	2.7	3.0	3.3	3	2.9
COD (mg/l)	0.5	0.6	1.2	7	7.5	7.9	8.3	8.4	8	9.6
Total solids (mg/l)	22	22	30	30	35	35	40	42	45	45

Table- 3: Abundance of mayfly species at each studied locality of the Tamiaraparani river

Species	code	Study sites									
		I	II	III	IV	V	VI	VII	VIII	IX	X
Baetidae											
Baetis acceptus	*Ba*	8	6	6	3	3	0	0	0	0	0
Baetis conservatus	*Bc*	5	7	0	0	0	0	0	0	0	0
Baetis frequentus	*Bf*	0	0	4	2	0	0	0	0	0	0
Choprella similis	*Cs*	3	2	0	0	0	0	0	0	0	0
Indobaetis sp.	*In.*	18	16	8	6	4	0	0	0	0	0
Labiobaetis geminates	*Lg*	15	16	4	9	4	0	0	0	0	0
Labibiella vera	*Lv*	2	2	0	0	0	0	0	0	0	0
Platybaetis sp.	*Pl.*	15	17	12	8	8	0	0	0	0	0
Caenidae											
Caenis kimminsis	*Ck*	0	0	12	10	8	8	9	6	4	4
Clypeocaenis bisetosa	*Cb*	0	0	8	7	6	5	4	2	3	2
Ephemerellidae											
Torleya nepalica	*Tn*	0	0	5	6	0	0	0	0	0	0
Heptageniidae											
Afronurus kumbakkaraiensis	*Af*	18	14	0	0	0	0	0	0	0	0
Epeorus sp.	*Ep.*	16	13	0	0	0	0	0	0	0	0
Thalerosphyrus flowersi	*Tf*	7	6	0	0	0	0	0	0	0	0
Leptophlebiidae											
Choroterpes (Euthraulus) alagarensis	*Ca*	0	0	12	9	8	6	5	2	0	0
Choroterpes (Euthraulus) sp.	*Ch.*	16	18	0	0	0	0	0	0	0	0
Edmundsula lotica	*El*	6	4	0	0	0	0	0	0	0	0
Indialis badia	*Ib*	15	16	17	20	12	10	6	4	0	0
Isca purpurea	*Ip*	6	5	4	2	2	0	0	0	0	0
Notophlebia jobi	*Nj*	16	14	0	0	0	0	0	0	0	0
Petersula courtallensis	*Pc*	12	18	0	0	0	0	0	0	0	0
Thraulus gopalani	*Tg*	8	7	0	0	0	0	0	0	0	0
Teloganodidae											
Teloganodes insignis	*Ti*	8	9	0	0	0	0	0	0	0	0
Teloganodes kodai	*Tk*	2	4	0	0	0	0	0	0	0	0

Table - 4: Taxa richness, individuals, Shannon index and Simpson index values for the sites studied

	I	II	III	IV	V	VI	VII	VIII	IX	X
Taxa richness	19	19	11	11	9	4	4	4	2	2
Individuals	196	194	92	82	55	29	24	14	7	6
Shannon index	2.789	2.778	2.279	2.208	2.076	1.351	1.34	1.277	0.6829	0.6365
Simpson index	0.9326	0.9314	0.8868	0.8715	0.8621	0.7325	0.7257	0.6939	0.4898	0.4444

Substrate diversity, habitat diversity and mayfly assemblages

Substrate is a major factor governing the diversity and distribution of aquatic macroinvertebrates (Allan, 1995). Most species are restricted or more abundant in few (2 or 3) rather than several kinds of substrate (Ward, 1992). Most of the species here were found associated or presented higher densities in reference sites due to presence of different types of substrate while the species were gradually decrease some of absent at other sites . The diversity of habitats and microhabitats in lotic ecosystems is due to high diversity of substrates and the heterogeneity of the sediment (Ward, 1992).

These results showed that the mayflies were a diverse and abundant component in the reference sites presenting high taxonomic richness and well defined and structured assemblages. We consider that the diversity of mayfly assemblages is probably resulting from three major factors: ecosystem characteristics, such as substrate type and habitat diversity; watershed characteristics, such as canopy cover over the river basins and use and habitation of the watershed (reflecting in the availability of trophic resources and abiotic features, such as water quality); historical past of colonization, provoking the isolation of some groups, a situation which also prevails in streams Brazilian Tropical Headwaters of Serra do Cipó (Goulart and Callisto, 2005). Besides that we must point out that further intensive collections enlarging the sampling designs, and over longer periods of time, are necessary to clarify some of the differences observed in the mayfly diversity.

CCA analysis

The diversity of the insects of the analyzed communities was correlated with the physico-chemical parameters. The most influencing factor was the concentration of Oxygen. Obviously, species richness was high in the sampling sites towards upstream where the dissolved oxygen content was higher. Based on the CCA plot for the sites, the whole river basin has been classified into four reaches among which the first reach had good water quality marked by the presence of higher species diversity, the second level of sites had disturbances caused by the tourists and pilgrims thronging them during festivals and ceremonies. The two sites in this reach were represented by two species *Baetis frequentus* and *Torleya nepalica.* The third and fourth reaches had minimal entomofaunal representations which clearly indicated the gradual increase in pollution load and the corresponding deteriorated water quality. Localities that were towards the last reach had only two species namely *Caenis kimminsis* and *Clypeocaenis bisetosa* that usually inhabit localities impacted by some type of pollution.

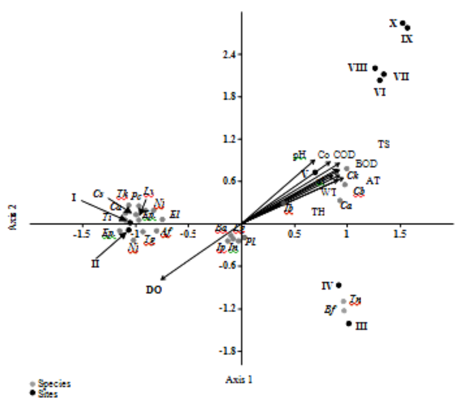

Fig.3: Canonical correspondence analysis (CCA) based on the insect diversity and physico - chemical parameters

Conclusion

Although synergic influences of other factors cannot be ruled out, catchment disturbance was the dominant factor controlling the diversity and distribution of Ephemeroptera in the streams. Furthermore, most structural aspects of the community were governed by physical factors such as the degree of heterogeneity and stability of the substratum, water quality and altitude. This is significant because the physical regime of the streams in this region is subject to alterations by anthropogenic impacts, inorganic agriculture, sewage mixing and sand mining. These, rather than industrial pollution, constitute the major source of pollution in the Tamiraparani river region of southern Western Ghats, India, a situation which also prevails in streams of Meghalaya State, India (Gupta and Michael, 1992) and most South and South-East Asian countries (Bishop, 1973). Conservation of the species richness and diversity of mayflies is very important for the maintenance of healthy ecosystem functioning. The diversity of mayfly species is important in aquatic systems due to the large and varied role they play in aquatic food webs.

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