# Species composition, diversity of mayflies (Insecta: Ephemeroptera) and their relationship with the environmental variables in hill streams of Tamiraparani river basin, Tamil Nadu

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### ABSTRACT

In recent years, the fresh water ecosystems have been increasingly threatened directly or indirectly by human activities. The combination of both chemical and biotic approaches has been shown to be the most appropriate method for monitoring water pollution. In this context, the present study revealed that the dynamics of environmental variables and their influence on mayfly communities in five streams of Tamiraparani river basin, Tamil Nadu. The physico-chemical parameters and mayfly populations were monthly sampled from November 2010 to October 2012. Total of 22 species belonging to 19 genera from 7 families of Ephemeroptera were recorded and the community of taxa differed among sampling sites. At family level, Baetidae contributed maximum number of individuals followed by Leptophlebiidae throughout sampling period. The value of Shannon-Weiner diversity index ranged from 1.26 to 2.373, which indicated the mildly polluted condition of selected streams. Based on Principal component analysis, mayfly species like *Afronurus kumbakkaraiensis, Petersula courtallensis, Notophlebia jobi* and *Epeorus petersi* associated with sampling sites Kallar and Nambiyar whereas pollution tolerant species such as *Caenis* sp., *Nigrobaetis* sp., *Choroterpes alagarensis* found in Sivasailam with high temperature.

Keywords: mayflies, pollution indicator, diversity index, tamiraparani river basin, PCA

# **INTRODUCTION**

Macroinvertebrates are the most diverse group of organisms in freshwater ecosystems. They include molluscs, crustaceans, annelids, larval forms of aquatic insects and nematodes. The composition, abundance and distribution of benthic organisms over a period of time provide an index of the ecosystem. In recent years, there is a greater emphasis world over for better understanding of benthic environment, its communities and productivity and this has led to increased exploitation of many inland water bodies [1]. Among the macroinvertebrates, insects are the most successful inhabitants of fresh water environment. This is demonstrated by their broad distribution and ability to exploit most types of aquatic habitats [2].

There are about thirteen orders of insects that have aquatic species. Aquatic insects of inland waters comprise some well known groups like mayflies (Ephemeroptera), dragonflies and damselflies (Odonata), and caddisflies (Trichoptera) besides aquatic bugs (Heteroptera), aquatic beetles (Coleoptera) and aquatic flies (Diptera) [3]. Mayflies (Ephemeroptera) constitute a major order of aquatic insects in standing and running water. A greater part of their life cycle is spent as

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larvae in water, while their short terrestrial adult life is simply for reproduction. They are major component of food webs, forming a link between primary production and secondary consumers such as fish. They are often the most abundant taxa in macroinvertebrate and are sensitive to aquatic pollution. They are therefore useful in the assessment of water quality [4-6]. So far number of studies has been focused on environmental factors influencing macroinvertebrates and aquatic insects from streams and rivers of South India particularly Tamiraparani river, Courtallam streams, Kaveri river and its tributaries, Kurangani stream of Cardamom hills, Kumbakkarai stream of Palni hills, streams of Meghamalai hills and streams of Western Ghats [3, 7-21]. However there is an urgent need to examine local, regional and global patterns of species composition and diversity for different species of each macroinvertebrate for conservation of important localities and much more data is required. In this context, the present study was attempted to investigate the species composition, diversity, relative abundance of mayflies and factors governing them in the selected streams and rivers of Tamiraparani river basin, Tamil Nadu.

### **MATERIALS AND METHODS**

Physico-chemical parameters were measured based on the procedures suggested in APHA [22]. Latitude, longitude, elevation and basin location were determined by Global Positioning System. Water and Air temperatures were recorded by thermometer in the field. Water current of the stream was determined by cork floatation method. Stream depth and stream width were measured with the help of metal tap. Total solid, Total dissolved solid and Total suspended solid of stream water sample were also determined. pH was measured by using portable pH meter. Dissolved oxygen was estimated by Micro-Winkler method. Stream bed substrates were classified by using Jowett et al. [23]. For statistical analyses, substrate composition was converted to a Substrate index [24]: Substrate Index =  $(0.08 \times \% \text{ bedrock}) + (0.07 \times \% \text{ boulder}) + (0.06 \times \% \text{ cobble}) + (0.05 \times \% \text{ gravel}) + (0.04 \times \% \text{ sand}) + (0.03 \times \% \text{ mud/silt}).$ 

### **Description of study area**

Tamiraparani, a major east flowing river with catchment area of 5482 km<sup>2</sup> 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, 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 Papanasam, Manimuthar and Servalar, in the upper reaches and eight check dams or weirs in the middle and lower reaches of the 11 feeder canals. Tamiraparani river basin benefits from both the north-east and south-west monsoons [10]. The study was carried out from selected sampling sites Kallar (Gadana), Sivasailam, Thalaiyanai (Papanasam), Sorimuthu ayyanar temple and Nambiyar of Tamiraparani river basin during November 2010 to October 2012.

# Collection and preservation of mayfly community

Mayfly communities were collected from selected five streams of Tamiraparani river basin by using kick net method (mesh size: 0.5 to 1.0 mm). The methodology was adapted for sampling throughout the study by following sampling strategy of Balasubramanian et al. [12]. The duration of each kick net operation was for two minutes. The substratum such as bed rocks, boulders, and

cobbles vigorously disturbed by the hand strictly restricted to one  $m^2$ . The every movable boulders or cobbles in this area were lifted up and the organisms were washed by the hand into the net. All organisms trapped in the net were carefully collected without any morphological damage using fine forceps and brush. Collected specimens would be preserved in 80% ethanol in the field and brought back to laboratory for identification. Samples would be assigned to genus and species by making use of standard published literature on the Western Ghats [25-38].

#### **Statistics**

The richness and density of the mayflies were summarized as mean values, standard deviation. Alpha diversity indices of the Shannon-Wiener diversity index and Simpson diversity index, species richness index of Margalef, and evenness of index Pielou were calculated. Principal Component Analysis was performed to find relationship between the faunal changes and physico-chemical variables. Calculations were done by using package PAST software.

# **RESULTS AND DISCUSSION** Physico-chemical characteristics of the sampling sites

The perennial Nambiyar is situated at 77°31'45.88"E longitudes and 8°26'23.88"N latitudes. The elevation is 504 m. The Nambiyar is partially canopy covered due to thick growth of trees like Syzygium cumini and Pongamia pinnata when compared to other sampling sites. The substrate index of the Nambiyar is 7.0 which represent heterogenous nature of substrate (Table 1). The basic habitat consists of series of 25% bedrocky, 30% boulders, 20% gravels integrated with 10% sandy and silty particles. The average substrate index was 5.6, being lowest at Kallidai river (2.8) and highest at Palaruvi (7.6) from Southern Western Ghats [18]. Physically complex substratum types generally support more benthic diversity than the structurally simple substrates of sands and silts [39, 40]. Summary of the physico-chemical characteristics of selected five streams of Tamiraparani river basin is given in table 2. The Nambiyar averages 5.3m wide and Average depth is 30.7cm. Similar pattern of results observed from Courtallam streams [7]. The study revealed that Sivasailam stream had the maximum water temperature (27.7°C) and Nambiyar stream had the minimum temperature (24.2°C). The difference in water temperature may depend on the climate and the environment nearby the stream as well as sampling time, wind, water mixing and the amount of sunlight in Mekong river, Thailand [41]. The water current was high in Sivasailam (0.51m/sec). The streamflow variability was identified as a major factor affecting other abiotic and biotic factors that regulate lotic macrozoobenthic patterns [42]. Similarly high water velocity during monsoon months with frequent flash floods caused by rain in the upper catchment areas of Chhirapani, a hill stream in Kumaon Himalaya, India [43]. The average pH ranged from 7.0 to 7.25 and the dissolved oxygen of sampling streams ranged 7.45 to 8.9 mg/L. The recorded dissolved oxygen in tributaries of Kaveri river basin was 4-8 mg/L [8].

### Species composition and diversity of mayfly

During the period of a total of twenty two species belonging to nineteen genera from seven families of Ephemeroptera were recorded and the community of taxa differed among sampling sites from Tamiraparani river basin during November, 2010 to October 2012. The mayfly species were represented by *Baetis acceptus, Baetis frequentus, Baetis conservatus, Labiobaetis sp., Nigrobaetis sp., Indobaetis sp., Choroterpes (Euthraulus) alagarensis, Choroterpes(Euthraulus) nambiyarensis, Notophlebia jobi, Petersula courtallensis, Edmundsula lotica, Nathanella* 

saraswathiae, Indialis badia, Thraulus gopalani, Caenis sp., Clypeocaenis sp., Eperous petersi, Afronurus kumbakkaraiensis, Telogonades sp., Torleya nepalica. Seasonal changes in the density and taxa richness of Ephemeroptera larva from five sampling sites were depicted in figure 1, 2, 3, 4 and 5. Kallar stream had the maximum number of individuals in the month of October 2011, January and July 2012 and the minimum number of individuals was noticed in the month of March and November 2011 (Figure 1). The number of species exhibited low in Sivasailam stream when compared to other sampling sites. The maximum density of Ephemeropteran population was found in the month of January 2011 in Papanasam whereas density was low during February 2012.

Physical characteristics	Kallar	Sivasailam	Thalaiyanai	Sorimuthu Ayynar	Nambiyar
Latitude(N)	8°48'10.25"	8°47'17.03"	8°42'51.50"	8°39'13.75"	8°26'23.88"
Longitude(E)	77°17'45.85"	77°20'49.51"	77°22'06.67"	77°20'13.13"	77°31'45.88"
Elevation (m)	623	326	264	717	504
Appearance	Clear	Slightly turbid	Clear	Slightly turbid	Clear
Colour	Colourless	Pale brown	Colourless	Pale brown	Colourless
Odour	Odourless	Partially odoured	Odourless	Partially odoured	Odourless
Canopy cover	No canopy cover	No canopy cover	No canopy cover	No canopy cover	Canopy covered
Substrate index	5.85	5.2	6.05	6.2	7.0

Table 1. Physical characteristics of streams of Tamiraparani river basin, Tamilnadu.



Figure 1. Seasonal abundance and taxa richness of mayflies (Ephemeroptera) in Kallar stream of Tamiraparani river basin.

The number of individuals was high in October 2011 and low in June 2011 at Sorimuthu ayyanar temple (Figure 4). Kallar had the maximum number of taxa (14), whereas the Sivasailam stream harboured only about five to seven taxa (Figure 1 and 2).

Parameters	Kall	ar-Gadan	a	Siv	asailam		Th	alaiyanai		Sorim t	ithu ayya emple	nar	Na	ambiyar	
	Max-	Mean	SD	Max-	Mean	SD	Max-	Mean	SD	Max-	Mean	SD	Max-	Mean	SD
	Min			Min			Min			Min			Min		
Air Temperature ( <sup>0</sup> C)	34-24	28.3	2.61	37-25	30.0	2.88	32-26	29.1	1.84	32-25	28.9	1.93	31-24	26.7	1.84
Water Temperature ( <sup>0</sup> C)	31-21	25.4	2.56	35-22	27.7	3.02	30-23	26.5	1.99	29-23	26.2	1.91	27-21	24.2	1.69
Water Current (m/sec)	0.68- 0.18	0.418	0.14	0.85- 0.18	0.51	0.19	0.58- 0.32	0.449	0.07	0.8- 0.24	0.49	0.15	0.54- 0.2	0.35	0.08
Stream Width (m)	7.0-3.4	5.46	1.19	16-5.6	8.3	2.14	13-6.0	8.4	1.53	16-4	8.9	3.31	7.3-3.1	5.3	1.28
Stream Depth (cm)	48-18	32.37	8.85	62-12	25.3	11.9	80-20	41.8	17.0	85-25	51.0	16.8	72-18	30.7	12.1
pH	8.5-6.5	7.25	0.41	8.2-6.4	7.2	0.42	8.0-6.4	7.1	0.38	8.1-6.6	7.1	0.33	7.8-6.5	7.0	0.30
Total Solids(mg/L)	6.8-2.5	3.82	1.08	8.4- 3.16	4.61	1.32	9.0-2.9	4.5	1.52	9-2.4	4.6	1.80	8.6-2.2	4.1	1.61
Total Dissolved Solids(mg/L)	0.86- 0.34	0.58	0.14	0.80- 0.20	0.40	0.14	0.80-0.30	0.46	0.13	0.85- 0.20	0.46	0.15	0.81- 0.28	0.43	0.14
Total Suspended Solids(mg/L)	6.2- 2.16	3.25	0.98	7.7- 2.86	4.2	1.23	8.38- 2.52	4.10	1.45	8.54- 2.03	4.2	1.74	8.24- 1.83	3.7	1.57
Dissolved oxygen (mg/L)	13.2- 6.5	8.9	1.66	12-6.2	7.45	1.55	11.0- 6.1	8.0	1.01	11-5.8	7.6	1.28	9.8-6.2	8.2	0.92

Table 2.Summary of the physico-chemical characteristics of selected streams of Tamiraparani river basin, Tirunelveli district, Tamilnadu.

The density of organism in a water body is a useful index of water quality, although the density of some benthic invertebrates fluctuates widely with season [44]. The number of species and individuals changes depending on the ecological factors and food availability in the aquatic system [45]. The maximum density of benthic fauna was observed during winter months, this can be related to the availability of phytoplankton population in the form of food supply as also observed on Ganga River [46]. On the other hand decline in the density of benthic fauna during monsoon months may be due to increase load of suspended solids, reduced transparency and increased water flow. Similar findings have also been observed by many workers [47, 48]. Previous studies have shown that aquatic insects are best sampled in the Western Ghats during post monsoon period [9].



Figure 2. Seasonal abundance and taxa richness of mayflies (Ephemeroptera) in Sivasailam stream of Tamiraparani river basin.

Table	3.	Relative	abundance	of	recorded	mayfly	species	(Ephemeroptera)	in	Kallar	stream	during
Nover	nbe	r 2010 to	October 201	2.								

Species	Total no. of individuals	Percent abundance
Baetis acceptus	137	5.82483
Labiobaetis sp.	376	15.98639
Choroterpes(Euthraulus)	178	7.568027
alagarensis	1,0	,
Notophlebia jobi	369	15.68878
Petersula courtallensis	288	12.2449
Edmundsula lotica	79	3.358844
Indialis badia	70	2.97619
Thraulus gopalani	9	0.382653
Caenis sp.	151	6.420068
Epeorus petersi	170	7.227891
Thalerosphyrus flowersi	86	3.656463
Afronurus kumbakkaraiensis	345	14.66837
Tricorythus sp.	53	2.253401
Telogonades sp.	41	1.743197



Figure 3. Seasonal abundance and taxa richness of mayflies (Ephemeroptera) in Thalaiyanai (Papanasam) stream of Tamiraparani river basin.

Table 4. Relative abundance of recorded	mayfly	species	(Ephemeroptera)	in	Sivasailam	stream	during
November 2010 to October 2012.							

Species	Total no. of individuals	Percent abundance
Labiobaetis sp.	408	28.73239
Nigrobaetis sp.	277	19.50704
Choroterpe (Euthraulus) alagarensis	164	11.5493
Notophlebia jobi	27	1.901408
Indialis badia	101	7.112676
Caenis sp.	344	24.22535
Epeorus petersi	34	2.394366
Thalerosphyrus flowersi	20	1.408451
Telogonades sp.	45	3.169014



Figure 4. Seasonal abundance and taxa richness of mayflies (Ephemeroptera) in Sorimuthu Ayyanar temple stream of Tamiraparani river basin.

# **Diversity indices**

Diversity indices were chosen because of its wide acceptance and it could be utilized for any community irrespective of its species abundance and distribution patterns [49]. Diversity indices showed that the Kallar and Nambiyar streams had higher diversity and species richness (Table 8). The values of Shannon-Weiner's index ranged from 1.26 to 2.373. The high value of diversity index suggests a more healthy ecosystem, while a low value suggests a less healthy or degraded ecosystem [50]. The Shannon-Weiner diversity index proposed as diversity index greater than (> 4) is clean water; value range of 1-3 is mildly polluted water and less than 1 (< 1) is heavily polluted water [51]. The present study revealed that mildly polluted conditions of selected streams of Tamiraparani river basin.

Table 5. Relative abundance of recorded mayfly species (Ephemeroptera) in Thalaiyanai-Papanasam stream during November 2010 to October 2012.

Species	Total no. of individuals	Percent abundance
Baetis acceptus	60	2.712477
Baetis frequentus	36	1.627486
Indobaetis sp.	233	10.53345
Labiobaetis sp.	169	7.640145
Choroterpes (Euthraulus)alagarensis	83	3.75226
Notophlebia jobi	44	1.98915
Indialis badia	470	21.24774
<i>Caenis</i> sp.	240	10.84991
Clypeocaenis sp.	146	6.600362
Epeorus petersi	119	5.379747
Thalerosphyrus flowersi	73	3.300181
Telogonades sp.	149	6.735986
Torleya nepalica	390	17.6311

Table 6. Relative abundance of recorded mayfly species (Ephemeroptera) in Sorimuthu ayyanar temple stream during November 2010 to October 2012.

Species	Total no. of individuals	Percent abundance
Baetis acceptus	141	10.58559
Labiobaetis sp.	223	16.74174
Indobaetis sp.	228	17.11712
Choroterpes(Euthraulus)alagarensis	57	4.279279
Notophlebia jobi	58	4.354354
Edmunsula lotica	45	3.378378
Indialis badia	289	21.6967
Caenis sp.	77	5.780781
Epeorus petersi	102	7.657658
Thalerosphyrus flowersi	39	2.927928
Afronurus kumbakkaraiensis	15	1.126126
Tricorythus sp.	58	4.354354

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Figure 5. Seasonal abundance and taxa richness of mayflies (Ephemeroptera) in Nambiyar stream of Tamiraparani river basin.



### Component 1

Figure 6. Biplot ordination based on physico-chemical parameters and abundance of mayfly taxa of Tamiraparani river basin by Principal component analysis.



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Figure 7. Bray-Curtis dendrogram for mayfly (Ephemeroptera) taxa in streams of Tamiraparani river basin.



Figure 8. Dendrogram showing similarity of faunal composition between streams of Tamiraparani river basin, Tamilnadu.

Species	Total no. of individuals	Percent abundance
Baetis conservatus	145	5.751686
Labiobaetis sp.	295	11.70171
Choroterpes (Euthraulus) nambiyarensis	229	9.083697
Notophlebia jobi	70	2.776676
Petersula courtallensis	275	10.90837
Indialis badia	235	9.321698
Nathanella saraswathiae	339	13.44704
<i>Caenis</i> sp.	88	3.490678
Epeorus petersi	252	9.996033
Thalerosphyrus flowersi	108	4.284014
Afronurus kumbakkaraiensis	397	15.74772
Telogonades sp.	88	3.490678

Table 7. Relative abundance of recorded mayfly species (Ephemeroptera) in Nambiyar stream during November 2010 to October 2012.

### **Relative abundance of species**

At family level Baetidae had widest niche followed by Leptophlebiidae and Heptageniidae. Genus *Labiobaetis* sp., *Indialis badia* had widest distribution followed by *Caenis* sp. and *Notophlebia jobi*. The total number of individuals of mayfly communities present in five sampling sites and percent value were given from Table 3 to 7. The number of individuals of *Labiobaetis* sp. was highest at Sivasailam stream followed by Kallar. The percent abundance at Sivasailam and Kallar stream were 28.73 and 15.98. In terms of percent abundance of *Indialis badia* at Papanasam, Sorimuthu ayyanar temple and Nambiyar were 21.24, 21.69 and 13.44 respectively.

# **Principal Component Analysis**

According to the PCA ordination (Figure 6), the upper portion of the ordination represented the most influencing factors was the stream depth in mayfly species richness of sampling site Sorimuthu ayyanar temple. The water current, total dissolved solids and total supended solids were centrely grouped and considered as these factors might not be influenced the assemblage of mayfly community. The results implied that species like *Labiobaetis* sp., *Afronurus kumbakkaraiensis, Petersula courtallensis, Notophlebia jobi* and *Epeorus petersi* associated with sampling sites Kallar and Nambiyar. The two species such as *Caenis* sp., *Nigrobaetis* sp. regularly found in Sivasailam. These species might be responsible for rate of maximum changes in taxa richness of mayfly throughout the investigation. Quantitative data belonging to each species were used to calculate percent similarity index using Bray-curtis similarity index (Figure 7). Figure 8 showed similarity of faunal composition between five sampling sites of Tamiraparani river basin, Tirunelveli district, Tamil Nadu.

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Diversity Index	Kallar-Gadana		Sivasailam		Thalaiyanai		Sorimuthu ayyanar		Nambiyar	
	Max-Min	Mean	Max-Min	Mean	Max-Min	Mean	Max-Min	Mean	Max-Min	Mean
Shannon index	2.369-2.015	2.199	2.061-1.26	1.602	2.359-1.57	2.098	2.302-1.407	1.912	2.373-2.042	2.226
Simpson index	0.889-0.836	0.864	0.858-0.648	0.754	0.894-0.716	0.846	0.888-0.673	0.808	0.901-0.851	0.875
Evenness index	0.866-0.631	0.752	0.873-0.559	0.701	0.882-0.480	0.724	0.832-0.481	0.698	0.894-0.714	0.809
Margalef index	3.03-1.99	2.428	2.015-1.003	1.538	2.635-1.93	2.324	2.771-1.519	2.244	2.569-1.934	2.270

Table 8. Summary of the diversity indices of streams of Tamiraparani river basin, Tirunelveli district, Tamilnadu.

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