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RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Diversity of the EPT complex (Ephemeroptera, Plecoptera and Trichoptera) in the Western and Eastern Ghats (South India) caused by the variations of landscape elements and mesohabitats

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Abstract: The present study was carried out in 27 streams of the southern part of the Western Ghats and the Eastern Ghats from January to December 2018. The outcomes show that there is an increase in the percentage of Ephemeroptera (71%) in the first order and there was a negligible fall in the abundance of the fourth-ordered stream. LSE results show a gradual increase of Plecoptera and a gradual decrease of Trichoptera and no such variations in Ephemeroptera. Variations in mesohabitat richness were highest in the run (38.38%) and it was lowest in silt (0.5%). To compare the taxa composition in Western and Eastern Ghats taxa, five different types of river basins were classified. The species richness and abundance were higher in Tampiraparani East flowing and Vamanapuram River basin communities (Western Ghats) than in the Eastern Ghats and this shows mega diversity of Western Ghats compared to the Eastern Ghats. The results of both cluster and ordination analysis also strongly support the discrimination between Western and Eastern Ghats diversity and distribution of EPT taxa.

Keywords: Western Ghats, Eastern Ghats, LSE, PCA, DCA, ordination

INTRODUCTION

The larvae of Ephemeroptera, Plecoptera, and Trichoptera are important members of the freshwater ecosystem due to nutrient cycling (Ross and Wallace, 1983), coarse organic particulate breakdown and they form the diet of many fishes and other aquatic vertebrates (Wiggins, 1996; Pflieger, 1997). Moreover, members of these orders generally act as bioindicators of good water quality (Rosenberg and Resh, 1993; Wiggins, 1996), although an exception exists. The altitudinal/ latitudinal gradient which have a direct and indirect influence on spatial distribution and community structure of organisms (Sivaramakrishnan and Venkataraman, 1990). The anthropogenic factors or stressors (Dinakaran and Anbalagan, 2007), riparian landuse (Subramanian et al., 2005; Chakona et al., 2009), and habitat heterogeneity also determine the diversity and distribution of EPT organisms.

Studies of aquatic insects give more knowledge about the species-habitat relationship and interpretation of water quality (Azrina et al., 2005). Pollution becomes a major concern nowadays; it causes adverse effects to aquatic ecosystem health. Aquatic insects play a vital role in the functioning of the stream ecosystem. EPT along with other benthic macroinvertebrates find a wide range of suitable substrates in headwater streams. EPT diversity increases with habitat diversity. Given the lack of information concerning EPT biodiversity of some unexplored River basins in Eastern and Western Ghats, especially those in the unprotected areas, and in the context of the high potential for these organisms to be important and diverse biotic components of the stream ecology.

This study is aimed to characterize the diversity of mayflies, stoneflies, and caddisflies taxa occurrences in terms of geographic distributional patterns, species-genera/ habitat preferences, and distinctive faunal elements. This EPT faunistical survey is essentially descriptive in scope and attempts to investigate patterns of EPT richness and assemblage structure and to test their correlation to physico-chemical parameters associated with stream altitudinal/latitudinal environmental gradients.

MATERIAL AND METHODS

Study area

The present study was carried out in 27 streams of the southern part of the Western Ghats and the Eastern Ghats

(Figure 1) from January to December 2018 and they were listed in Table 1. Each sampling site was selected after assessing the habitat heterogeneity, canopy cover, and riparian taxa. Each stream was sampled during three seasons namely summer (February, March, April, May), south-west monsoon (June, July, August, September), and north-east monsoon (October, November, December, January).

Measuring water quality parameters

The physico-chemical parameters of stream water like dissolved oxygen, pH, conductivity, hardness, alkalinity, calcium, magnesium, sodium, iron, and chloride were analyzed in all the 27 sites using the guidelines of APHA, (2005). Water temperature was measured with a thermometer. Water velocity was measured by a flow meter.

Macroinvertebrate collection and identification

EPT complex was sampled by using a 1m wide Kick-net (Burton and Sivaramakrishnan,1993) with a mesh size of about 1mm. Limited opportunistic collections (hand picking) were also made. The organisms were carefully picked from the net and were preserved in 80% ethyl alcohol. All specimens from each of the 27 streams were sorted and identified with the help of a field guide by Sivaramakrishnan et al. (1998) and other taxonomic literature.

Analysis of data

Alpha and beta diversity

Alpha and beta diversity were used to measure the generic diversity within and between latitudinal and altitudinal zones. Simpson's index and Shannon-Wiener index were used to calculate alpha diversity whereas Jaccard's index was used to measure the beta diversity. The data analysis was done with the help of the PAST software to measure the various diversity indices (Hammer et al. 2001).

Cluster analysis

Insect assemblages were analyzed with relative abundance data, cluster analysis employing both Q (the relationship between regions based on the description of taxa) and R (measures the relationship between descriptions based on regions) modes were performed using the unweighted group method of arithmetic averages (UPGMA). To test that the data contains clusters, the matrix of the original data to produce a cophenetic correlation value. Values of $r>0.9$, $0.8<0.9$, $0.7<0.8$, and $r<0.7$ indicate very good, poor, and very poor fits (Unmack, 2001). Spearman similarity matrix is a widely used clustering procedure used to group stations.

Principal component analysis and detrended correspondence analysis

Principal Component Analysis (PCA) is employed to evaluate the relationship between the abundance of taxa and the environmental variables of 27 study sites. Sites having unique physico-chemical features were being clustered together, whereas the ones having extreme conditions were plotted very far. Detrended Correspondence Analysis (DCA) is used to compare the Western and Eastern Ghats species richness and abundance. PCA and DCA were analyzed using PAST software (Hammer et al., 2001).

Description of mesohabitats

Based on flow, depth, and substrate mesohabitat has been evolved following the method of Vadas and Orth (1998) which was characterized by the EPT and habitat associations in temperate streams (Ferro and Sites, 2007). Seven mesohabitats were identified in the study.

The landscapes in study localities were classified into six Land Scape Element (LSE) types. The landscapes were assigned to specific LSE types (Nagendra and Gadgil 1998; Ghate et al., 1998) in the Western Ghats. LSE types of 27 stations are given in Table 2.

Table 1. Name, abbreviation and stream order of 27 study sites

No	Sites	Abbreviation	Stream order
1	Kumbakkarai	Kumb	Third
2	Sothuparai stream	Soth	Fourth
3	Suruli	Suru	First
4	Kurangani falls	Kura	Second
5	Gadana Nathi	Gada	Third
6	Iluppaiar	Ilup	Second
7	Ramanadi	Rama	Second
8	Chittar	Chit	Third
9	Ayyanar falls	Ayya	Second
10	Karuppar	Karu	First
11	Mundar	Mund	Third
12	Mothiramalai	Moth	Second
13	Kumbar	Kumr	Second
14	Illanguruparai	Illa	Second
15	Kalikesam River	Kali	Third
16	Kaippillai thodu-Kallar	Kaip	Third
17	Golden valley-Kallar	Gold	Second
18	Kallar	Kall	Third
19	Aranakuzhi-Kallar	Aran	Second
20	Panivadi-Kallar	Pani	Second
21	Meenmutti	Meen	Third
22	Downstream-Kallar	Down	Fourth
23	Odamundurai odai-Karanthamalai	Odam	Second
24	Ayyan odai-Karanthamalai	Ayyn	First
25	Sirumalai	Siru	Third
26	Bison vally-Alagarmalai	Biso	First
27	Periaaruvi-Alagarmalai	Peri	Second

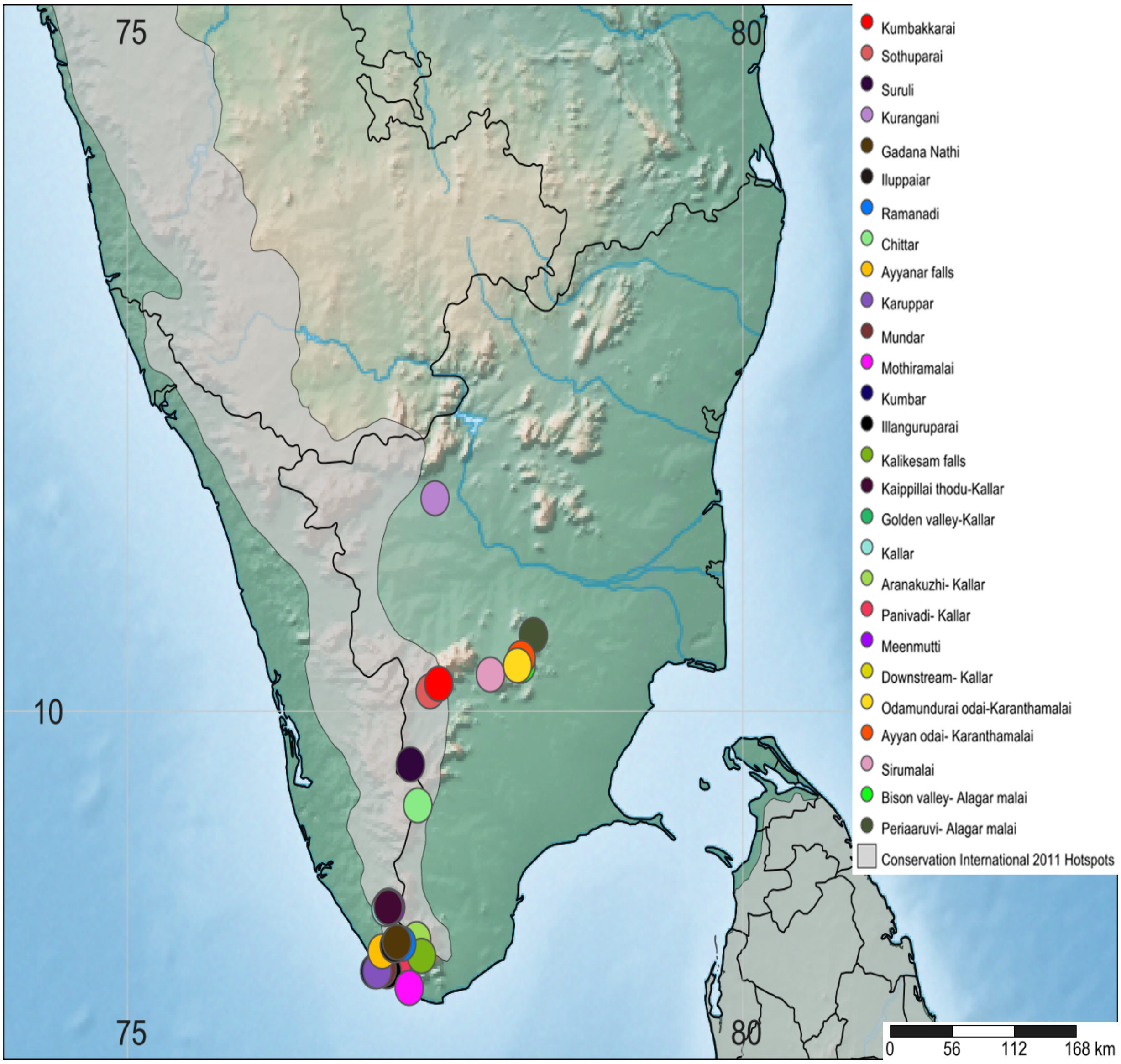

Figure 1. Map showing 27 study sites

Table 2. Categorization of study sites in terms of LSE

Evergreen	Semi evergreen	Scrub	ARE	Forestry plantation	Dry deciduous
Suruli	Kumbakkarai	Ramanathi	Mundar	Panivadi	Odamundurai odai
Gadana	Illangurupparai		Mothiramalai	Chittar	Ayyan odai
Illuppaiar	Kumbar		Kurangani	Ayyanar falls	Sirumalai
Karuppar	Kalikesam			Bisonvalley	
Kaipillai thodu	Goldenvalley			Periaaruvi	
KTC	Aranakuzhi				
Downstream	Meenmutti				
	Sothuparai				

RESULTS AND DISCUSSION

Overall, 4,216 specimens were collected and studied. The result shows that 21 genera of Ephemeroptera belonging to 6 families, two species of genus *Neoperla* belonging to one family, and 19 genera of Trichoptera were belonging to 12 families were identified in the Western Ghats. In the Eastern Ghats, 10 genera of Ephemeroptera belonging to 6 families, one species of genus *Neoperla* belonging to one family, and 11 genera of Trichoptera belonging to 9 families were identified.

The abundance of EPT changes with stream order. Species diversity was generally high and pollution intolerant organisms were present at most stations throughout the study period, indicating the high quality of the water in the streams. There is an increase in the percentage (71%) of Ephemeroptera in the first order and there was a negligible fall in the abundance of the fourth-order stream. The Plecoptera shows a gradual decrease from first to fourth-order. Most stonefly nymphs are related to cool, lotic waters while those of mayfly nymphs have a broader ecological range with a preference for warmer lotic water (Wiggins and Mackay, 1978).

Of the 27 stations, five streams belong to the first order; nine streams belong to the second order; eleven streams belong to the third order, and two streams belong to the fourth order.

The percentage of Ephemeroptera shows no major deviation in any of the LSE types (Table 3). The percentage of Plecoptera shows a gradual increase from 3.8 – 10.9. This increase of predatory Plecoptera which are in dry deciduous LSE types may be due to the presence of more mayflies and caddisflies. The gradual decrease in the percentage of Trichoptera from 29% to 19% may be attributed to their feeding habits (shredders). Nair et al. (1989) stated that shredders were the dominant organisms in the headwaters of the Neyyar River in Southern India. Even in primary rainforest streams in New Guinea, shredders (a majority of Trichoptera in the present study) do not exceed 2% of the benthic populations (Dudgeon, 1994). Likewise, shredders are not more abundant in forested streams in Nepal. The under-representation of shredders which is typical of Hong Kong streams is a general feature of typical Asian Rivers. A possible explanation for this phenomenon is trophic flexibility and hence functional feeding group misclassification i.e. the same taxon acting as a shredder or collector of fine organic material under different circumstances (Dudgeon, 1999).

Table 3. EPT(%) in land scape element types

LSE types	% of E*	% of P**	% of T***
Evergreen	67.1	3.8	29.1
Semievergreen	66.9	5	28.1
Scrub	78.6	2.8	18.6
ARE	72.7	3.3	24
Forest plantation	70.6	6.8	22.6
Dry deciduous	70	10.9	19.1

*E – Ephemeroptera, **P – Plecoptera, ***T – Trichoptera

The EPT taxa present in different mesohabitats are listed in Table 4. Of the seven mesohabitats, richness was the highest in the run (38.38%) followed by riffle (24.2%) and bank (23.97%). The richness was the lowest in silt (0.5%) and the pool (1.1%). Leaf pack substrate types may influence species distributions; however, velocity and complex hydraulic characters also may be important (Sites and Willing, 1991; Llyod and Sites, 2000). The Riffle is dominated by the family Heptageniidae (Ephemeroptera) and Plecoptera. These forms require high velocity and turbulence of a riffle which increases aeration and provides an area where these forms can exploit the current and gather food with minimum energy expenditure (Cummins and Merrit, 1996).

Species richness and abundance values were higher in Tampiraparani (East flowing) River and Vamanapuram River sites and lower in Southern Eastern Ghats sites. Nine environmental variables were selected and the variance was explained a total variance of about 65.8%. The present variances explained by the first three axes were 35.49, 17.20, and 13.11 respectively. The PCA loading above >0.65 was considered significant and variables that showed higher loadings were Alkalinity, Fe, conductivity followed by hardness in the first component (Table 5). Mg showed in the second component and Ca was significant in the third component. Mg was higher in Bison valley and less in Ayyan Odai, Kaipillai thodu, Kallar, and Karuppar. Conductivity is very less compared to all the study sites and it was higher in Kumbakkarai, Kumbar, and Ayyanar falls (Figure 2).

Table 4. EPT complexes present in different mesohabitats in 27 sites

Silt/Mud	Bank	No flow organic	Pool	Leaf pack	Run	Riffle
Ephemera nadinae	*Centroptella similis*	*Caenis* sp.	*Polycentropus* sp.	*Afronurus* sp.	*Tenuibaetis frequentus*	*Afronurus kumbakkaraiensis*
	Choroterpes (Euthraulus) sp.	*Wormaldia* sp.		*Neoperla* sp.	*Baetis ordinatus*	*Epeorus petersi*
	Edmundsula lotica	*Macrostemum* sp.		*Anisocentropus* sp.	*Labiobaetis germinatus*	*Thalerosphyrus flowersi*
	Isca sp.	*Polymorphanisus* sp.		*Leptocerus* sp.	*Acentrella vera*	*Indialis badia*
	Nathanella indica	*Lepidostoma* sp.			*Rhyacophila* sp.	*Notophlebia jobi*
					Diplectrona sp.	*Petersula courtallensis*
					Hydropsyche sp.	*Thraulus gopalani*
					Potamyia sp.	*Dudgeodes bharathidasani*
					Goerodes sp.	*Teloganodes* sp.
					Oecetis sp.	*Stenopsyche kodaikanalensis*
					Setodes sp.	*Adicella* sp.
					Helicopsyche sp.	*Neoperla biseriata*
					Ecnomus sp.	
					Gumaga sp.	

Table 5. PCA loadings for the environmental variables in the first three components

	Environmental variables	First component	Second component	Third component
1	Water temperature	-0.613	-0.192	0.246
2	Conductivity	**-0.687***	0.011	0.372
3	Hardness	**-0.652***	0.121	0.33
4	Alkalinity	**-0.794***	0.241	0.148
5	Ca	0.154	-0.576	**0.669***
6	Mg	-0.185	**-0.859***	-0.371
7	Na	-0.63	-0.508	-0.278
8	Fe	**-0.722***	0.078	-0.35
9	Cl	0.551	-0.319	0.251

* >0.65 Significant

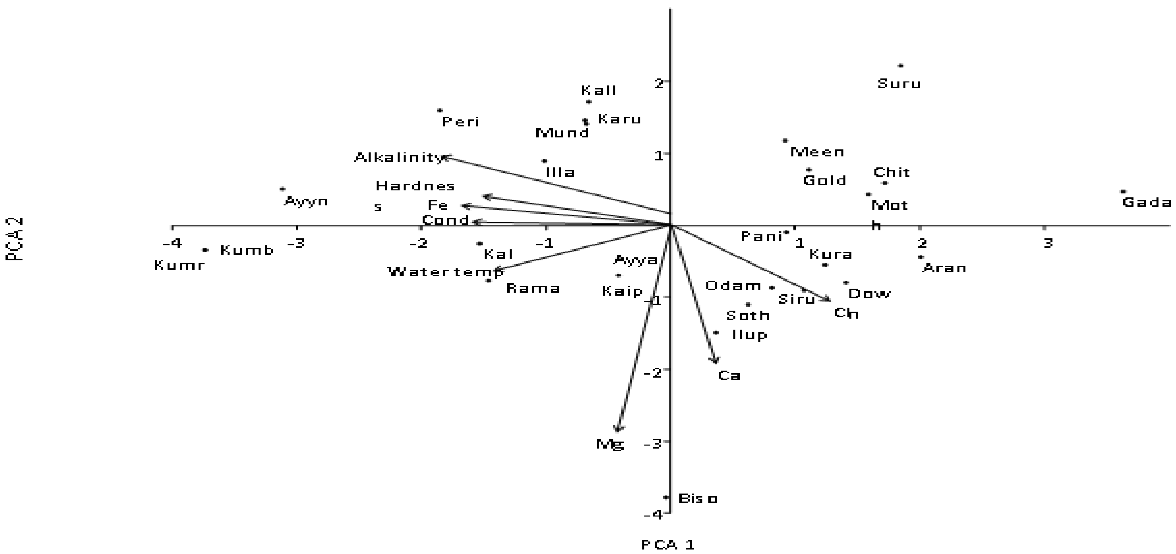

Figure 2. Principal component analysis for the 27 study sites

The similarity matrix and UPGMA dendrogram (Figure 3) quantify the degree of similarity in the EPT complex among 27 stations. Stations were grouped into a hierarchical framework that is useful for proposing a community classification.

The dendrogram shows hat two highly similar (0.97) stations in the Vamanapuram River basin namely Golden valley and Kallar which represent a distinct community showing low similarity (0.45) to stations constituting the Southern Eastern Ghats River basin.

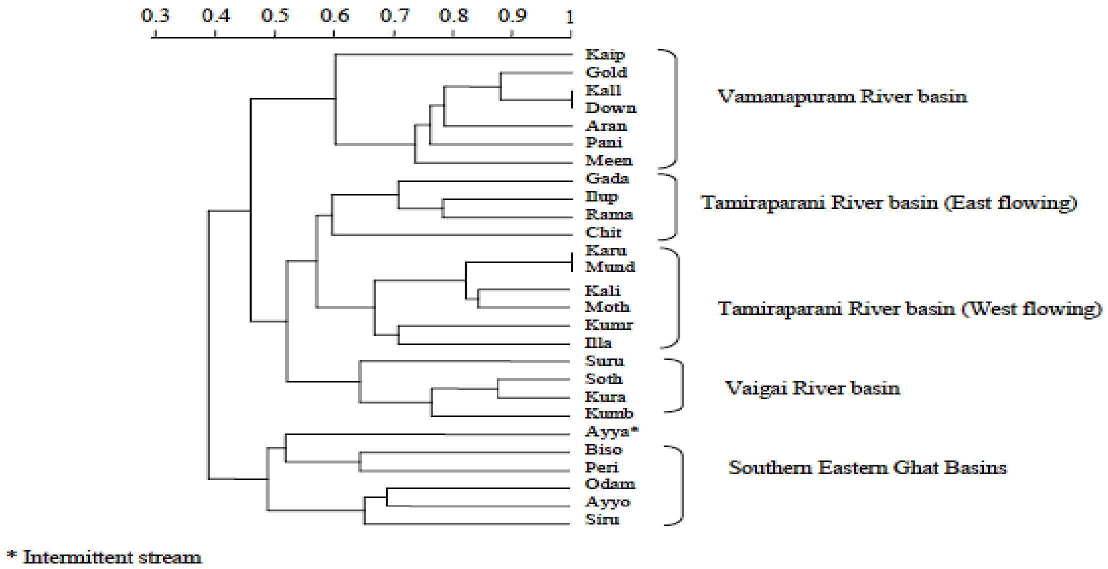

Figure 3. Cluster analysis of the sampling sites using Spearman's rank order correlation coefficient as measure of similarity based on the abundance of EPT complex

Based on the interpretations of the DCA analysis, five distinct communities are recognized namely Vamanapuram River basin, Tamiraparani East flowing, Tamiraparani West flowing, Vaigai River basin, and Southern Eastern Ghats River basin (Figure 4). The sampling sites namely Ayyanar falls is excluded as it is an intermittent stream.

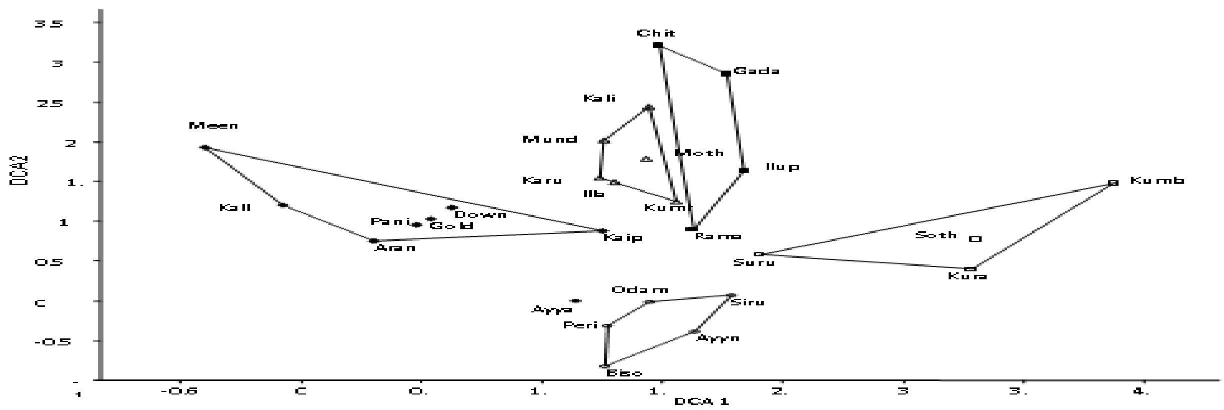

Figure 4. DCA for the 27 study sites based on the EPT complex distribution.

Tamiraparani east flowing basin (closed square), Vaigai River basin (open square), Vamanapuram River basin (closed diamond) and Tamiraparani west flowing (open triangle) Of the five distinct communities recognized, species richness and species abundance value are greater in Tampiraparani East flowing and Vamanapuram River basin (Figure 5). These values are least in southern Eastern Ghats River basins. The Western Ghats is a recognized 'hot spot' for mega diversity (Myers et al., 2000), species richness and species abundance values are higher in streams located in it than in the southern Eastern Ghats which is not as high as the Western Ghats or not even a rain forest. Streams are not canopied and the water flow is less when compared to the Western Ghats. These reasons may be attributed to the less biodiversity of southern Eastern Ghats Rivers. In all the study sites of southern Eastern Ghats Rivers, the mayfly species *Epeorus* sp. is conspicuously absent, since this is a rhithrogenic form and requires shade and less temperature.

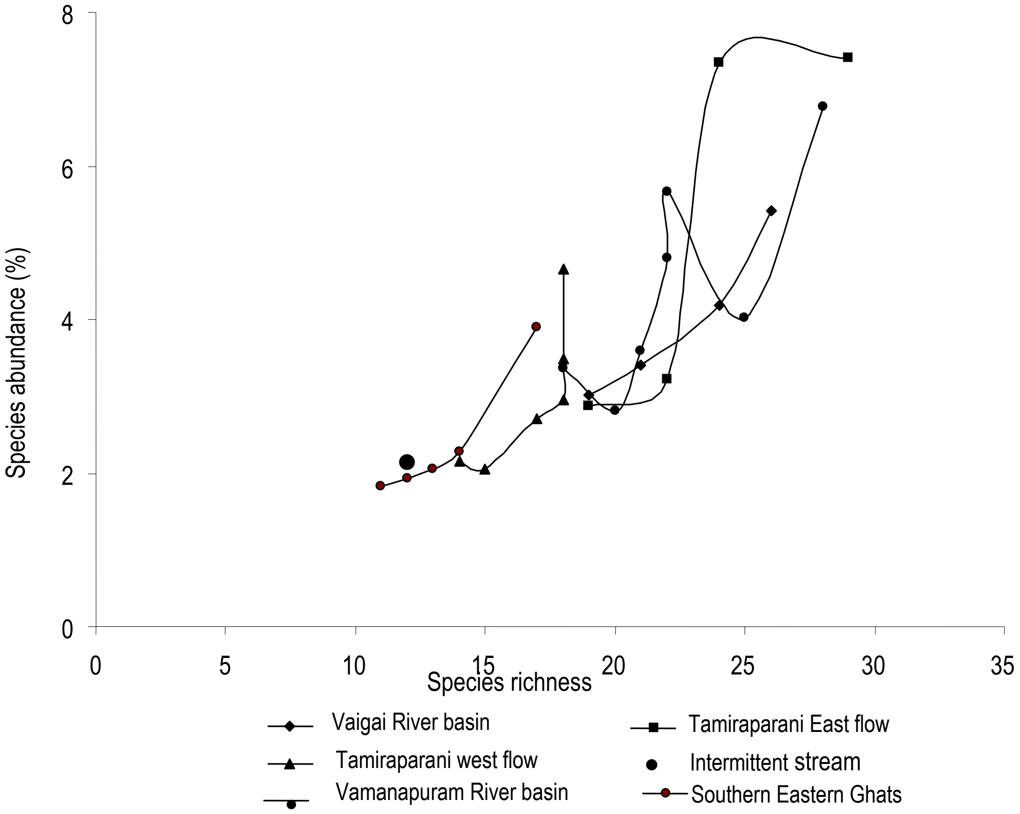

Figure 5. Species richness and abundance in 27 sites

The DCA ordination of all 27 stations, from the five different Rivers of Western and Eastern Ghats, is shown in Figure 4. The analysis resulted in the station being ordinated along four axes with values of 0.2636, 0.1319, 0.07904, and 0.04588 respectively. It does not appear in general axis 1 that is related to the geographic gradient (different mountain ranges of Western and Eastern Ghats) and axis 2 is related to the abundance of EPT complex among the 27 stations. This assessment is in general agreement with the cluster analysis wherein, basal grouping corresponds with stations of Rivers in Western and Eastern Ghats.

CONCLUSIONS

The results of the present study reveal that Ephemeroptera tends to increase in the first-order stream and a negligible fall in the abundance of the fourth-order stream. LSE results show a gradual increase and decrease of Plecoptera and Trichoptera respectively. Mesohabitat results show, these EPT taxa prefer to run (38.38%) compared to silt (0.5%). Based on DCA results of both Western and Eastern Ghats taxa, species richness and abundance were higher in the Western Ghats compared to the Eastern Ghats and the results again prove the mega diversity of Western Ghats.

REFERENCES

APHA (American Public Health Association). (2005). *Standard methods for the examination of water and wastewater.* 21st Edition, Washington D.C.

Azrina, M.Z., Yap, C.K., Rahim Ismail, A., Ismail, A. & Tan, S.G. (2005). Anthropogenic impacts on the distribution and biodiversity of benthic macro-invertebrates and water quality of the Langat River, Peninsular Malaysia. *Ecotoxicology and Environmental Safety*, 16, 184-210.

Burton, T.M. & Sivaramakrishnan, K.G. (1993). Composition of the insect community in the streams of the silent valley National Park in South India. *Tropical Ecology*, 34, 1-16.

Chakona, A., Phiri, C. & Day, J.A. (2009). Potential for Trichoptera communities as biological indicators of morphological degradation in riverine systems. *Hydrobiologia*, 621, 155-167. DOI:10.1007/s10750-008-9638-z

Cummins, K.W. & Merritt, R.W. (1996). *Ecology and distribution of aquatic insects.* Third edition, Kendall/Hunt Publishing Company, Dubuque, Iowa, 862 pp.

Dinakaran, S. & Anbalagan, S. (2007). Anthropogenic impacts on aquatic insects in six streams of South Western Ghats. *Journal of Insect Science*, 7, 37. DOI:10.1673/031.007.3701

Dudgeon, D. (1994). The influence of riparian vegetation on macroinvertebrate community structure and functional organization in six New Guinea streams. *Hydrobiologia*, 294, 65-85. DOI:10.1007/BF00017627

Dudgeon, D. (1999). *Tropical Asian streams Zoobenthos, Ecology and Conservation*. Hong Kong University Press, Hong Kong, 830pp.

Ferro, M.L. & Sites, R.W. (2007). The Ephemeroptera, Plecoptera and Tricoptera of Missouri State Parks, with Notes on Biomonitoring, Mesohabitat Associations, and Distribution. *Journal of the Kansas Entomological Society*, 80(2), 105-129. DOI:10.2317/0022-8567(2007)80[105:TEPATO]2.0.CO;2

Ghate, U., Joshi, N.V. & Gadgil, M. (1998). On the patterns of tree diversity in the Western Ghats of India. *Current Science*, 75(6), 594-603.

Hammer, O., Harper, D.A.T. & Ryan, P.D. (2001). PAST (Paleontological Statistics software package for education and data analysis). *Palaeontologia Electronica*, 4(1), 9.

Lloyd, F. & Sites, R.W. (2000). Microhabitat associations of three species of Dryopoidea (Coleoptera) in an Ozark stream: A comparison of substrate, and simple and complex hydraulic characters. *Hydrobiologia*, 439, 103-114. DOI:10.1023/A:1004151731374

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A. & Kent J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403(6772), 853. DOI:10.1038/35002501

Nagendra, H. & Gadgil, M. (1998). Linking regional and landscape scales for assessing biodiversity: A case study from Western Ghats. *Current* Science, 75(3), 264-271.

Nair, N.B., Arunachalam, M., Mathusoothanan Nair, K.C. & Suryanarayanan, H. (1989). A spatial study of the Neyyar River in the light of the River-Continuum-Concept. *Tropical* ecology, 30, 101-110.

Pflieger, W.L. (1997). *The Fishes of Missouri.* Missouri Department of Conservation, Jefferson City, 372pp.

Rosenberg, D.M. & Resh, V.H. (1993). *Freshwater biomonitoring and benthic macroinvertebrates.* New York (NY), Springer, 488 pp.

Ross, D.H. & Wallace, J.B. (1983). Longitudinal patterns of production, food consumption and seston utilization by net spinning caddisflies (Trichoptera) in a southern Appalachian stream (USA). *Holarctic Ecology*, 6, 270-284. DOI:10.1111/j.1600-0587.1983.tb01091.x

Sites, R.W. & Willing, M.L. (1991). Microhabitat associations of three sympatric species of Naucoridae (Insecta: Hemiptera). *Environmental entomology*, 20, 127-134. DOI:10.1093/ee/20.1.127

Sivaramakrishnan, K.G., Madhyastha, N.A. & Subramanian, K.A. (1998). Field guide to aquatic macroinvertebrates. Life scape, Bangalore, 8 pp.

Sivaramakrishnan, K.G. & Venkatraman, K. (1990). Abundance, altitudinal distribution and swarming of Ephemeroptera in Palni hills, South India. In Campbell, I.C (Ed.). *Mayflies and Stoneflies* (pp. 209-213). Kluwer Academic Publishers. DOI:10.1007/978-94-009-2397-3_24

Subramanian, K.A., Sivaramakrishnan, K.G. & Gadgil, M. (2005). Impact of riparian land use on stream insects of Kudremukh National Park, Karnataka state, India. *Journal of insect science*, 5(1), 10-49. DOI:10.1093/jis/5.1.49

Unmack, P.J. (2001). Biogeography of Australian freshwater fishes. *Journal of biogeography*, 28: 1053-1089.

DOI:10.1046/j.1365-2699.2001.00615.x

Vadas, R.L. & Orth, D.J. (1998). Use of physical variables to discriminate visually determined mesohabitat types in North American streams. *Rivers*, 6, 143-159.

Wiggins, G.B. & Mackay, R.J. (1978). Some relationships between systematics and trophic ecology in Nearctic aquatic insects, with special reference to Trichoptera. *Ecology*, 59: 1211-1220. DOI:10.2307/1938234

Wiggins, G.B. (1996). *Larvae of the North America caddisfly genera (Trichoptera)*. University of Toronto Press, London, 457pp. DOI:10.3138/9781442623606