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Composition and distribution of aquatic insect communities in relation to water quality in two freshwater streams of southern western ghats, India

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Abstract
The anthropogenic activities on aquatic insect communities in two freshwater streams (Kurangani and Valiparai) in Theni district, Tamilnadu, India were analysed. A total of 7473 aquatic insects belonging to 21 genera, 17 families from 8 orders were collected from August 2009 to July 2012. There is minimum significant difference was find out for the total dominance of aquatic insects between Kurangani (0.09197) and Valiparai stream (0.08774) respectively. Ephemeroptera, Plecoptera and Tricoptera (EPT) were the most dominant groups collected in two streams. The EPT showed that the pollution indicator group were highly abundant and more diverse at the upstream stations, but higher numbers of pollution-tolerant taxa Simulium was recorded at the downstream stations in both streams. In the present study revealed that distribution of aquatic insect communities could provide useful bioindicators of the biomonitoring approach in relation to water quality parameters to assess classify and compare the water quality of freshwater streams in southern Western Ghats, India.

Keywords: Aquatic insects, composition, distribution, water quality, bioindicator, India

Introduction
Streams are unique habitats which sustain substantial biodiversity. A large number of animal and plant species are restricted to streams and their survival is totally depending on the existence of these habitats. The stream ecosystem provides many tangible and intangible benefits on a sustainable basis, not only to an urban society but also to the associated dependent ecosystems. Macroinvertebrates and water quality are interrelated to each other, as macroinvertebrates are potential indicators of water quality. Benthic macroinvertebrates are one of the most common groups of organisms used to assess the health of aquatic ecosystem [1]. Comprehensive information on the physico-chemical and biological parameters will aid in developing conservation strategies for the riverine ecosystem of trophical biodiversity hot spots such as Western Ghats. The influence of human on streams and rivers used for recreational purposes such as personal hygiene has caused habitat impairment in several areas of south India. Direction of resulting impacts on streams depends on the use of biomonitoring combined with physical and chemical data [2].

The huge amounts of wastes that are generated in urban cities may find their way into surface waters of streams and rivers when carried by run-off from rain water, effluent discharges from industries and ruptured or blocked sewage lines in domestic areas. Water in streams and rivers may thus carry large amounts of matter comprising inorganic, organic and dissolved matter which may render the water unsuitable for direct use. Such water is said to be polluted. Oxygen levels may be reduced and the biochemical oxygen demand (BOD) may be increased. If the critical oxygen levels are exceeded then biological organisms may either die or migrate to regions with adequate oxygen [3].

In addition, sampling of aquatic insects has minimal detrimental effects on the resident biota. These are involved in nutrient recycling and form an important component of natural food web in aquatic ecosystem. These also serve as reliable indicators of ecological characteristics of water. Insects with their abundance and diversity dominate fresh water ecosystem. However, the aquatic insect fauna of this part in India is rather poorly documented. Limited numbers of studies have been carried out on the ecological aspects of aquatic insects [4, 5, 6].

Studies of aquatic insects of freshwater river and stream ecosystems have frequently examined

The species-habitat relationship with regard to the water quality of the habitat [7, 8].

Some species are known to have particular requirements with regard to nutrients, water quality substrate components and the structure of vegetation. Once these are defined, the presence of a particular species in a habitat indicates that the given determinants or parameters are within the tolerance limits of the species. Thus, the species is considered to belong to the habitat or ecosystem [9]. Data provided by indicator organisms can be used to estimate the degree of environmental impact and its potential dangers for other living organisms [10]. Biological monitoring, whereby living organisms are used to estimate the water quality or its chemical contents, is important in determining the health of an aquatic ecosystem. Physic-chemical monitoring of a water body is known to be insufficient to fully characterise its status or reliably detect adverse impacts [11]. However, it has been recognised as a vital component of an integrated assessment utilising physic-chemical and biological measure for assessing a waterway's condition [9].

Studies of freshwater aquatic insects as biological monitoring techniques have been widely reported and descried. Many have studied on the effects of anthropogenic activities, such agriculture and recreational [8, 12] aquaculture [13], runoff from land clearing and urban development [14]; river impoundment [15, 16], organic and metal contamination [17].

Indian subcontinent is blessed with diverse freshwater habitats. Three comprehensive and systematic reviews [18, 19] have clearly ascertained that hydrobiological studies in past were highly restricted to lentic ecosystems. Studies on lotic ecosystems especially streams have lagged behind those on the lentic ecosystems not only in India but throughout Asia [20]. Streams are physically heterogenous ecosystems consisting of a diverse assemblage of hydraulic habitats, associated environmental variables and biotic communities.

Several prominent native Indian scientists were associated with Annandale at the Indian Museum or worked in the universities at Calcutta, Madras and Bombay. Practically all kinds of habitats such as lakes, swamps, ponds, thermal springs, streams, torrents, rivers, coastal lagoons and estuaries were surveyed [21-25]. These surveys included detailed observations on water quality and related habitat characteristics, and their relationships with the organisms [26].

The emergence patterns in several odonate insects in a south Indian pond and calculated the loss of energy from the pond through the adults [27]. They simply accounted for the difference between the energy content of the eggs (import) and the adults (export) but did not consider the amount of energy consumed by the larvae during their development. The effects of salinity at different temperatures on the survival, development and oxygen consumption of an isopod, *Alitropus typus* and some other insects were reported [28]. The distribution and abundance in relation to substrate characteristics, food and feeding behaviour, and factors affecting growth and reproduction of many ephemeropteran insects have been investigated in the north-eastern[29, 30] and south Indian (28, 31, 32, 33, 47, 48, 49] streams and ponds.

Although the impact of anthropogenic activities on aquatic insect communities has been reported previously, very little is known about such effects particularly on Indian aquatic insect communities. Thus, this research attempted to determine the potential use of aquatic insect communities as bioindicators, as well as assess, classify and compare the health status of two freshwater streams in south India, India. It is hoped that the results from this study will provided baseline information that can be used as a first step towards establishing an efficient monitoring tool for the development of water-management system across south India [33].

Materials and Methods

Site description

The present study was conducted from August 2009 to July 2012 in two perennial hill streams of Kurangani (11°N and 77°.50°E) and Valiparai (11°N and 70° 50°E) Western Ghats. Kurangani was an amazing hill spot which was situated in Theni district, Tamilnadu, India. It is about 16 km away from Bodinayakkanur. The altitude of 650 above Meter Sea level (m.s.l) and Valipparai was situated about 105 km away from Madurai district. These two streams are more important water source for Vaigai reservoir. Both river basins received similar annual rainfall of approximately 1500 mm per year. During this study, the monthly rainfall was between 225 to 700 mm, with the highest amount of rain recorded in November but lowest in September. Both streams flow into Vaigai river. Each has a different land use patterns, sources of disturbance and pollution, and hydrological characteristics. At each stream, upstream and downstream stations were determined the health of the stream.

Both Kurangani and Valiparai streams are about 50 kilometers in length and have a catchment area approximately 15 km^2 and 12 km^2. Kurangani stream width of the upstream station ranged from 10.4-10.7 m and 0.40- 0.80 m deep, whereas width of the downstream station ranged between 10.2-10.4 m and 0.3-0.8 m deep. Valparai stream width of the upstream station ranged from 9.5-10.4 m and 0.30- 0.8 m deep, whereas width of the downstream station ranged between 10.2-10.4 m and 0.3-0.8 m deep. The stream bed of each station is almost debris- free, mainly comprising sand, pebbles, cobbles, small boulders and rocks. The upstream site is used for recreational activities. Therefore, more human disturbances were observed as compared to the downstream. Some parts of the stream reaches, particularly at middle between banks were totally exposed to sunlight, but banks were mostly covered by forest canopy, with grasses and shrubs growing in the undergrowth along the streams edges.

Riparian vegetation

Along the banks of the stream of Kurangani region is a sea of ridges and mountain peaks separated by valleys filled with virgin forests of *Ficus virens, F. calosa, F. hirsute, Pongamia pineta, Elage elaegues, Clerodendrum sp, Cipadessa baccifera, Bischofia javanica, Oreocnid infegrifolia, Trigonairridia pennies, Mallots ramnifolius,* and *Melia dubia, Landana camara* and various plantations like tea, coffee and cardamom. The riparian vegetation of Valiparai stream having thick stands of trees, shrubs, like *Pongamia pinnata, Lantana camera* are dominate the stream banks. Whose leaves are the streams principal source of organic detritus for the macroinvertebrates including aquatic insects [34].

Physico-chemical measurement

Width and depth of the streams were measured by using a marked pole and measuring tape at each station. Three replicates of air and water temperature, pH level, dissolved oxygen (DO) and free carbon dioxide were analyzed at sampling site. Water current was recorded by using cork and stopwatch. The time taken for a propeller to stop was recorded and later used to calculate water current. Total suspended solids (TSS) were measured through filtration of water samples using millipore with pre-weighted glass microfire filter papers (Whattman 47 mm). The millipore was used to sieve the suspended solids out of 1 L of water sample from each station on filter paper. The filter papers were the oven-dried and weighed.

Substrate index

Substrates were classified by using [46]. The following criteria: <0.5 mm for mud/silt, 0.5-2 mm for sand, 2-64 mm for gravel, 65-256 mm for cobbles, and >256 mm for boulders. For statistical analysis, substrate composition was converted to a substrate index [35].

Calculation

Substrate Index = (0.07 x% boulder) + (0.06 x% cobble) + (0.05 x% gravel) + (0.04 x% sand) + (0.03 x% mud/silt).

Collection of aquatic insect sampling (Quantitative method)

The larvae of aquatic insects were collected by taking kick net (mesh size; 0.5 to1.0 mm) method [32]. The duration of each kick net operation was 2 minutes. The substratum viz., bed rocks, boulders and cobbles was vigorously disturbed strictly restricted to one m^2 area. All specimens from the net surface were carefully collected without any morphological damage using fine forceps or brush and preserved in 80% alcohol immediately. Identification upto genus level was carried out by following the key provided [28, 33, 36, 50, 51]. The collected samples were transported to laboratory for further processing. Large aquatic insects were sorted by naked eyes whereas the sorting of the smaller ones was done under a dissecting microscope. All the sorted samples were kept in properly-labelled screw cap vials containing 80% ethanol.

Tropic categorization and Biomonitoring

Tropic categorization was based on the general category of functional feeding group (FFG) type involves the use of information on feeding habits of benthic taxa. The functional feeding group information was mostly derived from the ecological data in tables [37].

Biological Monitor Working Party (BMWP)

Biological Monitor Working Party (BMWP) score may otherwise be known as TSS (Total Site Score). Families of aquatic insects were tabulated separately for each station. Each family was ascribed the suitable score (10-1) depending on its sensitivity to pollution as prescribed by BMWP score system. Scores of indicator families were just added to arrive at BMWP or TSS [39].

Average Score Per Taxon (ASPT)

Average Score Per Taxon value was obtained from TSS by dividing it with total number of families recorded as follows, ASPT= Total Site Score/ Total number of families [40].

Data analysis

Biological indices were used to monitor the impact of disturbances and pollutions on the streams. The indices value will indicate but not specify what type of disturbances negatively impact of water quality [40]. Ephemeroptera, Plecoptera and Trichoptera (EPT) abundance and richness [41]. These metrics were based on the idea that unstressed streams and rivers have richer invertebrate taxa that were dominated by intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and were dominated y tolerant species. The indices used in this study were widely known and used in such similar studies elsewhere, including Taxa, Individuals, Dominance, Shannon, Simpson, Evenness, Margalef and Equotaility by using PAST software.

Results and Discussion

A total of 7473 individuals of aquatic insects representing 21 genera, 17 families from 8 orders were successfully collected and identified from both Kurangani and Valiparai streams from August 2009 to July 2012. Table 1 shows the overall composition and distribution of aquatic insect communities in both streams. More aquatic insects were recorded in Kurangani stream (3917 individuals) than in Valiparai stream (3556 individuals). However, the total numbers of individuals recorded in both streams were not significantly different (Shannon 2.842, 2.89 and 2.629, 2.748; Simpson 0.9346, 0.9379 and 0.9147, 0.9219; Margalef 2.541, 2.791 and 2.585, 2.826 up and down streams respectively). Ephemeroptera (60%) was the most dominant order with the highest number of individuals in both streams. It was followed by Trichoptera (22.0%) Coleoptera (8.7%), Plecoptera (3.4%), Diptera (1.5%), Hemiptera (2.3%) and Odonata (1.9%) in Kurangani stream. In contrast, Valiparai stream supported a slightly different aquatic insect community. The second highest order was Trichoptera (30.3%) followed by Coleoptera (8.4%), Plecoptera (3.9%), Diptera (1.1%), Hemiptera (2.4%), Odonata (2%). The least dominant order in Kurangani and Valiparai were Lepidoptera.

There was a significant difference of total individuals between the upstream and downstream stations in both streams. The number of individuals was higher at upstream stations than downstream stations in both streams (2623, 2291 and 1294, 1265) respectively. Ephemeroptera, Plecoptera and Trichoptera (EPT) were significantly abundant in both streams, especially at the upstreams. Members of EPT are considered to be sensitive to environmental stress, thus their presence in high abundance at the upstream signified a relatively clean environment [38]. Therefore, EPT were found to be a potential bioindicatios for a clean ecosystem.

Spatial and temporal variability of environmental factors may determine the organization of communities of aquatic insects [42]. In this study, both spatial and temporal sources of variation were important for the structuring of the EPT fauna during the investigation. During the period of study, field observations showed that the sites with smaller flow were more stable environments, as sudden increases in flow forced smaller perturbations than the great and quick increases in flow observed in rainy days at the upstream stations. Based on this observation, it would be expected the EPT fauna to show a larger temporal variability in streams of larger order. The percentage of EPT data confirm such assumption since, when considering the temporal variability of the fauna was clearly smaller in the upstream stations with lower flow in relation to those with larger flow.

The spatial variability of environmental variables in different scales is an important factor, which determines the organization of the communities of aquatic organisms in lotic environments. So, it is expected that the sample collected in the same site, in different periods of the year, would e more similar among themselves than the samples collected in other sites, though such assumption may not e confirmed in a highly seasonal environment [43], when studying highly seasonal streams in Ecuador, did not register very similar samples from the same station in two seasons (dry and rainy). In the present study, which also took place in a highly seasonal environment with much defined dry and rainy seasons, part of the samples collected in two streams in four stations. So, the samples collected in those four stations grouped together in two different groups, independently of the station. This pattern could be explained by the explained by the high environmental seasonality of the biome, that is, the seasonal variability can conceal the effect of spatial variability on the faunal structure. Seasonality was also an important factor in structuring the EPT fauna.

Diptera (primarily *Simulium*) were more abundant at the downstreams of both streams. Simulium was the most abundant and was found in all stations. They showed no habitat restriction as they exhibit a great variety of feeding types. Simulidae and Chironomidae is probably the most diverse and abundant group of all stream macroinvertebrates [44]. The number of Simulidae was higher at the downstream of both Kurangani and Valiparai streams. Standing and slow-flowing streams and muddy or sandy areas, with high fine-sediment particles are known to support higher diversity and abundance of Simulidae and Chironomidae.

The water quality data of Kurangani and Valiaparai streams collected during the survey is summarised in Table 2. In this study, total suspended solids (TSS), pH and width of the stream showed a significant relation the dominance of aquatic insects. The TSS concentration was negatively related with the number of aquatic insect orders (TSS 0.36, 0.46 and 0.46, 0.56; dominance of aquatic insects 0.06535, 0.08534 and 0.06212, 0.07806) respectively. This result indicated that, as TSS concentration increased, the diversity and dominance of aquatic insect declined. However, the pH level (7.63, 7.8 and 7.07, 6.85) was positively correlated to the number of genera. There was an also positive correlation between width (11.7, 10.4 and 10.4, 9.5) and depth (0.4, 0.8 and 0.3, 0.8) of streams and number of families (21) and individuals in both streams. Other water-quality parameters did not show a significant correlation to the aquatic insect communities. The dissolved oxygen concentration in the streams ranged from 8.07 to 10.64 mg/ L and 8.8 to 9.79 mg/L. In Kurangani stream, maximum of 10.64 mg/L of dissolved oxygen was recorded in the upstream. Whereas in Valiparai stream maximum dissolved oxygen was recorded in 9.79 mg/L upstream. Free carbon di-oxide concentration of the selected streams ranges from 1 to1.1 accordingly and the maximum record was in downstream with respect to Kurangani and Valiparai streams.

Data generated from this study were used to classify water quality for both stream. The classifications of the water quality of Kurangani and Valiparai streams are presented in table 2. All these biological indices and cluster analysis (Figure 1) provided better information about the environmental conditions under which they lived than a consideration of the individual taxa alone [38]. The evenness value in Kurangani and Valiparai were (0.8165, 0.8564 and 0.6598, 0.7435) indicating that the water quality of both streams was excellent. Based on the BMWP value, both streams scored a very high/good water quality but Valiparai downstream slightly lower BMWP value than Kurangani downstream. ASPT indicated that upsteam and downstream stations in Kurangani and Valiparai had clean water. The ASPT score foe Kurangani was 7.04, whereas Valiparai scored 6.94. The EPT index indicates the EPT taxa richness was higher in Kurangani stream than Valiparai stream. Both upstream and downstream of Kurangani had higher EPT Index than both station of Valiparai stream. The sensitive taxa (Ephemeroptea, Plecoptera and Trichoptera) were abundant in both streams, especially at upstresms. Diptera, especially Simulidae, were found comparatively more abundant in downstreams. Thus the results indicated that a better water quality was recorded in upsterems compared with downstresms of both Kurangani and Valiparai streams, where the impact of anthropogenic activities on the water quality and distribution of aquatic insects were clearly associated.

Human activities might change the normal development of these fragile ecosystems, especially at the downstream of Kurangani and Valiparai streams. The poorer water quality at downstream stations than at upstream stations in both streams could be attributable to several man-induced activities, such as sedimentation, sewage/ nutrients runoff and agricultural pesticides. A similar study done in Sekayu stream also found that human activities, such as recreational and agricultural activities, were clearly associated with a reduction in species diversity of aquatic insect communities in Sekayu Rereational Forest [45].

It shows that the variation of the aquatic insect assemblages is moulded by their different levels of sensitivity to pollution, together with many other abiotic factors in the stream ecosystem. Therefore, the water physic-chemical data, together with the presence/absence of aquatic insects at upstream and downstream stations indicated a function of a combination of natural and anthropogenic influences. Thus suggests that aquatic insects could be used as potential bioindicators for better water management in India.

Table 1: The composition and total abundance of aquatic insect communities in Kurangani and Valiparai streams, Southern Western Ghats during Aug-2009-July2012.

Order	Family	Genera	Kurangani stream			Valiparai stream		
			Upstream	Downstream	Total	Upstream	Downstream	Total
Ephemeroptera	Baetidae	*Beatis sp*	254	137	391	265	108	373
	Leptophlebiidae	*Choroterpes sp*	204	112	316	203	133	336
		Notophlebia sp	100	49	149	46	34	80
	Caenidae	*Caenis sp*	195	122	317	253	51	304
	Heptageniidae	*Epeorus sp*	149	34	183	31	48	79
	Tricorythidae	*Tricorythodes sp*	145	53	198	204	50	254
	Ephemeridae	*Ephemera sp*	96	86	182	86	32	118
Plecoptera	Perlidae	*Neoperla sp*	187	40	227	14	30	44
Trichoptera	Hydropsychidae	*Homoplectra sp*	25	16	41	296	116	412
		Hydropsyche sp	246	66	312	30	25	55
		Potamiya sp	70	42	112	66	32	98
		Macronema sp	91	47	138	24	26	50
		Leptonema sp	28	26	54	13	65	78
	Polycentropodidae	*Polycentropus sp*	35	65	100	150	100	250
	Stenopsychidae	*Stenopsyche sp*	165	99	264	100	3	103
Diptera	Simuliidae	*Simulium sp*	83	56	139	189	62	251

Coleoptera	Hydrophilidae	*Hydrobiomorpha sp*	146	49	195	62	35	97
	Psephenidae	*Ectopria sp*	80	84	164	233	182	415
Hemiptera	Gerridae	*Gerris sp*	258	76	334	9	38	47
Odonata	Coenagrionidae	*Coenagrion sp*	57	8	65	7	10	17
Lepidoptera	Pyralidae	*Petrophila sp*	9	27	36	10	5	15
Total			2623	1294	3917	2291	1265	3556

Table 2: The Physico-chemical parameters for each station in Kurangani and Valiparai streams of Western Ghats during Aug-2009- July-2012.

Parameters	Kurangani Stream		Valiparai Stream	
	Upstream	Downstream	Upstream	Downstream
Water Temperature (ºC)	21±0.47	23±0.47	22±0.47	23±0.94
Air Temperature (ºC)	24±0.94	25±0.47	25±0.47	26±0.94
Water Current (M/Sec)	7.80±0.47	7.4±0.12	7.2±0.47	7.0±0.47
Width (M)	11.7±0.12	10.4±0.12	10.9±0.47	9.5±0.47
Depth (M)	0.4±0.12	0.8±0.08	0.3±0.12	0.8±0.47
Dissolved oxygen (mg/L)	10.64±0.27	8.07±0.03	9.79±0.12	8.8±0.12
Free CO_2 (mg/L)	1.1±0.21	1±0.04	1±0.47	1±0.47
pH	7.63±0.27	6.93±0.06	7.8±0.12	6.85±0.12
Total Suspended Solids (TSS) (mg/L)	0.36±0.07	0.46±0.04	0.45±0.21	0.56±0.07
Substrate index	6.25	5.75	5.70	5.65

Table 3: Classification of water quality in Kurangani and Valiparai streams based on biological indices. (Note:% of Functional Feeding Groups (FFG); Biological Monitoring Work Party (BMWP); Average Score Per Taxon (ASPT); Ephemeroptera, Plecoptera and Tricoptera (EPT)

Study site		% of Functional Feeding Groups (FFG)											
		Coll.	Gath.	Scrp.	Filt.	Eng.	Pre	Class	BMWP	Class	ASPT	Class	(%) EPT
Kurangani stream	Upstream	38.88	19.44	13.88	19.44	2.77	5.55	Excellent	108	Good	7.33	Rather clean	33.33
	Downstream	35.48	25.80	16.21	6.45	9.67	6.45	Excellent	103	Good	6.75	Rather clean	25.55
	Total	37.18	22.62	15.04	12.94	6.22	6.00	Excellent	105.5	Good	7.04	Rather clean	29.44
Valiparai stream	Upstream	37.83	18.91	8.10	16.21	8.10	5.40	Excellent	106	Good	7.14	Rather clean	30.25
	Downstream	34.37	21.87	18.75	8.82	9.37	6.25	Excellent	100	Good	6.75	Rather clean	26.55
	Total	35.77	20.39	13.42	12.51	8.73	5.82	Excellent	103	Good	6.94	Rather clean	28.44

(Coll.- Collectors; Gath.- Gatherers; Scrp.- Scrapers; Filt.- Filterers;; Eng.- Engulfers; Pre.- Predators)

Table 4: Diversity indices of Aquatic insects in Kurangani and Valiparai up and downstreams Southern Ghats during Aug-2009- July-2012.

	Kurangani stream		Valiparai stream	
	Upstream	Downstream	Upstream	Downstream
Taxa	21	21	21	21
Individuals	2623	1294	2291	1185
Dominance	0.06535	0.06212	0.08534	0.07806
Shannon	2.842	2.89	2.629	2.748
Simpson	0.9346	0.9379	0.9147	0.9219
Evenness	0.8165	0.8564	0.6598	0.7435
Margalef	2.541	2.791	2.585	2.826
Equitability	0.9334	0.9491	0.8634	0.9027

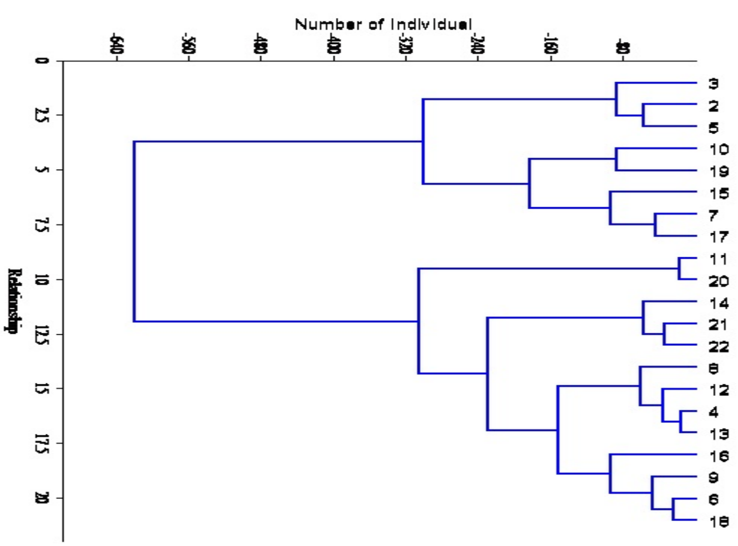

Fig 1: The cluster analysis of composition and total abundance of aquatic insect communities in 1nd Valiparai streams, Southern Western Ghats during Aug-2009-July2012.

Conclusion

Generally, the water quality of Kurangani and Valiparai streams can be considered as clean, based on the diversity and abundance of aquatic insects and values of biological indices used in this study. There were no significant differences between both streams in number of individuals, families and orders. The percentage of EPT (Ephemeroptera, Plecoptera and Trichoptera) to Simulidae was much higher at the downstreams stations in both streams, which shows the impacts of anthropogenic activities on the water quality, diversity and distribution of aquatic insects were clear. The biological indices (Shannon 2.842, 2.89 and 2.629, 2.748; Simpson 0.9346, 0.9379 and 0.9147, 0.9219; Margalef 2.541, 2.791 and 2.585, 2.826 up and down streams respectively; BMWP; ASPT) indicated the water quality of Kurangani and Valiparai streams as rather clean to excellent water quality. An updated list of aquatic insects found in Kurangani and Valiparai stream would be useful in determining the responses of aquatic insects to their surrounding environment. In conclusion, distribution of aquatic insect communities provides useful bioindicators of the biomonitoring approach in order to provide a complete spectrum of information for appropriate water management of freshwater streams in India.

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