

Community structure of mayflies (Insecta: Ephemeroptera) in tropical streams of Western Ghats of Southern India

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ABSTRACT

The main objective of this study was to evaluate the community structure of the order Ephemeroptera in the Southern Western Ghats ecoregion along with Principal Component Analysis (PCA) and Canonical Correspondence Analysis (CCA) from 2017 to 2018. Ecological parameters estimated at each collecting site were pH, dissolved oxygen, biological oxygen demand, hardness and alkalinity. This research investigation was carried out in 30 streams of Palni and Cardamom hills in Western Ghats of Southern India. With PCA examination, the sites like Dhobikana, Fern hill and Poomparai of Palni hills are plotted far apart and are not supported by the ecological parameters like in the other sites. Dhobikana of Palni hills is exceptionally contaminated in light of the fact that dhobis are associated with washing garments so cleanser contamination is prevalent around there. In cardamom hills, Santhamparai near bridge and Nayamakkadu are left far apart indicating they are not supported by physico-chemical parameters, mainly due to pollution. From the CCA results, it is discovered that *Baetis* species favor β -mesosaprobic habitat and *Indialis badia* inclines toward high altitudinal region. From the outcomes, it is presumed that pH, dissolved oxygen, biological oxygen demand, hardness and alkalinity were the essential components administering the mayfly community and structure.

Keywords: PCA, Dhobikana, Dissolved oxygen, pH, *Baetis*, *Ephemera nadinae*

Introduction

Ephemeroptera also called as mayflies and they are cosmopolitan in distribution (Barber-James *et al.*, 2008). They do secondary production activity in freshwater habitat. Most families of mayflies are sensitive to pollution and they inhabit only in freshwater environment, so they serve as bio indicators of water quality.

Streams and rivers are an example of an important habitat and source of water for all living organism and human being. Pollution either by anthropogenic activity or by nature can unfavorably influence any biological ecosystem. The pollution in the freshwater ecosystem affects the mayfly's richness and diversity. Streams become contaminated by water entering from the farming area or modern destinations, and the nature of the water will be reflected by the kinds of the animals that can endure such as mayflies.

The ecological attributes like pH, turbidity, dissolved oxygen, air temperature, water temperature, alkalinity, total dissolved solids and various pollutants legitimately and by implication influence the mayfly populations. Deforestation is one of the primary threats to mayfly biodiversity and conservation in the tropics (Benstead and Pringle, 2004) whereas pollution (Rosenberg and Resh, 1993) or habitat fragmentation (Zwick, 1992) are the major causes in the temperate areas.

Numerous investigations have been made in recent years on the effect of climate change on mayflies. Clearly, climate changes are affecting the behavior and ultimately the ecology of some mayflies, for example, small increases in temperature (3°C) over the short term cause early emergence of mayflies (McKee and Atkinson, 2000). Climate changes alter precipitation pattern, leading to greater flood magnitude and frequency in certain rivers. This results in changes in ecological structure and function, and loss of diversity through too frequent scouring. With the continuing trend of temperature increase, the proportion of glacial melt and snow melt waters will change and lead to drastic changes in macroinvertebrate communities, including mayflies.

Ephemeroptera have been extensively used as bioindicators in aquatic biomonitoring programs (Srinivasan *et al.*, 2019), in biomarker studies and in ecotoxicological studies. During the last two decades, EPT concept has successfully emphasized the significance of Ephemeroptera, Plecoptera, and Trichoptera in describing environmental conditions (Lenat and Barbour, 1994). In the current investigation, we utilize multivariate examination strategy Canonical Correspondence

Analysis (CCA) to establish the community structure of mayflies and Principal Component Analysis (PCA) to find the relationship between stations and environmental parameters. Multivariate investigation strategies have just been utilized to consider the connection between benthic macroinvertebrate community and ecological factors in all around the globe from the previous studies (Kazanci *et al.*, 2017; Duran and Akyildiz, 2011). As Palni and Cardamom hills belongs to the southern part of the Western Ghats, which is one of the eight hottest hotspots in the globe (Myers *et al.*, 2000) and no work had to be done in the population dynamics and community structure of mayflies in this part of Western Ghats, so this work aims to assess the relationship between mayfly community and environmental factors in Palni and Cardamom hills of Western Ghats.

Material and Methods

Study Area

Mayfly nymphs were collected from 2017- 2018 in thirty sites (16 from Palni hills and 14 from Cardamom hills) using 1m wide Kick-net (Burton and Sivaramakrishnan, 1993) with mesh size of about 1mm and they were identified with the help of various taxonomical literatures. Table 1 shows the descriptions of these sites. List of mayfly taxa of Palni and Cardamom hills is given in the Table 2 and 3 respectively.

Measuring Physicochemical Parameters

Water samples were collected from sampling sites and various physicochemical parameters like pH, dissolved oxygen, air temperature, water temperature, water current, width of the stream, hardness, alkalinity, total dissolved solids, conductivity and Biological oxygen demand were analyzed using APHA guidelines (2005).

Statistical Analysis

To view the trend of distribution of the stations based on environmental parameters the PCA (Principal Components Analysis) was used. PCA was calculated by using PAST software 4.02 (Hammer *et al.*, 2001). Mathematically, PCA consists of Eigen-analysis of a covariance or correlation matrix calculated on the original measurement data. To investigate the relationships between ecological factors and various stations, PCA was used. Canonical Correspondence Analysis (CCA) was made to found the community structure of mayflies in relationship to environmental variables.

Table 1. Details of the 30 study sites

S. No	Name of the study site	Abbreviation in PCA	Abbreviation in CCA	Stream order	Altitude (m)	Latitude (N°)	Longitude (E°)
1	Oothu	Ooth	P-1	3	1300	10°12'	77°26'
2	Perumalmalai	Peru	P-2	2	1400	10°18'	77°33'
3	Kurusadai	Kuru	P-3	2	1700	10°20'	77°28'
4	Ghandhi nagar	Gand	P-4	2	1600	10°18'	77°27'
5	Silver cascade	Silv	P-5	2	1700	10°12'	77°28'
6	Vattakanal	Vatt	P-6	2	1000	10°11'	77°25'
7	Fairy falls	Fair	P-7	3	290	10°13'	77°27'
8	Bear Shola falls	Bear	P-8	2	300	10°14'	77°27'
9	Fern hill falls	Fern	P-9	3	122	10°12'	77°20'
10	Pillar rock	Pill	P-10	1	2250	10°17'	77°28'
11	Near pillar rock	Near pill	P-11	1	2255	10°12'	77°30'
12	Pambar stream	Pamb	P-12	2	2248	10°13'	77°28'
13	Dhobikana	Dhob	P-13	3	2075	10°24'	77°24'
14	GundarFalls	Gund	P-14	2	2200	10°14'	77°26'
15	Poomparai	Poom	P-15	2	2133	10°13'	78°16'
16	Kouchi	Kouc	P-16	2	2360	10°29'	77°30'
17	Kurangani up	Kura-up	C-1	2	2410	11°00'	77°50'
18	Kurangani down	Kura-down	C-2	2	2345	11°00'	77°45'
19	B. L. Rave	B.L.Rave	C-3	1	1250	10°11'	77°25'
20	Poonthampanai	Poon	C-4	1	1300	11°12'	77°26'
21	Santhamparai near bridge	San-bridge	C-5	2	1350	11°00'	77°52'
22	Santhamparai near SDA school	San-SDA	C-6	4	1400	11°13'	77°28'
23	Mattupetty Dam stream	Matt	C-7	2	1700	11°16'	77°29'
24	Anayirankal stream	Anai	C-8	2	1950	11°18'	77°31'
25	Aranmanai parai	Aran	C-9	3	2050	11°21'	77°33'
26	Popparai	Popp	C-10	4	1785	11°44'	77°26'
27	Bodimettu	Bodi	C-11	2	1500	11°15'	77°24'
28	Thoovanam falls	Thuv	C-12	3	1550	11°15'	77°15'
29	Nayamakkadu falls	Naya	C-13	2	2197	11°20'	77°10'
30	Chinnakanal falls	Chin	C-14	1	1800	11°27'	77°30'

Table 2. Species of Mayflies in Palni hills

ORDER	FAMILY	GENUS AND SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
			Ooth	Peru	Kuru	Gand	Silv	Vatt	Fair	Bear	Fern	Pill	Near pill	Pamb	Dhob	Gund	Poom	Koun
	Baetidae	<i>Baetis acceptus</i>	11	12	8	31	11	19	22	19	27	17	11	17	17	24	30	17
		<i>Baetis conservatus</i>	8	17	11	11	8	21	18	11	17	20	23	22	18	26	19	32
		<i>Tenuibaetis frequentus</i>	12	21	22	8	17	43	52	29	29	33	42	32	20	42	17	42
		<i>Baetis ordinates</i>	8	11	5	0	0	0	14	5	10	5	10	19	10	27	42	12
		<i>Labiobaetis geminatus</i>	5	7	11	11	17	45	29	28	17	7	5	8	0	42	29	32
Ephemeroptera		<i>Centroptella similis</i>	12	11	20	21	17	46	23	17	12	11	0	21	0	0	17	14
		<i>Centroptella ceylonensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		<i>Acentrella vera</i>	0	0	0	0	0	0	0	0	0	0	0	0	12	11	0	11
	Heptageniidae	<i>Afronurus sp.</i>	26	0	0	22	0	0	0	0	0	0	0	0	34	41	0	0
		<i>Afronurus kumbakkaraiensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		<i>Epeorus petersi</i>	0	0	0	0	0	0	0	0	0	10	0	0	0	26	0	0
		<i>Thalerosphyrus flowersi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0
	Leptophlebiidae	<i>Choroterpes alagarensis</i>	22	18	0	47	41	39	52	37	23	47	32	38	65	27	0	35
		<i>Edmundsula lotica</i>	0	0	17	10	0	33	29	27	15	53	62	31	24	17	17	33
		<i>Indialis badia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	13
		<i>Isca purpurea</i>	24	19	21	25	41	43	21	26	37	27	18	23	36	28	0	39
		<i>Nathanella indica</i>	10	5	17	0	0	0	19	22	27	0	5	11	0	0	0	0
		<i>Notophlebia jobi</i>	5	0	11	0	23	16	6	17	17	7	0	23	0	0	21	0
		<i>Petersula courtallensis</i>	15	0	0	20	17	18	14	10	18	11	11	10	17	14	17	0
	Neophemeridae	<i>Potamanthellus ganges</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
		<i>Thraulius gopalani</i>	0	0	6	4	0	8	5	9	0	0	13	21	0	0	21	0
	Teloganodidae	<i>Teloganodes dentata</i>	11	8	17	14	17	11	8	21	14	24	19	12	19	0	32	32
		<i>Teloganodes kodai</i>	17	14	8	27	14	21	22	23	33	16	62	42	0	0	27	28
		<i>Teloganodes insignis</i>	13	6	15	8	19	0	0	0	0	14	5	45	52	38	54	0
	Ephemeridae	<i>Ephemera nadiniae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52
	Caenidae	<i>Caenis sp.</i>	32	14	8	10	27	12	21	32	29	13	18	7	8	12	29	36

Table 3. Species of Mayflies in Cardamom hills

ORDER	FAMILY	GENUS AND SPECIES	17	18	19	20	21	22	23	24	25	26	27	28	29	30
			Kura-up	Kura- down	B.L.Rave	Poon	San-bridge	San-SDA	Matt	Anai	Aran	Popp	Bodi	Thuv	Naya	Chin
	Baetidae	<i>Baetis acceptus</i>	0	0	17	17	0	0	0	42	0	0	22	0	41	12
		<i>Baetis conservatus</i>	0	0	11	15	0	0	0	31	0	19	0	12	29	32
		<i>Tenuibaetis frequentus</i>	42	21	29	42	13	21	32	31	17	23	33	27	17	27
		<i>Baetis ordinatus</i>	0	0	33	27	31	17	17	21	22	17	22	18	23	30
		<i>Labiobaetis geminatus</i>	32	17	21	41	0	39	32	42	17	10	17	27	37	41
Ephemeroptera		<i>Centroptella similis</i>	37	21	17	31	34	13	33	27	0	15	16	22	0	30
		<i>Centroptella ceylonensis</i>	0	0	16	34	5	25	29	0	11	0	0	0	17	0
		<i>Acentrella vera</i>	0	0	25	0	0	30	31	0	0	21	32	0	0	0
	Heptageniidae	<i>Afronurus sp.</i>	0	0	0	32	0	0	33	24	29	42	0	33	32	25
		<i>Afronurus kumbakkaraiensis</i>	37	17	42	42	15	19	47	37	33	32	21	37	29	33
		<i>Epeorus petersi</i>	31	20	33	27	23	22	31	33	12	42	32	33	37	12
		<i>Thalerosphyrus flowersi</i>	47	28	0	0	0	0	0	0	0	33	14	0	0	0
	Leptophlebiidae	<i>Choroterpes alagarensis</i>	62	32	52	21	33	41	21	35	27	55	32	41	24	32
		<i>Edmundsula lotica</i>	0	0	0	0	16	17	31	0	31	32	37	33	23	27
		<i>Indialis badia</i>	23	32	0	0	0	0	0	29	0	0	0	0	0	0
		<i>Isca purpurea</i>	5	0	15	33	21	55	36	44	32	17	13	31	21	30
		<i>Nathanella indica</i>	32	17	0	0	0	28	0	0	0	0	0	0	0	21
		<i>Notophlebia jobi</i>	13	11	27	13	14	10	19	0	35	27	20	27	30	21
		<i>Petersula courtallensis</i>	10	15	0	0	0	0	23	27	34	32	15	13	11	0
	Neoephemeridae	<i>Potamanthellus ganges</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		<i>Thraululus gopalani</i>	17	11	0	0	0	0	0	0	25	0	0	0	5	0
	Teloganodidae	<i>Teloganodes dentata</i>	0	0	0	27	21	18	0	16	20	19	27	0	27	23
		<i>Teloganodes kodai</i>	0	0	0	0	23	21	43	0	34	0	14	17	10	0
		<i>Teloganodes insignis</i>	0	0	0	0	17	17	0	0	25	0	0	0	0	0
	Ephemeridae	<i>Ephemera nadinae</i>	98	5	0	0	0	0	0	0	0	0	0	0	0	0
	Caenidae	<i>Caenis sp.</i>	27	42	42	33	17	29	21	32	19	31	0	23	39	31

Results and Discussion

PCA Analysis of Palni Hills

Based on the scree plot results, three components were chosen in both Palni and Cardamom hills. PCA of Palni hills identified three principle components of water quality measures that explained 80.05% of the variation (Table 4) in water quality between streams. Figure 1 shows the PCA of Palni hills. PCA analysis of Palni hills categorize the sites into three groups which are referred as components namely component 1, component 2 and component 3.

Component 1 is positively correlated with the parameters like water temperature, air temperature and dissolved oxygen (DO), velocity and width of the stream (Figure 2), pH and hardness are not supporting these sites. The sites included in this component are Oothu, Fairy falls, Vattakanal, Perumalmai, Kurusadai and Bear chola. In this component Perumalmai is distantly placed.

The study sites in component 2 are Dhobikana, Poomparai and Pambar are highly correlated with Hardness, alkalinity, water temperature, air temperature and width of the stream (Figure 3). pH, conductivity, DO and BOD are negatively correlated with the component 2 sites. In this component,

Dhobikana and Poomparai are distantly placed. Component 3 (Figure 4) includes Silvercascade, Kouchi, Pillar rock, near pillar rock, Fern hill, Gundar and Ghandhinagar. Here pH, water temperature, air temperature, conductivity, width and TDS are highly positively correlated whereas DO, velocity, hardness, alkalinity and BOD are negatively correlated. Fern hill is placed away from other sites.

Table 4. Variance explained and the eigen values for the physico-chemical variables of Palni hills

Axis	Eigen value	% Variance
1	2.94849	26.804
2	2.5278	22.98
3	1.86774	16.979
4	1.23612	11.237
5	0.904433	8.2221
6	0.722309	6.5664
7	0.422977	3.8452
8	0.210023	1.9093
9	0.088112	0.80101
10	0.069933	0.63575
11	0.002067	0.018794

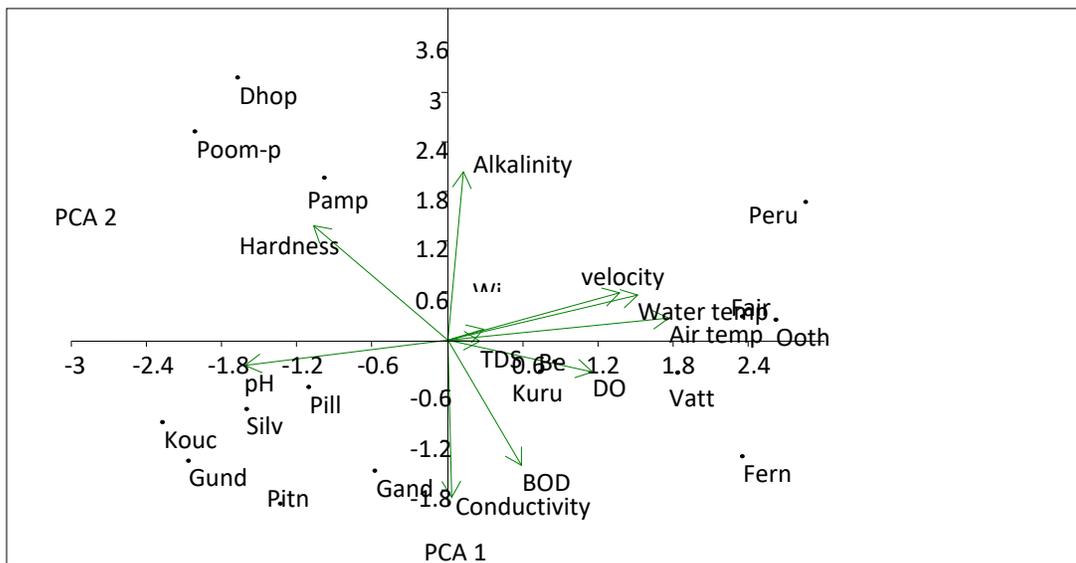


Figure 1. Principal component Analysis for Palni hills

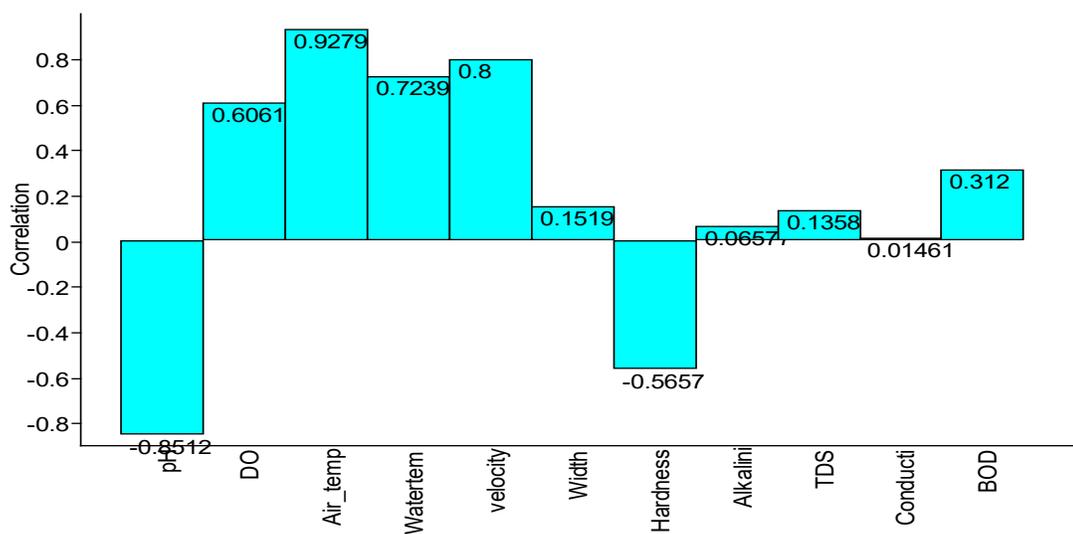


Figure 2. Component 1 of PCA in Palni hills

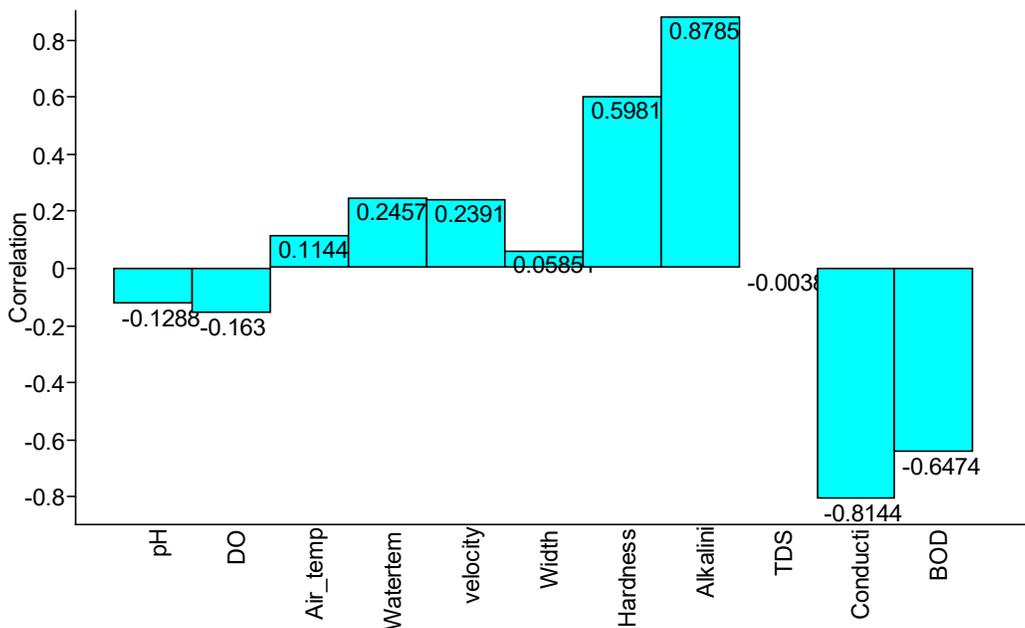


Figure 3. Component 2 of PCA in Palni hills

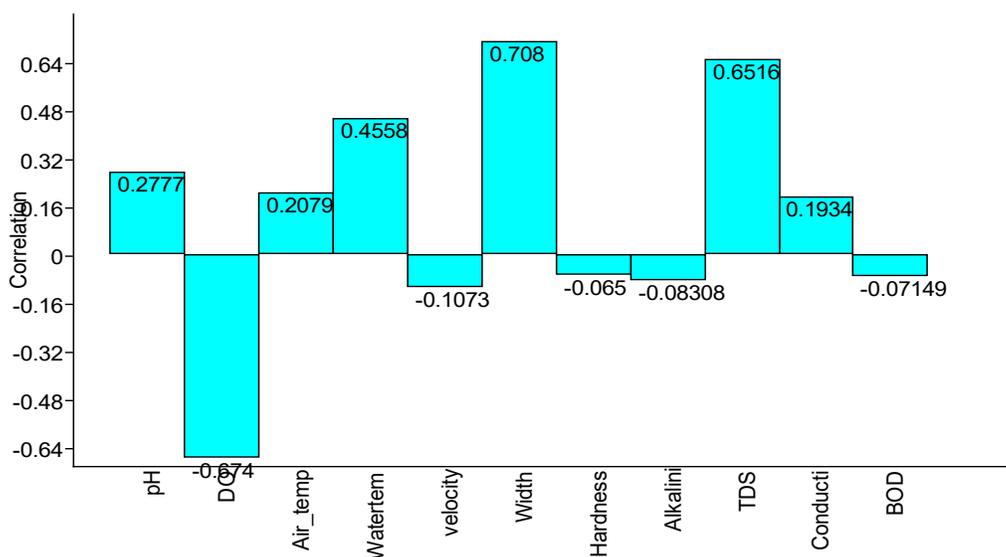


Figure 4. Component 3 of PCA in Palni hills

PCA Analysis of Cardamom Hills

PCA for Cardamom hill is shown in Figure 5. The first three components of the PCA for physicochemical parameters at the sites collectively explained 77% of the variability at these sites (Table 5).

In component 1 (Figure 6) DO, air temperature, water temperature, hardness, alkalinity, TDS, conductivity and BOD are positively correlated with the sites Popparai, Poonthampalai, Bodimettu, Anayirangal, Chinnakanal, Aranmanai-parai and Mattupatti. But these sites are negatively correlated with pH, velocity and width of the stream. Supporting factors of component 2 (Figure 7) are pH, velocity, width of the stream, hardness, BOD and alkalinity. Air temperature, water temperature, DO, TDS and conductivity are negatively correlated to the site Nayamakkadu. Nayamakkadu alone is placed under component 2.

Figure 8 representing component 3 shows that all the parameters are highly positively correlated with the sites. The sites included in this component are Kurangani up, Kurangani down, Thoovanam, B. L. Rave, Santhamparai SDA and Santhamparai near bridge. The site Santhamparai near bridge is plotted far away in the third components.

Table 5. Variance explained and the eigenvalues for the physico-chemical variables of Cardamom hills

Axis	Eigen value	% Variance
1	3.58035	32.549
2	2.38903	21.718
3	1.77327	16.121
4	1.06369	9.6699
5	0.880061	8.0006
6	0.468153	4.2559
7	0.416393	3.7854
8	0.222051	2.0186
9	0.118548	1.0777
10	0.062119	0.56472
11	0.026342	0.23947

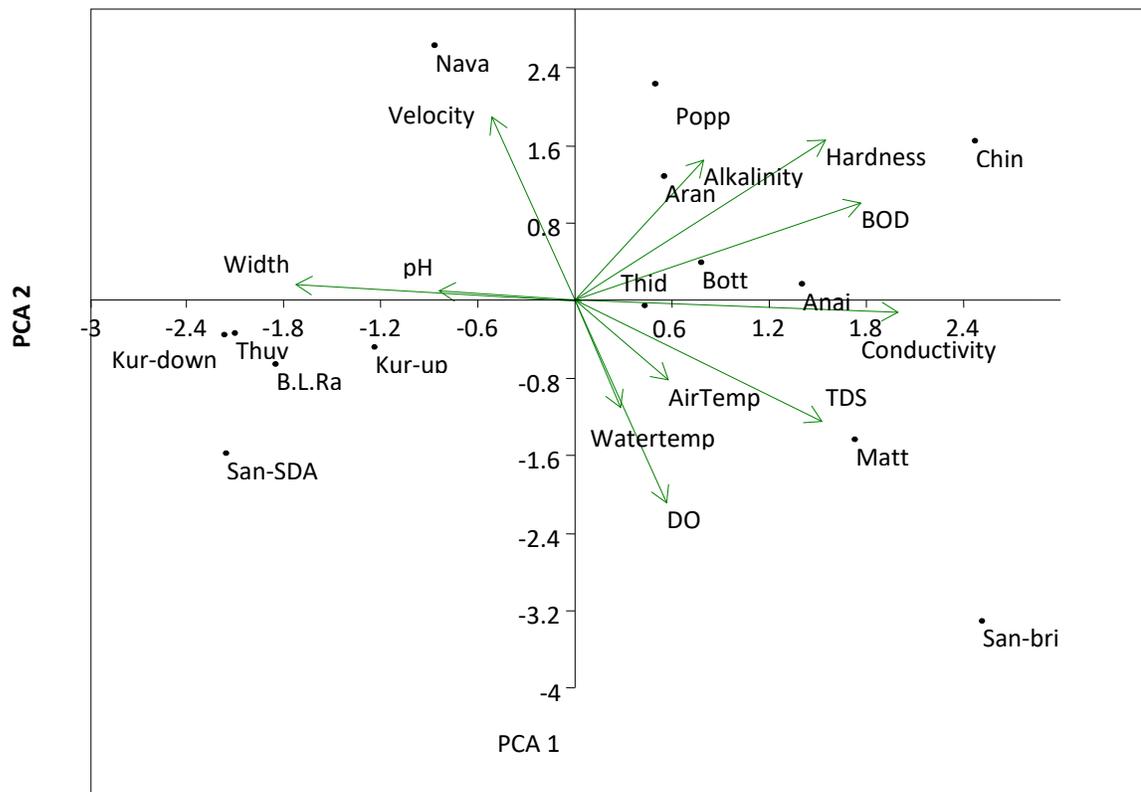


Figure 5. Principal component Analysis for Cardamom hills

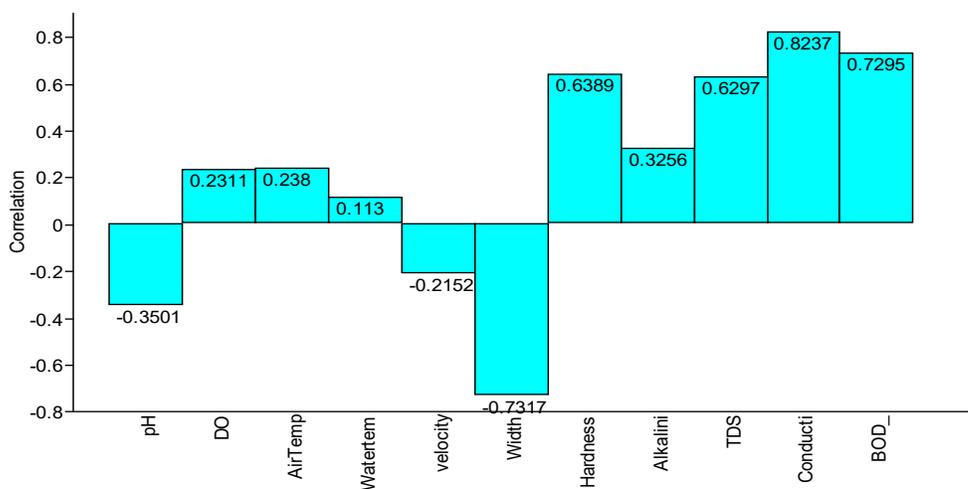


Figure 6. Component 1 of PCA in Cardamom hills

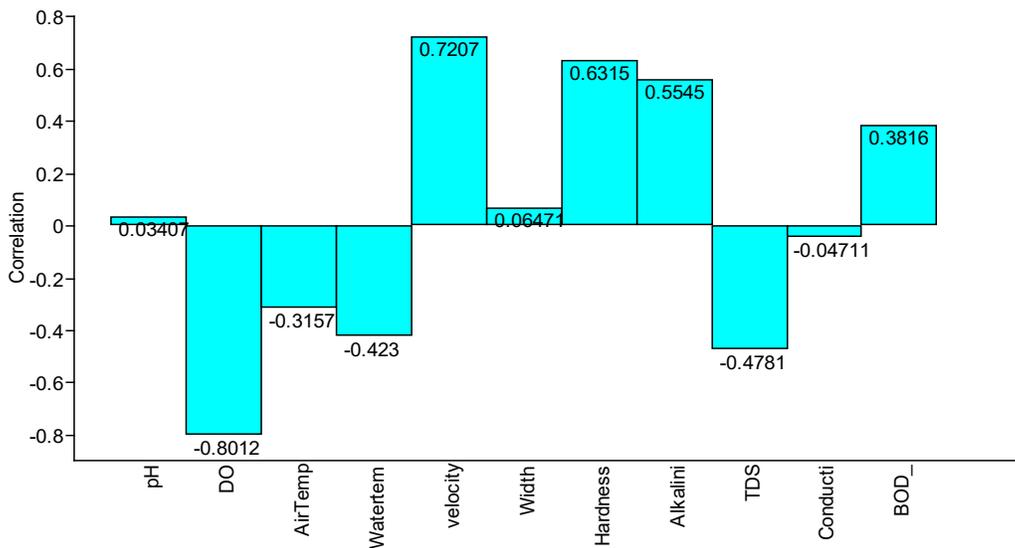


Figure 7. Component 2 of PCA in Cardamom hills

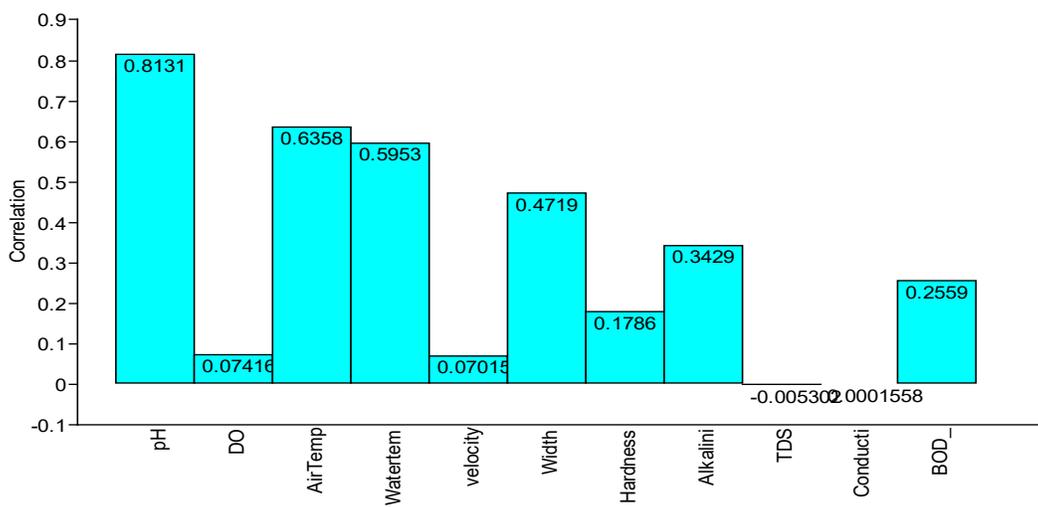


Figure 8. Component 3 of PCA in Cardamom hills

pH

Mayfly nymphs are sensitive to low pH. In Palni hills components 1 and 2 are negatively correlated with pH whereas, component three is positively correlated. The pH of the sites ranges between 6.3-7.52 (Table 6). Due to anthropogenic impacts, the pH is slightly acidic in certain sites like Vattakanal. Streams typically have a slightly basic pH value ranging from 7 to 8. Most organisms have optimal pH ranges in which they live that fall between 6 and 8 (Campbell and Wildberger, 2001). Even slight changes in the normal pH can have considerable effects on mayflies. In cardamom hills except component 1 the other two components are negatively correlated with pH. In this hill the pH ranges 6.0 to 7.4 (Table 7).

Dissolved Oxygen

The standard levels indicate that Dissolved Oxygen (DO) 4 – 7 mg/l is good for mayflies (Payne, 1986). DO plays a vital role in supporting aquatic life and is susceptible to slight environment changes and hence DO have been extensively used as a parameter delineating water quality and to evaluate the degree of freshness of a river (Fakayode, 2005). DO is positively correlated with component 1 of Palni and Components 1 and 3 are positively correlated in Cardamom hills. The DO in the sites was found within the range (4 -7.7 mg/L) (Table 6).

Water Temperature and Air Temperature

Based on the earlier works it is understood that the positive correlation with the water temperature and air temperature plays a major role in maintaining the number of organisms. The PCA results of both the hills show positive correlation for Water temperature and air temperature except component 2 in cardamom hills.

Alkalinity

Total alkalinity of water is due to presence of mineral salt present in it. It is primarily caused by the carbonate and bicarbonate ions. Levels of alkalinity between 100 and 200 mg/L provide ideal buffering within a stream. But it has the permissible limit up to 600mg/L. In the present study the alkalinity falls under the permissible limit (345-367 mg/L). Among both the hills alkalinity show positive relation with all components except Component 3 of Palni hills.

Total Dissolved Solids (TDS)

Total Dissolved Solid is a measurement of inorganic salts, organic matter and other dissolved materials in water, TDS above 1340 mg/l may adversely affect mayflies (Good fellow *et al.*, 2000; SETAC, 2004). TDS and the associated elevated conductivity seem to be particularly toxic and stressor to mayfly community in the streams (Pond *et al.*, 2008). In the

present study TDS is highly correlated with all the components.

Hardness

Total hardness is used to describe the effect of dissolved minerals (mostly Ca and Mg). Optimal values of hardness of aquatic life range from 100 to 200 mg/L. At levels above 250 mg/L, calcium carbonate will begin to precipitate. According to the results, hardness is negatively correlated with components 1 and 3 in Palni hills, and in Cardamom hills it is positively correlated with all the sites. The high value of total hardness may be due to discharge of sewage from nearby places, use of soaps and detergents by laundries, washing, bathing by people.

Biological Oxygen Demand (BOD)

Healthy streams which have BOD reading of less than 2 mg/l, whereas polluted streams is of 10 mg/L. In components 2 and 3 in Palni hills, the BOD is negatively correlated and the other components are positively correlated.

Conductivity

Most streams ranges between 50 to 1500 μ S/cm. Ideal levels of conductivity for the mayfly richness ranges 150 to 500 μ S/cm. In the study sites, components 2 of both the hills are negatively correlated.

Velocity and Stream Width

Velocity is correlated positively except component 3 for Palni hills and component 1 of Cardamom hills. Stream width is positively correlated except component 1 of Palni hills.

CCA Analysis

The relationship between the mayfly's communities and the environmental parameters was depicted by CCA (Canonical Correspondence Analysis). For CCA analysis, eleven environmental variables were used. Figure 9 shows the result of ordination of sites and Ephemeroptera with respect to environmental variables in Palni hills. From the outcomes, the destinations P-1, P-4, P-11, P-13, P-14 and P-16 were found away from the referenced ecological factors and were influenced by anthropogenic action and slightly polluted. The sites P-2, P-3, P-5, P-6 P-7, P-8, P-9 and P-10 were decidedly connected with factors like air temperature, water temperature, DO, BOD, TDS, conductivity and current speed whereas it is it is contrarily related with pH, altitude, hardness and alkalinity. Sites include P-12 and P-15 were positively correlated with pH, altitude, hardness and alkalinity and adversely related with air temperature, water temperature, DO, BOD, TDS, current speed and conductivity.

Table 6. Physico-chemical features, water quality parameters of the sampling sites in Palni hills

S. No	Site	pH	D.O (mg/L)	Air temp (°C)	Water temp (°C)	Current speed (sec m ⁻¹)	Width (m)	Hardness (mg/L)	Alkalinity (mg/L)	Total dissolved solids (ppt)	Conductivity (µs/cm)	BOD (mg/L)
1	Ooth	6.8	4.6	18.7	15	11	6 – 7	73	342	0.132	108	2.3
2	Peru	6.3	4.7	18.3	15.4	11	2 – 3	87	342	0.099	79	2.45
3	Kuru	7.3	4.2	17.7	16	6	2.5 – 3	83	312	0.089	87	3.88
4	Gand	7.35	4.3	16	14	5	2 – 3	90	288	0.093	112	2.65
5	Silv	7.36	4.2	15.7	13.4	3	5 – 10	98	299	0.084	103	2.34
6	Vatt	6.3	4.9	18.3	14	5	1 – 2	85	321	0.079	102	2.53
7	Fair	6.5	4.4	19.7	16.1	9	1 – 2	94	314	0.083	97	2.78
8	Bear	7.1	4	18.9	15	6	2 – 3	85	323	0.769	110	2.57
9	Fern	6.5	4.8	19	14.6	8	1 – 2	102	312	0.094	125	4.12
10	Pill	7.47	4.4	15	11.4	6	0.5 – 1	90	343	0.122	105	3.23
11	Near pill	7.4	4.5	15.4	10	6	1 – 2	92	288	0.093	112	2.65
12	Pamb	6.9	4.3	15.8	13.2	5	2 – 3	112	345	0.098	93	1.3
13	Dhob	7.52	4	16.3	14.1	6	1 – 2	156	367	0.085	76	2.32
14	Gund	7.45	4	14.5	13	4	4 – 6	107	304	0.097	126	2.87
15	Poom	7.25	4.3	15.4	12	5	2 – 3	143	353	0.112	88	1.4
16	Kouc	7.3	4.4	14	10.5	4	0.25–0.5	94	314	0.083	97	2.78

Table 7. Physico-chemical features, water quality parameters of the sampling sites in Cardamom hills

S. No	Site	Ph	D.O (mg/L)	Air Temp (°C)	Water temp (°C)	Current speed (sec m ⁻¹)	Width (m)	Hardness (mg/L)	Alkalinity (mg/L)	Total dissolved solids (ppt)	Conductivity (µs/cm)	BOD (mg/L)
1	Kura-up	6	6.7	21	18.5	3 – 4	10	72	312	0.077	80	1.74
2	Kura-down	7.3	6.4	22	18.4	4 – 5	11	82	267	0.089	79	1.32
3	B.L.Rave	7.2	6.3	23	19.1	4 – 6	8	48	333	0.082	92	0.89
4	Poon	7.4	6	22	20.2	3 – 4	10	94	384	0.132	108	2.3
5	San-bridge	6.5	7.7	23	18.3	2 – 3	5	87	267	0.688	124	1.65
7	San-SDA	7.4	6.8	23	20.2	4 – 5	11	55	237	0.073	86	1.54
6	Matt	6.4	7.4	24	19.1	3 – 4	4	89	306	0.129	105	2.65
8	Anai	7.1	7.4	24	20.3	3 – 4	8	173	435	0.1	89	3.46
9	Aran	6.5	6	23	16.5	4 – 6	7	102	354	0.093	106	2.32
10	Popp	7.5	5.2	23	18.4	5 – 6	12	156	345	0.098	105	4.32
11	Bodi	6.4	6.5	20	19.4	4 – 5	4	98	299	0.084	103	2.76
12	Thuv	6.4	6.8	22	17.1	3 – 4	10	61	321	0.043	79	1.32
13	Naya	6.8	4.1	21	16.4	4 – 5	8	143	342	0.098	93	1.3
14	Chin	6	6.3	22	18.3	5 – 6	3	156	345	0.096	106	4.35

The taxa like B con- *Baetis conservatus*, B ord- *Baetis ordinatus*, Ac ver- *Acentrella vera*, T flo- *Thalerosphyrus flowersi*, C ala- *Choroterpes alagarensis*, Ed lot- *Edmundsula lotica*, Ind bad- *Indialis badia*, Po gan- *Potamanthellus ganges*, Th gop- *Thraulius gopalani*, Te ins- *Teloganodes insignis* gets upheld by environmental attributes like pH, altitude, hardness and alkalinity and negatively correlated with air temperature, water temperature, DO, BOD, TDS, conductivity and current speed. If riparian vegetation is high, there is an increase of pH in natural water (Wetzel, 2001). So the outcomes appears, the above taxa lean toward denser riparian environment for their source of living. Te fre- *Tenuibaetis frequentus*, Lb ger- *Labiobaetis geminatus*, Ce sim- *Centropptella similis*, Ce cey- *Centropptella ceylonensis*, A kum- *Afronurus kumbakkaraiensis*, C ala- *Choroterpes alagarensis*, I pur- *Isca purpurea*, N ind- *Nathanella indica*, No jo- *Notophlebia jobi*, Cae sp- *Caenis* sp gets enriched by the attributes like air temperature, water temperature, DO, BOD, TDS, conductivity and current speed and diminished by the factors pH, altitude, hardness and alkalinity. They don't lean toward low temperature and low dissolved oxygen, so above reference taxa just incline toward cool condition and they are the markers of natural contamination since they are profoundly tolerant to the acidic and basic situations. B acc- *Baetis acceptus*, A ker- *Afronurus* sp., Ep pet- *Epeorus petersi*, P cour- *Petersula courtallensis*, Te den- *Teloganodes dentata*, Te kod- *Teloganodes kodai* and Eph nad- *Ephemera nadinae* shows no relation to any of the above 11 environmental variables.

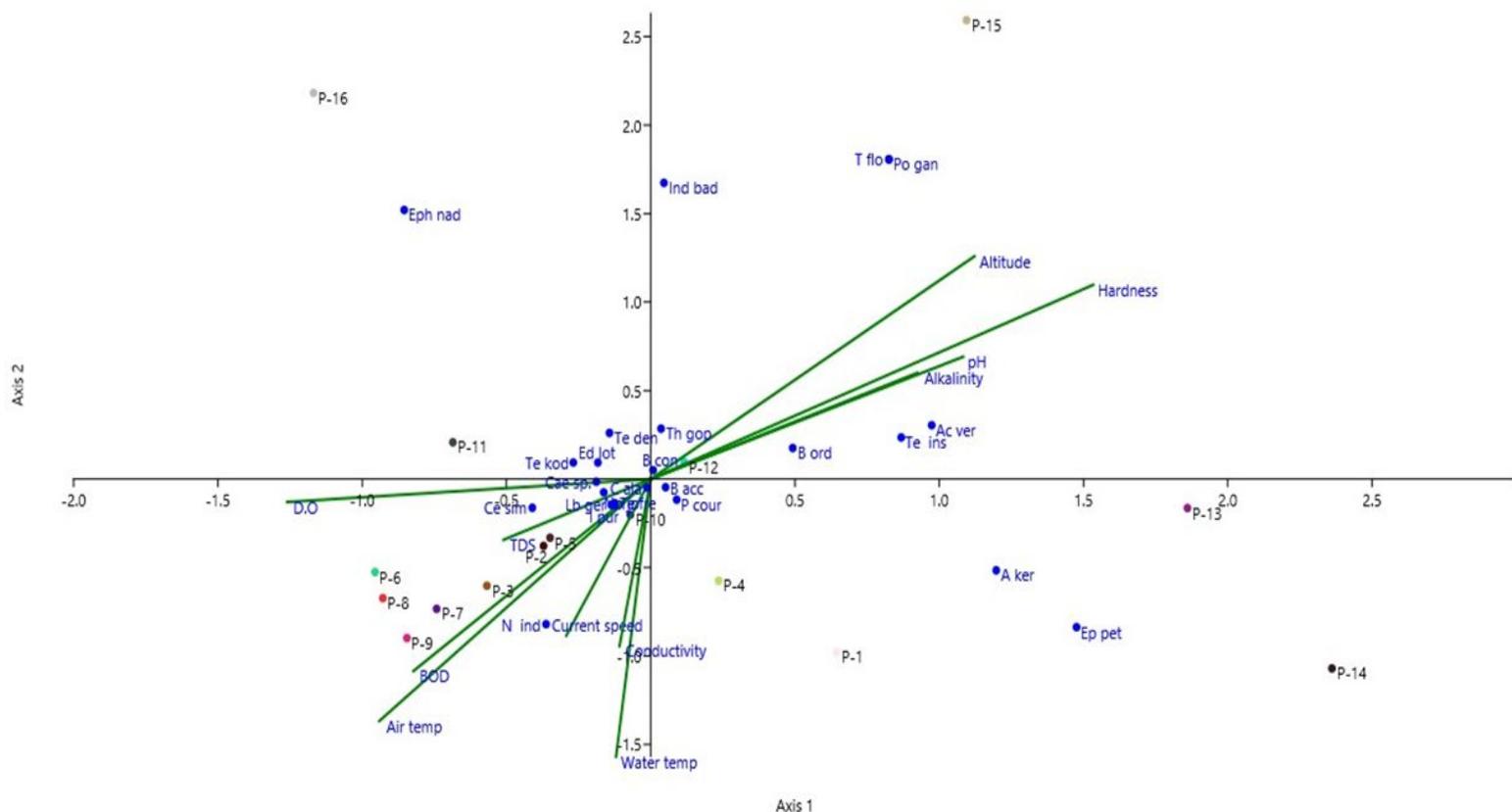
The ordination diagram of CCA (Figure 10) displays the sites of Cardamom hills with species of Ephemeroptera and environmental variables. They display variation in species composition over the sites. From the results, sites C-3, C-4, C-8, C-10, C-13 and C-14 shows positive correlation with BOD, pH, alkalinity and hardness and shows negative correlation with DO. Sites C-5, C-6, C-7, C-9, C-11 and C-12 shows positive correlation with TDS, conductivity and air temperature and negatively correlated with water temperature, current speed and altitude. Site 2 shows negative correlation with ecological attributes like TDS, conductivity and air temperature and shows positive correlation with water temperature, altitude and current speed.

Ce sim- *Centropptella similis*, T flo- *Thalerosphyrus flowersi*, N ind- *Nathanella indica*, P cour- *Petersula courtallensis* and Th gop- *Thraulius gopalani* were sensitive to low amount of DO and delicate to high discharge of BOD, pH, alkalinity and hardness. It proves the above reference organisms are good indicators of water quality because they are highly sensitive to acidic, alkaline environment. B acc- *Baetis acceptus*, B con- *Baetis conservatus*, B ord- *Baetis ordinatus*, Lb ger-

Labiobaetis geminatus, A ker- *Afronurus* sp., A kum- *Afronurus kumbakkaraiensis*, Ep pet- *Epeorus petersi*, P cour- *Petersula courtallensis*, Po gan- *Potamanthellus ganges* and Te den- *Teloganodes dentata* were sensitive to low BOD, pH, alkalinity and hardness and sensitive to high DO. It shows that *Baetis* genera are tolerant to acidic and alkaline environment. Taxa such as Ce cey- *Centropptella ceylonensis*, Ac ver- *Acentrella vera*, Ed lot- *Edmundsula lotica*, I pur- *Isca purpurea*, No jo- *Notophlebia jobi*, Te kod- *Teloganodes kodai* and Te ins- *Teloganodes insignis* shows sensitivity to low levels of TDS, conductivity and air temperature and shows sensitivity to high levels of water temperature, current speed and altitude. Te fre- *Tenuibaetis frequentus* and Cae sp- *Caenis* sp shows sensitivity to high levels of TDS, conductivity and air temperature and shows less sensitivity to high levels of water temperature, whereas Ind bad- *Indialis badia* shows less sensitivity to altitude and current speed

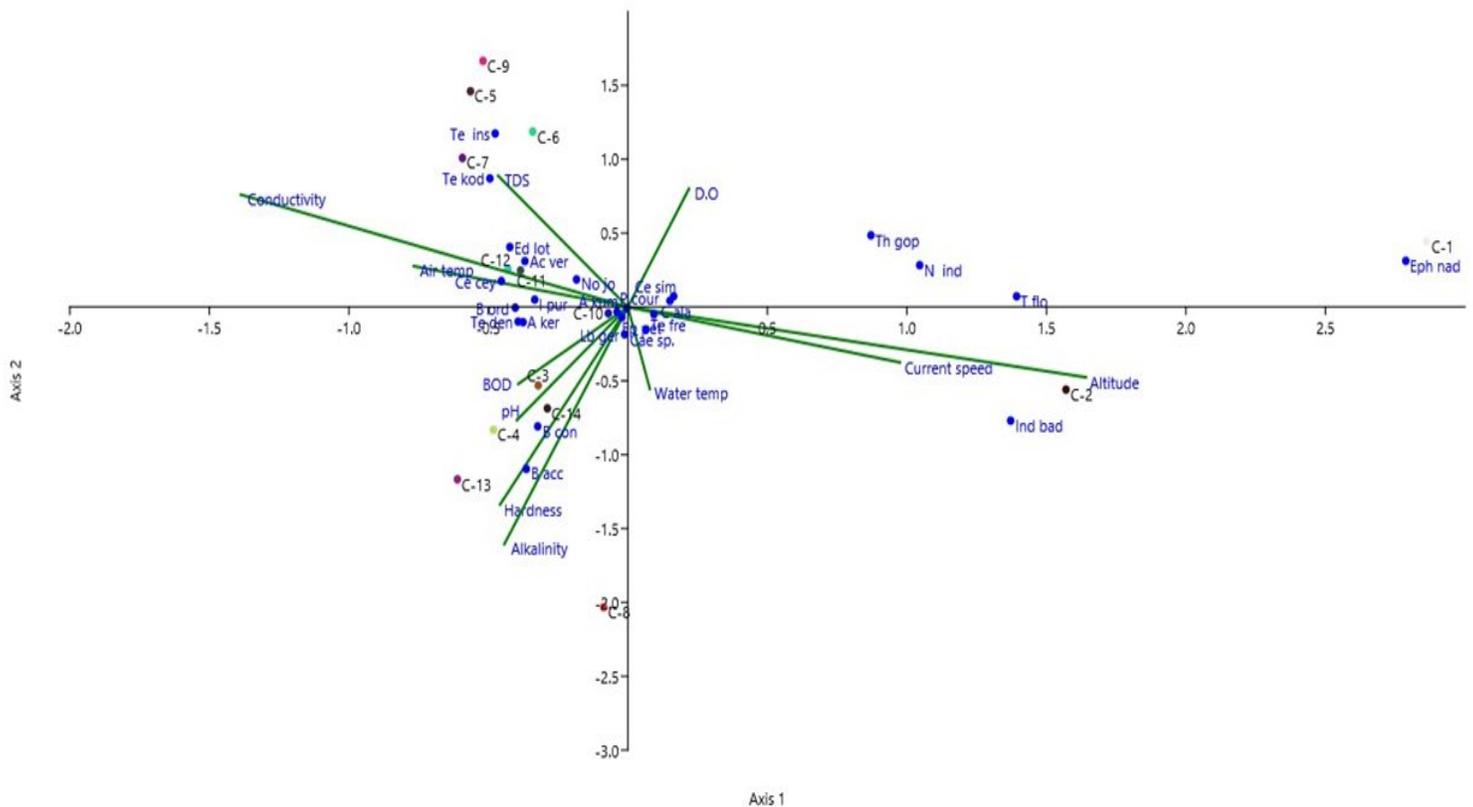
Site C-1, which is not delicate to any of the eleven ecological factors, and *Ephemera nadinae*, which additionally shows no relationship or availability with any of the variable. The CCA results of both Palni and Cardamom hills substantiates that the distribution and community structure of *Ephemera nadinae* is mysterious and still needs further more investigation of overwhelming metals and other environmental properties. *Baetis* and *Tenuibaetis* both shows distinctive community structure pattern, though they both originates from a single ancestor. Gencer Turkmen and Ozkan (2011) and Gencer Turkmen and Nilgun Kazanci (2020) suggests that *Baetis milani* is β -mesosaprobic, our results also substantiates with that as *Baetis* species are sensitive to high DO and it prefers β -mesosaprobic habitat. According *Caenis* sp. in both Palni and Cardamom hills prefers different habitats and it proves that more *Caenis* species complex were present in Palni and Cardamom hills. The outcome likewise demonstrates *Indialis badia* diversity and distribution were more in high altitudinal area. From the results, it is apparent that *Centropptella similis* prefer oligosaprobic environment.

It was noticed that locales Poomparai, Dhobikana, Kouchi of Palni hills and Kurangani up and down of Cardamom hills are plotted away from all the variables and the only reason that can be suggested is human impedance (i.e. Anthropogenic impacts).



(B acc- *Baetis acceptus*, B con- *Baetis conservatus*, Te fre- *Tenuibaetis frequentus*, B ord- *Baetis ordinatus*, Lb ger- *Labiobaetis geminatus*, Ce sim- *Centroptella similis*, Ce sey- *Centroptella ceylonensis*, Ac ver- *Acentrella vera*, A ker- *Afronurus* sp, A kum- *Afronurus kumbakaraensis*, Ep pet- *Epeorus petersi*, T flo- *Thalerosphyrus flowersi*, C ala- *Choroerpes alagarensis*, Ed lot- *Edmundsula lotica*, Ind bad- *Indialis badia*, I pur- *Isca purpurea*, N ind- *Nathanella indica*, No jo- *Notophlebia jobi*, P cour- *Petersula courtallensis*, Po gan- *Potamanthellus ganges*, Th gop- *Thraulius gopalani*, Te den- *Teloganodes dentata*, Te kod- *Teloganodes kodai*, Te ins- *Teloganodes insignis*, Eph nad- *Ephemera nadinae*, Cae sp- *Caenis* sp.)

Figure 9. Canonical Correlation Analysis of Palni hills



(B acc- *Baetis acceptus*, B con- *Baetis conservatus*, Te fre- *Tenuibaetis frequentus*, B ord- *Baetis ordinatus*, Lb ger- *Labiobaetis geminatus*, Ce sim- *Centroptella similis*, Ce cey- *Centroptella ceylonensis*, Ac ver- *Acentrella vera*, A ker- *Afronurus sp.*, A kum- *Afronurus kumbakkaraiensis*, Ep pet- *Epeorus petersi*, T flo- *Thalerosphyrus flowersi*, C ala- *Choroerpes alagarensis*, Ed lot- *Edmundsula lotica*, Ind bad- *Indialis badia*, I pur- *Isca purpurea*, N ind- *Nathanella indica*, No jo- *Notophlebia jobi*, P cour- *Petersula courtallensis*, Po gan- *Potamanthellus ganges*, Th gop- *Thraulius gopalani*, Te den- *Teloganodes dentata*, Te kod- *Teloganodes kodai*, Te ins- *Teloganodes insignis*, Eph nad- *Ephemera nadinae*, Cae sp- *Caenis sp.*)

Figure 10. Canonical Correlation Analysis of cardamom hills

Conclusions

Based on PCA results, it tends to be reasoned that the sites in Palni hills, which are plotted far apart like Dhobikana, Fern hill and Poomparai, are not supported by the physico-chemical parameters like the other sites in Palni hills. This is absolutely a direct result of anthropogenic activity, because Fern hill and Poomparai are excursion spots where human obstruction is more in these streams. Whereas Dhobikana is a place where dhobis are involved in washing clothes so detergent pollution is more there. In cardamom, hills Santhamparai near bridge and Nayamakkadu are left far apart indicating they are

not supported by physicochemical parameters, mainly due to pollution. However, Ephemeroptera were sensitive to water quality changes specially to DO, pH, conductivity and hardness their number is less in these stations compare with other stations. From the CCA results, it is found that *Baetis* species lean towards β -mesosaprobic habitat and *Indialis badia* favors high altitudinal area. Sites like Poomparai, Dhobikana, Kouchi of Palni hills and Kurangani up and down of Cardamom hills are plotted away from all the environmental variables.

In this work, it is discovered that not all physicochemical parameters are emphatically or adversely corresponded. But it is understood that pH, dissolved oxygen, BOD, hardness and alkalinity were the crucial factors. This agrees with numerous investigations that have been done previously (Steinman *et al.*, 2003). Dissolved oxygen is the key to the abundance of Ephemeroptera as oxygen is the significant component to all living creature to remain alive and slight changes on the pH likewise change the presence of Ephemeroptera.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: This study was conducted in accordance with ethics committee procedures of animal experiments.

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Disclosure: -

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