MONTHLY VARIATION OF MACROINVERTEBRATE DENSITY AND DIVERSITY IN THE THREE EPHEMERAL STREAMS OF LAKHIMPUR DISTRICT OF ASSAM, INDIA

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ABSTRACT

This study is based on assessment of ecological health of the three forested ephemeral streams situated on the Lakhimpur district of Assam using macroinvertebrate as biomonitoring agent and also physicochemical parameters. A total of 23 macroinvertebrate species belonging to 13 families, 5 orders of class Insecta of phylum Arthropoda have been recorded from the three streams with monthly fluctuation. Post monsoon showed comparatively more numbers of macroinvertebrates than monsoon. Species composition and quantitative characteristics of the macro invertebrates have been assessed by different diversity indices (Shannon diversity index, Simpsons diversity index, Margalef index, McIntosh index) and evenness indices (Pielou evenness index and McIntosh evenness index).Less stable condition of the three streams was clearly understood through the present assessment.

Keywords: Density,Diversityindices,Ephemeral,Monsoon,Post Monsoon,Macroinvertebrate

INTRODUCTION

Macro invertebrates are one of the important components of the aquatic food chain which provides important information for understanding stream health. Many other aquatic and terrestrial animals feed on macro invertebrates, so they constitute a critical component to the life of the stream and are indicators of stream health and normal functioning. In forest streams, much of the productivity is sustained by the input of terrestrial organic matter, mostly leaves from surrounding forest trees (Kaushik and Hynes, 1971).Many of the invertebrates play a vital role in transforming this coarse particulate organic matter by scraping, gouging and shredding it, making it available to other invertebrates and facilitating microbial colonization and decomposition(Pearson and Connolly,2000).As they are important food source of many aquatic and terrestrial animals, they constitute a critical component to the life of stream, river and other aquatic sources and thus act as an indicator of stream health and its normal functioning. Macro invertebrates are comparatively easier to sample than other aquatic organism like fish. They are not restricted in their distribution as aquatic vascular plants and are easier to identify and to quantify than algae or fungi. Composition and relative abundance of each species undergo changes in response to the change occur in the environment. The main objective of the present study was to study the ecological health of

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the three forested ephemeral streams through macro invertebrate as biomonitoring agent and analysis of physicochemical parameters.

MATERIALS AND METHODS

Study Area

The three different ephemeral streams viz. Baghjan, Singijan and Ghagorjan originate from the foothills of Arunachal Pradesh and located about 20-25 kilometres away from North Lakhimpur of Assam traversed through Dulung reserve forest in the Assam Arunachal border region. Baghjan lies within $27^{0}26^{/}522^{//}$N and $94^{0}12^{/}599^{//}$E, while Singijan is located within $27^{0}26^{/}701^{//}$N and $94^{0}12^{/}869^{//}$E and Ghagorjan lies between $27^{0}26^{/}608^{//}$N and $94^{0}12^{/}691^{//}$E. Since the streams are ephemeral, so they completely dependent on monsoon rain. Monsoon starts from June and from the end part of November the streams starts dry up. Therefore the analysis of physicochemical parameters and biological assemblages were done only for two seasons viz. monsoon and post monsoon.

Study Period

All the selected parameters were studied for consecutive three years (June 2011-May 2014) on monthly (June, July, August, September, October and November) basis.

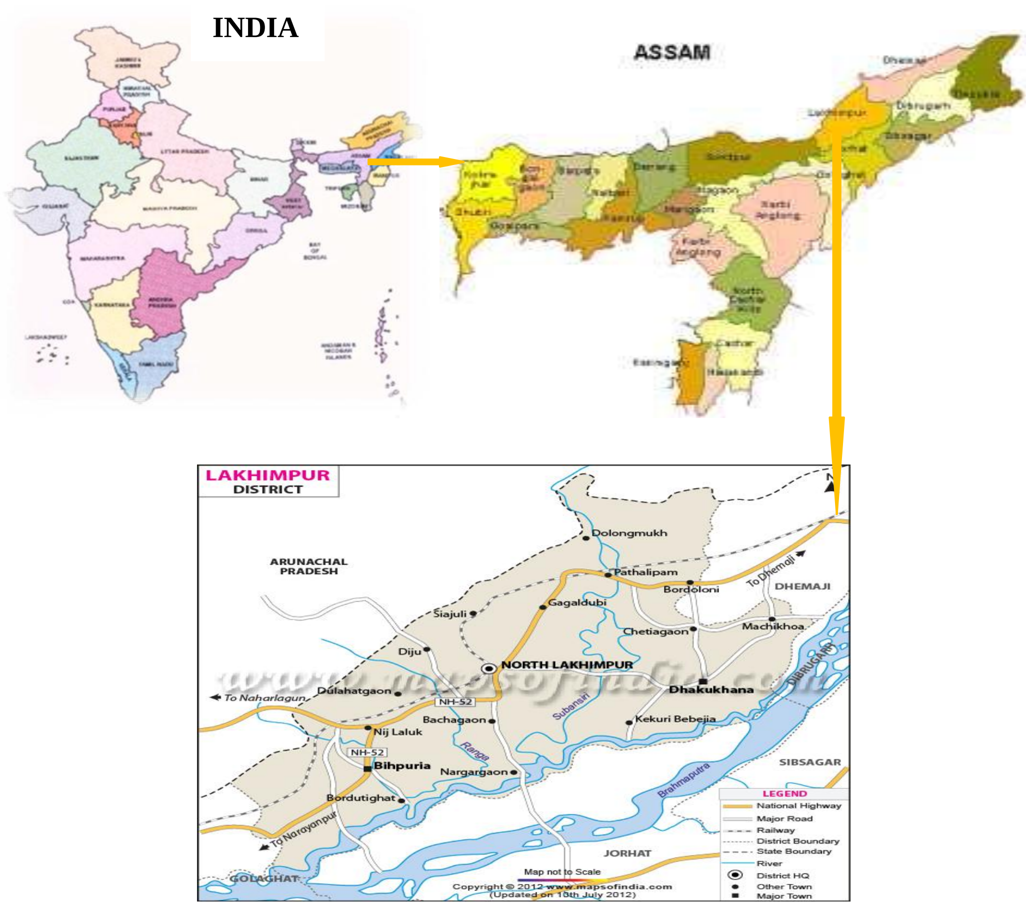

Fig 1(a). Location map of Lakhimpur district of Assam

Fig 1(b): Satellite image of three ephemeral streams

Collection and Identification and Quantification of Macro invertebrate:

Sampling of macro invertebrates were performed at each stream segments using a 600 micron mesh “D” net by kicking and sweeping in all microhabitats present at the sites likely to support greatest taxonomic diversity. The net contents were then checked and deposited periodically in some plastic jars to avoid losing organisms by overflow from nets. A maximum of 10 samples were taken for macro invertebrate study at all the three ephemeral streams, where ten howls were considered as one sample. Macro invertebrate samples were then successfully filtered at the laboratory with 4 mm to 0.4 mm mesh size sieves to remove fine sediment and waste materials. The samples were then preserved in plastic jars containing 10% formalin. The identification of macro invertebrates were done up to genus level in the laboratory by use of keys of Needham and Needham, 1966; Edmonson, 1992.

The densities of abundant species were analyzed for each of the sampling streams using the formula:

$D = n/A$, where, D = Density, n= total number of macro invertebrates sampled, A= area of sampling unit

Biological Indices:

Four diversity indices, Shannon diversity index (Shannon-Weaver, 1948), Simpson diversity index(Simpson, 1949), Margalef diversity index (Margalef 1958) and McIntosh diversity index(McIntosh, 1967) and two evenness indices (Pielou evenness index(Pielou, 1966) and McIntosh evenness index(McIntosh, 1967) were used in the study of macro invertebrates.

Measurement of Water Quality (Physical and Chemical Variables)

The location of the three study sites were measured by GPS (GarminGPSMAP76), water temperature was measured by using a Mercury thermometer graduated up to 110°C, pH was measured by portable pH meter (Cyber scan pH 300 series), conductivity was measured by Digital conductivity meter (CD600, Milwaukee), current velocity was measured by Digital flow meter (Swoffer 3000 Flow Meter, GeoScientific Ltd.). Dissolved Oxygen was measured by following the Winkler’s modified method (Trivedy and Goel, 1986), free carbondioxide,

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total acidity, total alkalinity and chloride were measured titrimetrically following the method of (APHA,1995) and (Trivedy and Goel, 1986).

RESULT and DISCUSSION:

A total of 23 species of macro invertebrate (*Libellula sp., Pantala sp., Plathemis sp., Tramea sp., Aeshna sp., Dromogomphus sp., Calopteryx sp., Trepobates sp., Limnogonus sp., Potamobates sp., Gerris sp., Belostoma sp., Nepa sp., Ranatra sp., Notonecta sp., Buenoa sp., Coptotomus sp., Hydaticus sp., Cybister sp., Hydrophilus sp., Palaemonetes sp., Potamon sp., Neoperla sp.,*

Table 1: Inventory of macro invertebrates in the three ephemeral streams

Phylum	Class	Order	Family	Genus
Arthropoda	Insecta	Odonata	Libellulidae	*Libellula sp.*
				Pantala sp.
				Plathemis sp.
				Tramea sp.
			Aeshnidae	*Aeshna sp.*
			Gomphidae	*Dromogomphus sp.*
			Calopterygidae	*Calopteryx sp.*
		Hemiptera	Gerridae	*Trepobates sp.*
				Limnogonus sp.
				Potamobates sp.
				Gerris sp.
			Belostomatidae	*Belostoma sp.*
			Nepidae	*Nepa sp.*
				Ranatra sp.
			Notonectidae	*Notonecta sp.*
				Buenoa sp.
		Coleoptera	Dytiscidae	*Coptotomus sp.*
				Hydaticus sp.
				Cybister sp.
			Hydrophilidae	*Hydrophilus sp.*
		Decapoda	Palaemonidae	*Palaemonetes sp.*
			Potamidae	*Potamon sp.*
		Plecoptera	Perlidae	*Neoperla sp.*

belonging to 13 families (Libellulidae, Aeshnide, Gomphidae, Calopterygidae, Perlidae, Belostomatidae, Gerridae, Notonectidae, Dytiscidae, Hydrophilidae, Nepidae, Palaemonidae, Potamidae) ; 5 orders (Odonata, Hemiptera, Coleoptera, Decapoda, Plecoptera) of class Insecta of phylum Arthropoda have been collected from the three streams (**Table1**).

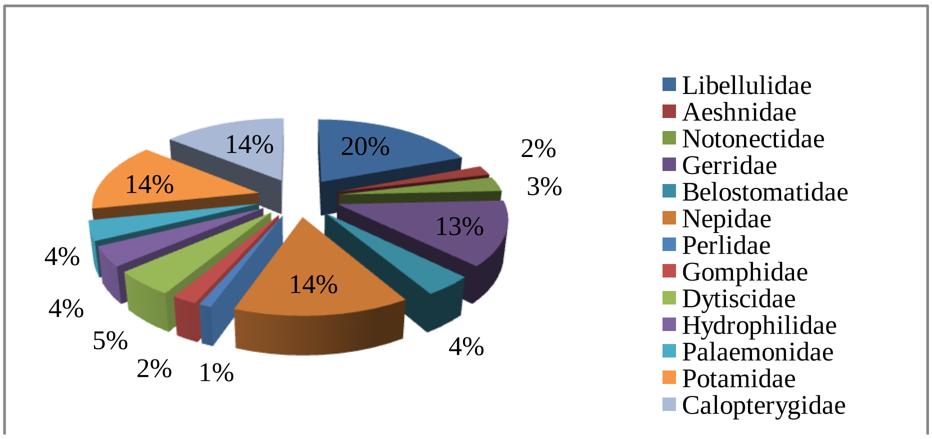

Fig 1(a): Percent composition of macroinvertebrate families of Baghjan

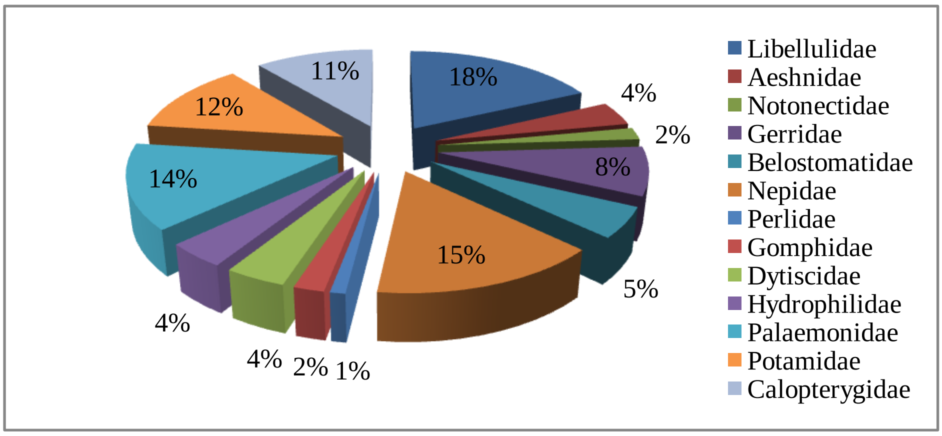

Fig 1(b): Percent composition of macroinvertebrate families of Singijan

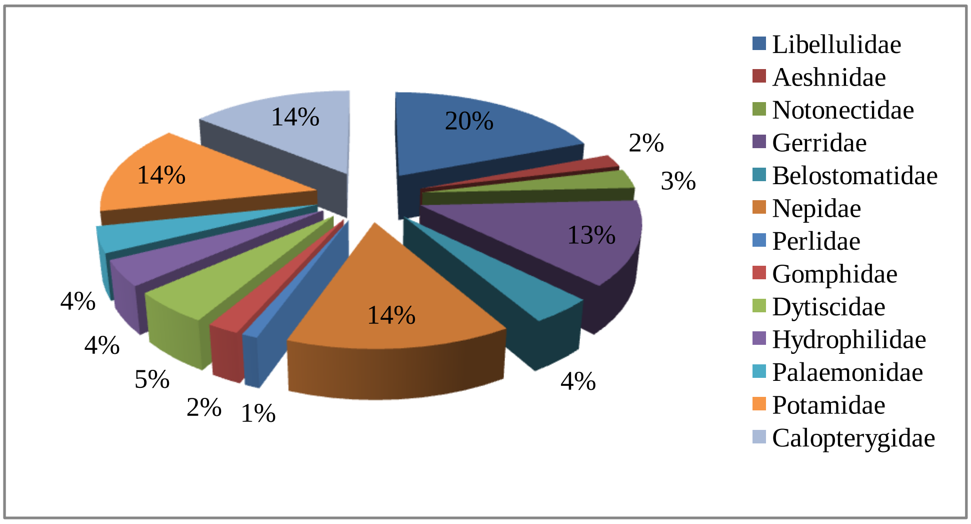

Fig 1(c): Percent composition of macroinvertebrate families of Ghagorjan

Percent composition of different macroinvertebrate families is shown in **Fig 1(a),1(b) and 1(c)**. Libellulidae of order Odonata was recorded as dominant family in all the three streams (Baghjan 21%; Singijan 18%; Ghagorjan 19%). Perlidae of order Plecoptera was recorded as least available family (Baghjan, 1%; Singijan, 1%; Ghagorjan, 1%).

The monthly mean variations of mean macroinvertebrate density (no./m^2) are given in **Table 2.** In Baghjan, maximum density was recorded in October (34.45±8.14 no./m^2) and minimum in July (10.37±4.95 no./m^2). In Singijan, maximum density was recorded in November (37.12±4.31 no./m^2) and minimum in August (10.81±3.12 no./m^2). In Ghagorjan, maximum density was recorded in October (36.17±5.47 no./m^2) and minimum in July (10.42±2.11 no./m^2). Among the three streams, maximum density was recorded at Singijan in November and minimum at Baghjan in July.

Table 2: Monthly mean variation of macroinvertebrate density (no./m^2)

Fam	S	Months					
		Jun	Jul	Aug	Sep	Oct	Nov
Lib	S1	2.75±1.25	2.25±0.95	2.75±1.25	4.25±1.5	4.5±1.29	4.25±1.5
	S2	2.25±0.95	3.25±0.95	2.5±1.03	3.5±1.03	5.75±1.7	7.5±2.51
	S3	3.25±0.5	3.5±1.0	3.5±0.5	4.75±0.95	5.5±0.57	4.75±0.5
Aes	S1	0.25±0.5	---	0.25±0.5	1.5±0.57	1.5±0.57	---
	S2	0.25±0.5	---	---	1.22±1.15	1.5±1.29	0.25±0.5
	S3	0.25±0.5	1.5±0.57	3.5±1.0	3.25±0.5	3.5±1.29	---
Gom	S1	---	---	0.25±0.5	1.5±0.57	2.25±0.95	2.25±0.95
	S2	---	---	---	0.25±0.5	1.5±0.57	---
	S3	---	---	2.25±0.95	---	2.75±1.25	---
Cal	S1	---	2.25±0.95	---	2.75±1.25	4.25±1.5	---
	S2	2.25±0.95	---	1.5±0.57	2.5±0.57	---	1.5±0.57
	S3	2.25±0.95	---	2.5±0.57	3.25±0.5	3.75±0.95	3.25±0.5
Per	S1	---	---	---	0.25±0.5	0.25±0.5	---
	S2	0.25±0.5	---	---	0.25±0.5	---	---
	S3	0.25±0.5	---	---	1.5±0.57	---	2.25±0.95
Bel	S1	0.25±0.5	---	0.25±0.5	1.5±0.57	2.25±0.95	2.5±0.57
	S2	1.5±0.57	---	0.25±0.5	1.5±0.57	2.5±0.57	2.25±0.95
	S3	---	---	---	1.5±0.57	2.5±0.57	---
Ger	S1	---	0.25±0.5	---	1.5±0.57	2.25±0.95	2.5±0.57
	S2	0.25±0.5	---	---	0.25±0.5	---	1.5±0.57
	S3	0.25±0.5	---	---	0.25±0.5	---	1.5±0.57
Not	S1	---	0.25±0.5	---	---	1.5± 0.57	---
	S2	---	---	0.25±0.5	1.5±0.57	---	1.5±0.57
	S3	---	1.25±0.95	---	---	1.5±0.57	---
Dyt	S1	---	---	2.25±0.95	---	4.75±0.95	3.75±0.95
	S2	---	2.5±0.57	---	4.75±0.5	4.75±0.95	5.5±0.57
	S3	1.5±0.57	2.5±0.57	---	3.5±1.0	3.5±1.29	2.25±0.95
Hyd	S1	---	---	1.5±0.57	2.25±0.95	4.25±1.5	3.5±1.0
	S2	---	---	---	---	4.5±1.29	4.75±0.95
	S3	---	---	2.25±0.95	---	2.5±0.57	1.5±0.57
Nep	S1	2.25±0.95	1.0±1.15	---	---	2.75±1.25	2.25±0.95
	S2	---	2.0±1.15	---	2.75±1.25	3.5±1.0	3.75±0.89
	S3	---	---	3.5±1.03	3.5±1.29	3.75±0.95	3.5±1.21
Pal	S1	4.5±1.29	3.25±1.5	4.25±1.5	3.75±0.95	4.75±0.5	3.5±0.57
	S2	3.75±0.95	---	3.25±0.5	0.75±0.5	3.25±0.5	2.75±0.95
	S3	2.5±0.57	---	---	3.5±1.29	4.5 ±1.29	3.5±1.05
Pot	S1	4.5±1.29	3.75±0.5	5.5±0.57	4.75±0.5	6.5±1.29	5.75±1.7
	S2	3.5±1.0	4.25±0.5	2.5±0.57	4.5±1.29	6.5±1.29	5.5±0.57
	S3	3.5±1.21	2.5±0.57	---	3.5±1.29	4.5±1.29	3.25±0.5
	S1	12.67±5.15	10.37±4.95	15.68±6.15	20.25±5.61	34.45±8.14	25.62±4.75

Tot	S2	12.21±4.61	11.31±3.42	10.81±3.12	23.25±5.28	35.41±8.12	37.12±4.31
	S3	14.12±3.85	10.42±2.11	15.56±4.23	27.32±6.31	36.17±5.47	22.29±4.59

Key: Fam=Family, **Lib**=Libellulidae, **Aes**=Aeshnidae, **Gom**=Gomphidae, **Cal**=Calopterygidae, **Ger**=Gerridae, **Bel**=Belostomatidae, **Nep**=Nepidae, **Not**= Notonectidae, **Dyt**= Dytiscidae, **Hyd**=Hydrophilidae, **Pal**= Palaemonidae, , **Pot**= Potamidae, **Per**=Perlidae, **Tot**=Total, **S**= Stream, **S1**=Baghjan, **S2**=Singijan, **S3**=Ghagorjan.

The monthly mean variation of macroinvertebrate diversity and evenness indices are given in **Table 3.** In the present study, highest value of Shannon diversity index (Ĥ) was recorded at Singijan in October (2.77) and lowest at Baghjan in June (2.06). The Pielou evenness index (J) was recorded highest at Singijan in August (0.92) and lowest at Ghagorjan in October (0.84).

Table 3: Monthly mean variation of macroinvertebrate diversity and evenness indices

Indices	Streams	Months					
		Jun	Jul	Aug	Sep	Oct	Nov
Ĥ	Baghjan	2.06	2.33	2.41	2.25	2.56	2.55
	Singijan	2.09	2.37	2.34	2.70	2.77	2.69
	Ghagorjan	2.31	2.40	2.31	2.51	2.61	2.74
J	Baghjan	0.90	0.88	0.89	0.87	0.85	0.86
	Singijan	0.91	0.90	0.92	0.90	0.89	0.89
	Ghagorjan	0.90	0.88	0.89	0.89	0.84	0.87
1-D	Baghjan	0.86	0.88	0.89	0.87	0.89	0.91
	Singijan	0.87	0.89	0.89	0.92	0.92	0.93
	Ghagorjan	0.89	0.90	0.90	0.90	0.90	0.92
Ma	Baghjan	2.14	2.74	2.81	2.34	3.42	3.15
	Singijan	1.82	2.54	2.21	3.36	3.42	3.59
	Ghagorjan	2.37	2.72	2.88	2.82	3.51	3.56
Mc	Baghjan	0.72	0.72	0.73	0.72	0.76	0.73
	Singijan	0.73	0.71	0.74	0.74	0.75	0.74
	Ghagorjan	0.72	0.73	0.72	0.73	0.73	0.74
McE	Baghjan	0.91	0.89	0.90	0.89	0.91	0.89
	Singijan	0.91	0.90	0.89	0.92	0.91	0.91
	Ghagorjan	0.91	0.90	0.88	0.89	0.90	0.89

Key: Ĥ =Shannon diversity index, **J**=Pielou evenness index, **D**=Simpson's diversity index, **Ma**=Margalef diversity index, **Mc**=McIntosh diversity index, **McE**=McIntosh evenness index

Simpson's index of diversity (1-D) was recorded highest at Singijan in November (0.93) and lowest value was recorded in June at Baghjan (0.86). Margalef diversity index (Ma) was recorded highest in November at Singijan (3.59) and lowest value was recorded at Singijan in June (1.82). Highest value of McIntosh diversity index (Mc) was recorded in October at Baghjan (0.76) and lowest value was recorded in July at Singijan (0.71). McIntosh evenness index (McE) was recorded highest in September at Singijan (0.92) and lowest value was recorded in August at Ghagorjan (0.88).

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Table 4: Monthly variation of physicochemical parameters of the three streams

Parameter	Streams	months					
		Jun	Jul	Aug	Sep	Oct	Nov
Temp(^{0}C)	Baghjan	26.08±0.08	26.79±0.21	26.37±0.20	25.72±0.55	25.88±0.38	25.63±0.52
	Singijan	24.91±0.13	25.89±0.32	26.01±0.24	25.26±0.16	24.72±0.33	25.43±0.11
	Ghagorjan	25.62±0.12	25.48±0.26	25.31±0.21	25.04±0.53	25.08±0.33	25.13±0.22
pH	Baghjan	5.88±0.03	5.80±0.10	5.71±0.01	6.22±0.04	6.36±0.10	6.46±0.02
	Singijan	6.01±0.06	5.91±0.16	5.77±0.04	6.02±0.04	6.14±0.12	6.13±0.04
	Ghagorjan	5.46±0.05	5.57±0.05	5.51±0.04	6.07±0.03	6.07±0.07	6.11±0.03
Current velocity(m/sec)	Baghjan	0.39±0.02	0.54±0.07	0.63±0.02	0.37±0.02	0.48±0.08	0.57±0.05
	Singijan	0.63±0.03	0.82±0.07	0.84±0.11	0.58±0.01	0.59±0.02	0.31±0.15
	Ghagorjan	0.46±0.03	0.55±0.02	0.56±0.05	0.46±0.03	0.48±0.04	0.44±0.03
Conductivity(µS/cm)	Baghjan	618.19±1.04	618.19±1.33	620.68±2.63	593.21±4.72	597.06±4.39	586.99±2.55
	Singijan	584.51±6.06	577.92±7.22	588.86±1.73	568.72±1.77	574.69±7.13	576.81±19.77
	Ghagorjan	579.66±2.21	580.91±1.77	570.46±3.56	559.03±1.14	565.12±2.48	569.72±4.11
D.O.(mg/l)	Baghjan	3.07±0.16	3.01±0.26	3.16±0.31	5.28±0.24	4.83±0.53	4.36±0.09
	Singijan	4.18±0.12	3.79±0.14	4.01±0.11	4.71±0.18	4.53±0.5	4.61±0.16
	Ghagorjan	3.34±0.28	3.86±0.38	4.16±0.22	3.36±0.24	4.61±0.22	3.54±0.26
FCO_2.(mg/l)	Baghjan	13.64±0.61	16.15±2.61	18.79±1.11	13.14±0.52	13.94±0.67	14.51±0.39
	Singijan	18.08±1.14	18.66±0.49	17.44±1.06	13.66±0.34	14.34±1.28	17.26±1.31
	Ghagorjan	21.23±0.86	19.52±0.72	19.71±1.22	18.61±0.56	18.62±0.59	20.72±0.74
Total Acidity(mg/l)	Baghjan	19.54±0.59	20.96±0.79	19.32±0.18	18.21±0.31	19.43±1.49	20.09±1.13
	Singijan	19.31±0.76	19.93±1.43	21.16±0.88	15.81±0.31	17.12±1.17	18.55±0.31
	Ghagorjan	28.52±1.11	23.84±2.86	22.23±0.86	20.21±1.64	21.11±1.73	20.86±1.43
Total Alkalinity(mg/l)	Baghjan	21.16±0.88	67.17±1.07	68.57±2.31	73.29±0.96	77.31±3.99	82.78±3.01
	Singijan	15.81±0.31	54.52±2.06	55.97±1.08	68.67±1.11	71.87±2.05	71.42±1.15
	Ghagorjan	17.12±1.17	60.07±3.01	61.64±1.37	72.46±1.61	73.89±1.41	70.64±1.37
Chloride(mg/l)	Baghjan	18.55±0.31	19.44±0.77	19.52±0.61	23.41±0.33	22.56±1.19	21.62±0.69
	Singijan	21.26±0.37	20.67±0.72	19.87±1.15	20.93±3.12	22.78±1.01	21.48±0.78
	Ghagorjan	15.84±0.65	15.77±0.39	14.15±0.64	20.15±0.64	19.10±0.52	19.97±0.36
Stream depth(m)	Baghjan	0.38±0.05	0.37±0.04	0.39±0.03	0.29±0.01	0.29±0.01	0.26±0.01
	Singijan	0.41±0.01	0.45±0.05	0.40±0.06	0.36±0.04	0.37±0.01	0.28±0.05

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	Ghagorjan	0.35±0.02	0.35±0.07	0.36±0.01	0.34±0.01	0.33±0.01	0.32±0.02
Stream width(m)	Baghjan	10.54±0.41	9.81±1.16	8.16±0.77	7.31±0.32	7.55±0.41	7.86±0.36
	Singijan	5.23±0.11	5.46±0.25	5.77±0.26	4.18±0.19	4.14±0.12	3.04±0.48
	Ghagorjan	3.51±0.16	4.04±0.22	3.80±0.14	2.26±0.08	2.46±0.15	2.21±0.11

Stream macro-invertebrates have been used extensively for bio monitoring of numerous environmental stresses (Rosenberg and Resh, 1993). They are sensitive to watershed conditions and exhibit sufficient stability in assemblage structure over time to make them useful as long-term monitors of stream health (Richards and Minshell, 1992) and indicators of water quality (Resh, 1995).

Monsoon showed lower macroinvertebrate density than post monsoon in all the three sampling streams. High rainfall, increased suspended solids, high water discharge are considered to be the main reasons behind it. Heavy rainfall leads to destruction of habitat which finally results in decrease in total number of macroinvertebrate. In postmonsoon comparatively current velocity become slows down and substrate heterogeneity increases that favours formation of diverse microhabitat for the macroinvertebrates. There observed a negative correlation between macroinvertebrate density with precipitation ($p<0.01$) and water discharge ($p<0.01$) in all the three ephemeral streams. Similar findings have also been observed by many workers (Duffield and Nelson, 1993). Hynes (1970) had discussed in general the changes in faunal composition with longitudinal distance in lotic ecosystems and also mentioned oxygen, temperature and nature of substratum as possible contributor to this change. The low benthic macroinvertebrate density in the monsoon season due to the effect of heavy rainfall was also previously observed by Saravanakumar *et al*., (2007). According to Hynes (1970) a number of investigators have reported a reduction in the variety and abundance of benthic invertebrates as a result of highwater in monsoon season. The length of the period of recovery after high water depends upon the severity of the rainstorm, the distance to the nearest benthic community from which recolonization can occur, the season of the year, and the kinds of organisms.

Water temperature also has a marked effect on macroinvertebrate density and abundance. There observed negative correlation ($p<0.05$) between macro-invertebrate density and water temperature in all the three streams. Diversity of macroinvertebrates decreases as water temperature increases (Palit *et al*., 2013). Water temperature was found to be negatively correlated with the diversity of macroinvertebrates in the river Dhauli Ganga (Sharma *et al*., 2004.). Higher density of macroinvertebrate in postmonsoon is due to high level of dissolved oxygen as compared to monsoon. Dissolved oxygen was found to be positively correlated with macroinvertebrate density ($p<0.01$). Macroinvertebrate density showed a positive correlation with dissolved oxygen (Sharma *et al*., 2009). Also macroinvertebrate density was found to be positively correlated with pH ($p<0.01$), total alkalinity ($p<0.01$), chloride ($p<0.05$) but negatively correlated with free carbondioxide ($p>0.05$), total acidity ($p>0.05$), conductivity ($p<0.01$), stream depth ($p<0.05$) and stream width ($p<0.05$).

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In the studied ephemeral streams, with gradual disappearance of surface water from the main channel, macroinvertebrates use various refugia for survival during dry periods. Although they mostly prefer isolated pools, some macroinvertebrates have the ability to burrow to the hyporheic zone or to some other permanently flowing channels. Before complete drying of the stream channel, adult macroinvertebrates with development of larval stages starts dispersal to nearby perennial streams or use other terrestrial habitat as temporary refugia but recolonization occur quickly after flow resumes. Drying of stream channels normally occurs gradually, allowing time for behavioural adaptations. In these stressed streams, many macroinvertebrates have evolved life history or behavioural characteristics that enhance their survival or recovery. Among these, most successful adaptations are those related to life cycle (e.g., diapause states or resisting forms), to the ability to seek refuge from dryness in the hyporheic zone and to the dispersion capacity (Boulton, 1989; Williams, 1987,). In general, invertebrates are better able to withstand the effects of drought than are fish, because of egg, nymphal or pupal diapauses, emergence or burrowing (Canton *et al.*, 1984). Recolonization is rapid following resumption of flow (Hynes, 1975) In spite of the ephemeral conditions during the drought could cause a decline in species richness as was described in intermittent streams (Dieterich and Anderson, 2000), a prolonged dry period could not reduce the resource availability of the three streams.

Species diversity is a reliable parameter in biology to determine how healthy an environment is (Ogbeibu and Edutie, 2002). Various diversity indices are used to determine the distribution of benthic macroinvertebrates related to habitat quality. The usefulness of this diversity index for assessing water quality is based on the assumption that clean streams have high diversity indexes, because benthic communities of clean streams contain many species of relatively equal numbers of individuals per species (Wilhm and Dorris, 1968). In contrast, polluted streams are interpreted to have low diversity indices because many pollution-sensitive species are eliminated from the community and only a few pollution-tolerant organisms flourish in the absence of competition and in the presence of an abundant food supply.

In the present study, Shannon diversity index ranges 2.06-2.77. This indicates that the three ephemeral streams are moderately polluted (Wilhm and Dorris, 1968). The value of Simpson’s index of diversity ranges 0.86-0.93, which indicates that the diversity status is not at all satisfactory. The value of Margalef index ranges 1.82-3.59, which clearly indicate moderate to clean condition of the studied streams (Lenat *et al.*, 1980). The value of McIntosh diversity index ranges 0.71-0.76 ,which fairly reveals that the organisms belongs to this community are not distributed homogeneusly (McIntosh, 1967). In the present study, the value of Pielou’s evenness index ranges from 0.84-0.92, from which it is clear that individuals are not evenly distributed (Pielou, 1966). McIntosh evenness index ranges 0.88-0.92, which fairly indicate that the individuals were not equally distributed as the observed values are closer to 1 (Heip and Engels, 1974).

Low density and richness of macroinvertebrates was recorded in all the three ephemeral streams. Lower species richness is widely attributed to the more extreme conditions and variable habitat found in temporary streams (Boulton and Suter, 1986) and

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may also related to reduced aquatic habitat area as the result of drying (i.e., species-area effects) (Lake, 2000). A reduction in wetted bed area may also have long-term implications, because many adult insects lay eggs in fast-flowing or broken water (Sawyer, 1950); if suitable areas are reduced, subsequent populations may be affected (Hynes, 1958).

CONCLUSION

Monthly fluctuation was observed in physicochemical variables as well as density, abundance, diversity of macroinvertebrates in the three forested ephemeral streams. The value of density and diversity indices of macroinvertebrate revealed less stable condition of the studied streams. The present work fairly revealed the inter relationship between macroinvertebrate distribution and physico-chemical variables in the three ephemeral streams Although the biota present their in maintain its life period for a short time, with the onset of monsoon season, the hydrologic connectivity between ephemeral and other perennial reaches helps in energy dissipation through transport of water, sediment, nutrients and other biotic communities and thus plays hydrological, geomorphic and ecological roles.

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