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DEPENDENCE OF UPSTREAM ENTOMOFAUNA TO WATER QUALITY IN A SEMI-URBANIZED RIVER (KILLI AR), SOUTH KERALA, INDIA

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Abstract: The diversity and distribution of entomofauna in the upstream segment of Killi Ar were studied to assess their dependence to water quality parameters. The study was conducted from March 2014 to September 2014 covering pre-monsoon, monsoon and post-monsoon seasons. The study surveyed six stations at the upstream stretch of Killi Ar, reporting 33 families belong to 6 orders. Major aquatic insect families recorded in different seasons were Libellulidae and Protoneuridae (Pre-monsoon), Baetidae and Coenagrionidae (Post-monsoon) and Naucoridae and Baetidae (Post-monsoon). Coleopteran and Dipteran populations were comparatively less represented indicating clean water quality in the upstream segment. Significant variation in population density of this stream biota was established between various stations and seasons depending on the water quality. Relative abundance of Chironomids in the pre-monsoon indicates stagnation of stream during this season. The study also identified spatial and seasonal fluctuations in the diversity and richness of aquatic insect fauna in the upstream segment of this stream. The present study revealed that diversity and distribution of entomofauna in Killi River were positively correlated to the water quality.

Keywords: Bio-monitoring, Diversity, Richness, Aquatic insects, Water Quality

INTRODUCTION

The significance of aquatic insects in monitoring the quality of water bodies is attained a momentum in recent years. Considering the multifaceted functions, aquatic insects play a crucial role in stability and maintenance of ecosystems (Abhijna *et al.*, 2013). Exploring and documenting this stream biota occupy a central role in bio-monitoring and biodiversity studies. In the light of environmental damage on water bodies such documentation like entomofaunal diversity will aid real-time monitoring of habitat destruction and curb species loss. The poor water quality standards limit the aquatic diversity only to tolerable species (Cao *et al.*, 1996). Damages of lotic and lentic habitats were contributed to the disruption of the hydrological cycle.

About 3% of the earth land surface is covered by urban area; urbanization has an important role in biodiversity changes in associated water bodies (Grimm *et al.*, 2008). Since aquatic insects persistently exposed to variations in water quality, their stress is greater than any other freshwater organisms. Larvae of Chironomidae have a significant correlation with organic pollution (Bustos-Baez and Frid, 2003; Czerniawska-Kusza, 2005). Besides water quality, habitat type (Collier *et al.*, 2016) and land use pattern (Chessman, 1995; Subramanian *et al.*, 2005) also influence the diversity of invertebrate fauna. Faith and Norris (1989) reported a linear relationship between environmental variables on freshwater macro-invertebrates. Williams (1996) illustrated environmental constraints and their consequences on aquatic insect fauna in temporary freshwater bodies. The diversity of aquatic insects of River Kallar which is geographically close to Killi Ar was reported by Priyanka and Prasad (2014). Macroinvertebrate community of Neyyar River was studied by Santhosh *et al.* (2014). The diversity of macroinvertebrates from Veli and Kadinamkulam Lake (Latha and

Thanga, 2010) and Vellayani Lake (Abhijna *et al.*, 2013) highlight the significance of entomofauna in aquatic ecosystem. The diversity of macroinvertebrate community of lowland rivers (Sheeba and Ramanujan, 2009; Ambili and Reenamole, 2013) and relationship of macrobenthic community and water quality have also been investigated by several researchers in India (Jana and Manna, 1995; Garg *et al.*, 2009, Wang *et al.*, 2010; Edokpayi *et al.*, 2010; Al-Shami *et al.*, 2011; Basu *et al.*, 2012; Narangarvuu *et al.*, 2014; Singh and Sharma (2014). Moreover, macroinvertebrate fauna of headwater streams has been extensively reviewed by Clark *et al.* (2008). This paper documents the association of entomofauna with water quality standards in the upstream stretches of Killi River.

MATERIALS AND METHODS

River Killi, a major tributary of Karamana River (local name Killiyar) is located between latitudes 8° 40’30"N, 8°27’0"N and longitudes 76°57’E, 77° 2’0"E in Kerala of South India (Fig.1). It originates from Theerthankara near to Panavoor of Nedumangadu Taluk in Thiruvananthapuram District, South Kerala; flows through rapidly developing Thiruvananthapuram Corporation and opens to Karamana River at Kalladimukham near Thiruvallam, covering a distance of 24km. This river (average width 16.19 m) from its origin drains through diverse human settlements such as rural, agricultural landscapes, semi-urban and urbanized areas. According to the recent census data (Village/ Town-wise Primary Census Abstract, 2011), Thiruvananthapuram city holds an urban population of 16.8 lakhs individuals. During its course, Killi Ar receives waste water from several small scale industries, service stations and hospitals as well as domestic drainage and agricultural runoff from various cultivations directly without any proper treatment. In addition to the mass dumping of garbage, release of sewage and encroachments leads to decreased flow, which is considered detrimental to the health of the river. The head water of the river basin has also been witnessing rampant land use alteration.

On the basis of a pilot study, six different stations (Table 1) covering a length of about 13km, were chosen along the upper course of the river for monitoring aquatic insects of this stream. The substratum of the river was dominated by fine gravel (size 2-25mm) and coarse gravel (size 25-75mm) in

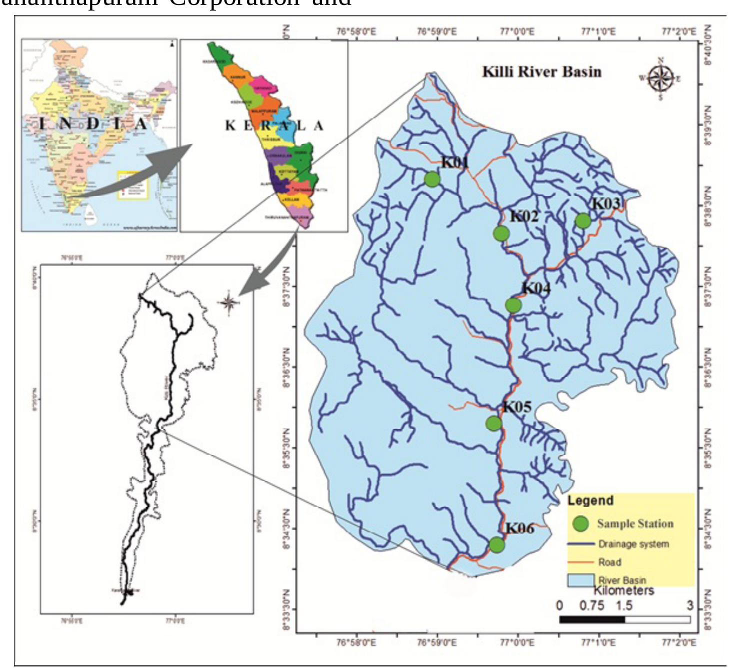

Fig. 1. Location map of the Killi Ar showing sampling stations in the upstream segment of Killi river basin, South Kerala, India.

all stations except station K04 and K06, which in turn dominated by boulders and rocky beds, respectively. Although the station K01 dominated by the coarse gravel, certain habitats of this segment was represented by cobble (size 75-250mm).

Seasonal sampling of macrobenthic entomofauna was conducted once in three months from March 2014 to September 2014. The insects were collected using a D-frame net (mesh size: 100µm). In all stations, sampling was standardized by restricting the sweeps to a length of 50-meter reach of the river with many trials for a total period of 40 minutes. During sampling, all the insects found were sorted out by thorough search using a white tray and were preserved in absolute alcohol. Aquatic insects collected were counted and identified up to the lowest possible taxonomic unit (family) using stereo microscope (Headz-HD600D) with the help of standard keys (MaCaferty, 1983; Morse *et al.,* 1984; Yule and Sen, 2004). The terminology of aquatic insects was used followed Morse *et al*. (1984). Physico-chemical characteristics of the water were analyzed following the standard methods (Bridgewater, 2012; Trivedi and Goel, 1986). Biodiversity of ponds was worked out using different diversity indices (Shannon and Weiner, 1963; Simpson, 1949; Mergalef, 1958; Pielou, 1966). Different diversity of aquatic insects viz; species diversity index, index of dominance, species richness index and species evenness index were calculated using PAST ver. 1.34 program (Hammer *et al*., 2005). Individual scores of aquatic insect diversity of each station were correlated with physical and chemical parameters and dependence of entomofauna to water quality was identified by the SPSS ver. 16.0 statistical package (SPSS Inc., 2007).

RESULTS AND DISCUSSION

The present study identified a total of 132 taxa represented by 33 families belonged to 6 orders during the period from March 2014 to September 2014 covering pre-monsoon, monsoon and post-monsoon seasons. The major aquatic insect taxa reported during pre-monsoon were Libellulidae, Protoneuridae, Baetidae, Chironomidae and Naucoridae (Table. 2). The families like Libellulidae and Protoneuridae were observed dominant during this season. Other families encountered in this study were Coenagrionidae > Caenidae > Gerridae > Gomphidae. This study observed 20 families during pre-monsoon season against the 22 families recorded during both monsoon and post-monsoon seasons. Population density in monsoon season was represented by 172 Individual/meter (Ind. /m^2), followed by 156 Ind. /m^2 in post-monsoon season and 137 Ind. /m^2 in pre-monsoon season. Moreover, individuals recorded during monsoon season were dominated by families like Baetidae (35 Ind. /m^2), Coenagrionidae (23 Ind. /m^2), Caenidae (19 Ind. /m^2), Libellulidae (17 Ind. /m^2) and Naucoridae (11 Ind. /m^2). In contrast to this, post monsoon season supported a considerable population of Naucoridae (38 Ind. /m^2). Other dominating families of this season were Baetidae (22 Ind. /m^2), Calopterygidae (14 Ind. /m^2), Hydrophilidae (13 Ind. /m^2) and Hydropsychidae (12 Ind. /m^2).

The seasonal study in Killi River revealed that diversity and distribution of aquatic insects were influenced by water quality factors. Despite all the water quality parameters remains in the desirable limit as per the Arghyam, 2012, a positive correlation of aquatic entomofauna with water quality was established during this study. The mean scores of macroinvertebrate diversity indices are shown in the Table 3. The station-wise analysis of aquatic entomofauna identified a maximum aquatic insect dominance at station K06 (0.814) than other stations and least at station K02 (0.56) during the pre-monsoon season. Dominance and evenness being interrelated exhibited a similar trend (Table 3) in all the seasons (Figure 2). The Shannon diversity index (*H'* score) varied significantly among stations and also between different seasons (Figure 3). Maximum diversity of aquatic insect taxa in pre-monsoon season was recorded at station K06 (*H'*=1.99) however, minimum diversity was found at station K02 (0.92). During monsoon, the *H'* score ranged from 1.29 (station K02) to 2.27 (station K05) with an average score of 1.77±0.17. During post-monsoon season maximum diversity of benthic entomofauna was observed at station K03 (*H'*=2.23) followed by station K02 (*H'*=2.00) and least diversity recorded at station K04 (*H'*=1.07).

The present study indicated that variations in macroinvertebrate richness existed between stations

Table 1. Descriptions of sampling stations in the upstream segment of Killi Ar, Thiruvananthapuram, South Kerala

#	Station	Latitude and Longitude	Land use	Vegetation	Bottom substrate	Threats
K01	Theerthankara	08° 38’47.8"N 77° 59' 02.2"E	Mixed plantation	Mixed	Cobble, coarse gravel	Bathing, Washing, Sand mining.
K02	Unnupalam	08° 38’29.9"N 76° 59’43.9"E	Rubber plantation	Rubber	Fine gravel, coarse sand, very coarse sand	Sewage, Garbage
K03	Anadu	08° 38’21.0"N 77° 00’45.3"E	Mixed plantation	Mixed	very coarse sand, Clay	Garbage, Agricultural wastes.
K04	Pazhakutti	08° 37’25.0"N 76° 59’51.7"E	Rubber plantation	Rubber	Boulders, Rock	Garbage, sewage, Washing.
K05	Nedumangadu	08° 35’58.7"N 76° 59’41.8"E	Semi-urban settlements	Mixed	Coarse gravel	Encroachment, Waste Dumping, Sewage.
K06	Azhikkodu	08° 34’30.9"N 76° 59’44.7"E	Mixed plantation	Mixed	Rocky, Fine gravel	Slaughterhouse waste, Garbage, Sewage and Bathing

Table 2. List of Aquatic insect families recorded from the upstream segment of Killi Ar, South Kerala, India during March 2014-September 2014.

Order	Family	PREM[1] (Indi/m^2)	MON[2] (Indi/m^2)	POM[3] (Indi/m^2)
Coleoptera	Hydrophilidae	3	5	13
	Dysticidae	4	5	1
	Gyrinidae	0	5	0
	Noteridae	1	4	5
Diptera	Tipulidae	0	1	0
	Chironomidae	13	6	3
	Culicidae	0	2	1
	Stratiomyidae	2	0	0
Ephemeroptera	Baetidae	16	35	22
	Caenidae	8	19	6
	Ephemerellidae	0	0	6
	Heptageniidae	0	13	0
	Leptophlebiidae	0	1	5
	Siphlonuridae	2	0	1
Hemiptera	Aphelocheriade	1	0	0
	Velidae	0	2	0
	Belostomatidae	0	0	2
	Gerridae	6	0	0
	Naucoridae	11	11	38
	Nepidae	2	1	0
	Pleidae	2	0	0
Odonata	Cordulidae	3	0	6
	Calopterygidae	0	0	14
	Chlorocyphidae	0	0	3
	Coenagrionidae	10	23	5
	Euphaeidae	0	7	0
	Gomphidae	4	8	8
	Libelliludae	22	17	2
	Platycnemidae	4	1	2
	Protoneuridae	22	0	0
Trichoptera	Limnephillidae	0	1	1
	Hydropsychidae	2	3	12
	Polycentropodidae	1	0	0
	Total	**139**	**170**	**156**

[1]Pre-monsoon, [2] Monsoon, [3] Post-monsoon.

Table 3. Summary of diversity of aquatic insects recorded from the various stations of upstream stretch of Killi Ar, South Kerala, India during March 2014 - September 2014.

Stations	K01	K02	K03	K04	K05	K06	Range
Pre-Monsoon							
No. of Taxa	5	3	6	9	4	10	03-10
No. of Individuals	27	11	22	31	13	33	11-33
Simpson Index	0.69	0.56	0.73	0.78	0.66	0.81	0.56 - 0.81
Shannon Index	1.33	0.92	1.46	1.78	1.21	1.99	0.92 - 1.99
Pielou's Index	0.76	0.83	0.72	0.66	0.83	0.73	0.66 - 0.83
Margalef Index	1.21	0.83	1.62	2.33	1.17	2.57	0.83 - 2.57
Monsoon							
No. of Taxa	7	5	9	6	11	10	05-11
No. of Individuals	35	24	19	18	29	47	18- 47
Simpson Index	0.66	0.66	0.8	0.75	0.88	0.76	0.66 - 0.88
Shannon Index	1.37	1.29	1.88	1.57	2.24	2.27	1.29 - 2.27
Pielou's Index	0.56	0.73	0.73	0.8	0.85	0.54	0.54 - 0.85
Margalef Index	1.69	1.26	2.72	1.73	2.97	2.34	1.26 - 2.97
Post-Monsoon							
No. of Taxa	9	11	14	4	5	4	4-14
No. of Individuals	24	40	56	12	15	9	9-56
Simpson Index	0.81	0.82	0.84	0.58	0.6	0.69	0.58 - 0.84
Shannon Index	1.91	2	2.23	1.08	1.21	1.27	1.08 - 2.23
Pielou's Index	0.75	0.67	0.66	0.73	0.67	0.89	0.67 - 0.89
Margalef Index	2.52	2.71	3.23	1.21	1.48	1.37	1.21 - 3.23

(Table 3). During pre-monsoon season maximum richness was observed at station K06 (*D*= 2.57) followed by station K04 (*D*=2.33) and least at station K02 (*D*=0.83). However, in monsoon, station K05 revealed higher richness (*D*=2.97) than other stations. In the post-monsoon season maximum and minimum richness score was observed at stations K03 (*D*=3.23) and K04 (D=1.21), respectively. The major insects orders recorded during this study are Coleoptera, Diptera, Hemiptera, Ephemeroptera, Odonata and Trichoptera (Figure 3).

The study shows variation in composition and distribution of macro benthic entomofauna between different seasons. Insect orders like Trichoptera, Hemiptera, Diptera and Coleoptera were showed seasonality in their occurrence and Odonata showed a uniform distribution pattern. The insect order Odonata was dominant during pre-monsoon season over the other taxa, which contribute about 47% of the total taxa. Other key taxa belonged to this season were Ephemeroptera and Hemiptera, which comprises about 18% and 16% of the total entomofauna respectively. Members of the order Trichoptera, one of the true indicators of disturbed environments were lesser in number (2%) during this season. The monsoon season is notably comprised of order Ephemeroptera. About 70% of individuals collected during this season belonged to these taxa. Order Odonata was represented by 33%. Other insect taxa found during the monsoon were Coleoptera (11%), Hemiptera (8%) and Diptera (5%). The post-monsoon season was dominated by Ephemeroptera, Hemiptera and Odonata. In this season macrobenthic fauna showed the lowest degree of taxonomical heterogeneity. The study revealed that all the dominant taxa of the previous season except Coleoptera (11%), Trichoptera (8%) and Diptera (3%) were found distributed evenly during this period.

The station wise data of the water quality parameters are shown in Table 4. Despite all the water quality parameters remains in the desirable limit as per the Arghyam, 2012, a positive correlation of aquatic entomofauna with water quality could be identified in this study. During pre-monsoon season preferences of aquatic entomofauna to the quality of the water were significantly evident across various seasons surveyed (Table 5). Water parameters like

Table 4. Summary of water quality parameters recorded from upstream segment of Killi Ar, South Kerala, India during March 2014-September 2014.

Stations	K01	K02	K03	K04	K05	K06	Range	SE*
Pre-monsoon								
Water Temp (ºC)	24	25	25	27	27	27	24 - 27	0.54
pH	7.7	6.8	7	8.1	5.8	6.8	5.8 - 8.1	0.33
DO (mg/l)	4.3	4	3.8	6	4.1	9	3.8 - 9	0.83
BOD (mg/l)	0.3	0.4	0.8	0.1	0.6	0.8	0.1 - 0.8	0.12
COD (mg/l)	7.1	8.3	9.3	4.2	7.2	6.1	4.2 - 9.3	0.72
EC (µs/cm-1)	80	91.8	71.4	87.3	97	87.3	71.4 - 97	3.68
TDS (ppm)	60	70	60	70	90	70	60 - 90	4.47
Hardness (mg/l)	18	24	18	28	32	22	18 - 32	2.28
Chloride (mg/l)	30.5	28.02	22.3	34	46.4	37.8	22.31 - 46.4	3.41
Monsoon								
Water Temp (ºC)	22	23	22	24	24	25	22 - 25	0.49
pH	7.6	7.7	8.6	7.8	6.6	7.9	6.6 - 8.6	0.26
DO (mg/l)	4.7	0.6	1	3.7	0.9	3.4	0.6 - 4.7	0.72
BOD (mg/l)	2	3.8	1.1	1.6	2.4	2	1.1 - 3.8	0.38
COD (mg/l)	6.2	12.4	8.5	4.6	7.2	6.2	4.6 - 12.4	1.11
EC (µs/cm-1)	74.2	52	74.2	80	110	102	52 - 110	8.58
TDS (ppm)	40	40	60	70	90	80	40 - 90	8.43
Hardness (mg/l)	8	16	20	26	24	26	8-26	2.88
Chloride (mg/l)	22.7	24.14	28.4	25.6	35.5	34.1	22.72 - 35.5	2.17
Post-Monsoon								
Water Temp (ºC)	25	23	26	25	26	24	23 - 26	0.48
pH	7.2	6.7	7.1	7.5	6.1	7.2	6.1 - 7.5	0.2
DO (mg/l)	5.3	2.6	0.8	3.1	2.1	4.6	0.8 - 5.3	0.67
BOD (mg/l)	2.8	1.5	1.1	1.2	1.3	0.5	0.5 - 2.8	0.31
COD (mg/l)	10.1	7.44	10.3	1.4	4.4	7.24	1.4 - 10.28	1.4
EC (µs/cm^{-1})	71.4	83.2	68.6	91.8	98	110	68.6 - 110	6.5
TDS (ppm)	60	60	40	70	70	90	40 - 90	6.71
Hardness (mg/l)	20	18	44	20	22	28	18 - 44	3.99
Chloride (mg/l)	22.7	38.34	44	34.1	38.3	41.2	22.72 - 44.02	3.06

temperature, pH and dissolved oxygen (DO), chemical oxygen demand (COD) and total dissolved solids (TDS) of water showed a positive correlation with benthic insect fauna during this season. Water temperature showed a positive correlation with richness (r=0.612) of the benthic entomofauna during this season and a positive correlation has also been found between pH and insect population (r=0.65). Diversity (*H'* index) of macrobenthic fauna showed a strong positive correlation with dissolved oxygen (r=0.84). Moreover, DO of water has a strong positive correlation with dominance (r=0.74) and richness (r=0.85) of entomofauna in this season. Interestingly, dominance, diversity and richness of the insect fauna were depended on biological oxygen demand (BOD), DO, temperature, pH and chloride concentration of water than the rest of the other parameters. Invertebrate taxa reported during this season were predominantly larvae of *Agriocnemis* sp., *Prodasineura* sp., *Paragomphus* sp. belong to the order Odonata, *Chironomus* sp of the order Diptera, *Rhyacobates* species of the order Gerridae, *Plecoris* species of family Naucoridae, order Hemiptera, and *Baetis* sp and *Caenis* sp of Ephemeroptera. Similar high Dipteran species richness (Chironomidae) was reported in the North African intermittent river by Arab *et al.* (2004). The diversity of benthic macroinvertebrates in hill streams and wetlands were reported to be influenced by environmental conditions (Latha and Thanga, 2008).

Table 5. Correlation coefficients (Spearman rank order correlation) of aquatic insects to water quality parameters observed from upstream segment of Killi Ar, South Kerala, India during March 2014- September 2014.

Diversity	WT[a]	pH[b]	DO[c]	BOD[d]	COD[e]	EC[f]	TDS[g]	HAR[h]	CH[i]
Pre-monsoon									
No. of Taxa	0.55	0.43	0.86*	0.08	-0.67	-0.19	-0.2	-0.07	0.11
No. of Individuals	0.21	0.65	0.72	-0.08	-0.62	-0.4	-0.46	-0.34	-0.05
Simpson Index	0.48	0.36	0.74	0.18	-0.57	-0.33	-0.2	-0.13	0.14
Shannon Index	0.53	0.37	0.84*	0.16	-0.62	-0.24	-0.18	-0.1	0.15
Pilou's Evenness Index	-0.19	-0.77	-0.44	0.22	0.55	0.54	0.51	0.26	0.29
Margalef Richness Index	0.61	0.36	0.86*	0.12	-0.65	-0.16	-0.13	-0.01	0.15
Monsoon									
No. of Taxa	0.35	-0.28	-0.16	-0.4	-0.31	0.89*	0.78	0.43	0.90*
No. of Individuals	0.45	-0.2	0.42	0.09	-0.23	0.49	0.21	-0.03	0.41
Simpson Index	0.36	-0.31	-0.43	-0.39	-0.27	0.75	0.87*	0.68	0.82*
Shannon Index	0.6	-0.22	-0.18	-0.35	-0.33	0.89*	0.89*	0.69	0.98**
Pilou's Evenness Index	0.05	-0.37	-0.61	0.08	0.13	0.08	0.36	0.41	0.18
Margalef Richness Index	0.18	-0.16	-0.32	-0.52	-0.27	0.77	0.76	0.47	0.82*
Post-monsoon									
No. of Taxa	0.03	0.53	-0.47	0.29	0.75	-0.85*	-0.89*	0.52	0.14
No. of Individuals	0.07	0.55	-0.62	0.13	0.64	-0.78	-0.89	0.59	0.31
Simpson Index	-0.25	0.59	-0.05	0.37	0.91*	-0.73	-0.63	0.37	-0.04
Shannon Index	-0.08	0.53	-0.27	0.39	0.85*	-0.83	-0.8	0.44	0.02
Pilou's Evenness Index	-0.35	0.18	0.73	-0.3	0	0.6	0.78	-0.06	-0.06
Margalef Richness Index	0.61	0.51	-0.36	0.38	0.81*	-0.86	-0.86	0.47	0.05

[a] Water temperature, [b] Physiological Hydrogen ion concentration, [f] Electrical conductivity, [g] Hardness, [i] Chloride.
[c] Dissolved oxygen, [d] Biological oxygen demand, [e] Electrical conductivity, [f] Total dissolved solids, [g] Hardness, [i] Chloride.
*correlation is significant at the 0.05 level **correlation is significant at the 0.01 level

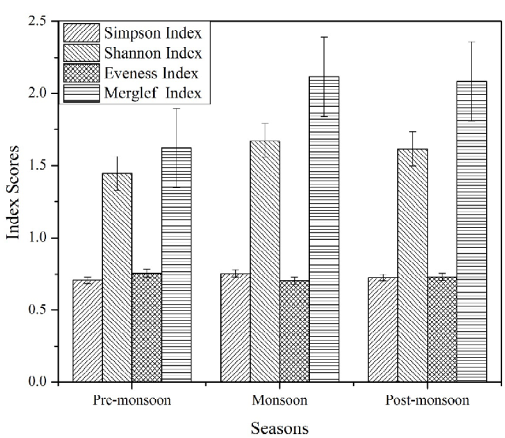

Fig. 2. Seasonal variation of aquatic insect diversities recorded from upstream segment of Killi Ar, South Kerala, India during March 2014 - September 12014.

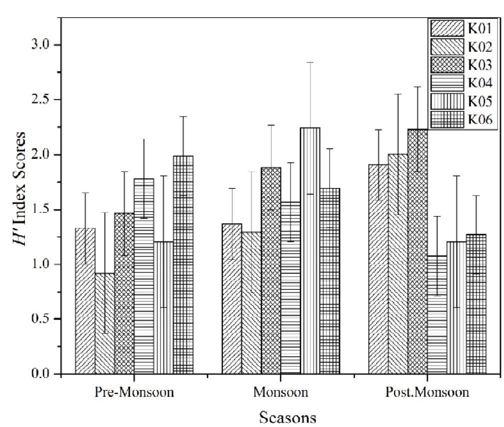

Fig. 3. Variation in Shannon diversity index score recorded from upstream segment of Killi Ar, South Kerala, India during March 2014 -September 2014.

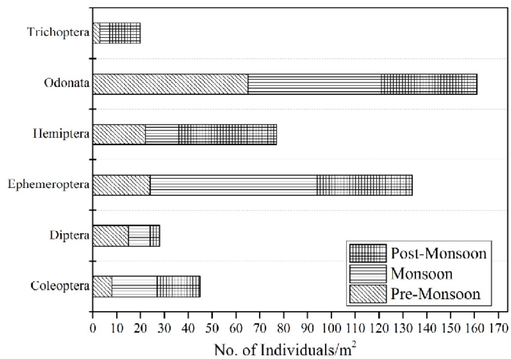

Fig. 4. Composition of entomofauna recorded in the Killi Ar, South Kerala, India during March 2014-September 2014.

Macrobenthic insect fauna of Killi Ar in monsoon season exhibit greater variation in their dependence to water parameters studied (Table 5). During this season macrobenthic entomofauna depended predominantly to water temperature, conductivity, TDS, hardness and chloride levels of the water. Conductivity during this season had a strong positive correlation with diversity (r=0.89), richness (r=0.77) and dominance(r=0.75) of benthic insect fauna under study. Hardness of the water established a positive correlation with dominance (r=0.683) and diversity (r=0.688) of entomofauna during this season. All the other water quality parameters were not influencing the benthic macro insect communities during monsoon, probably due to heavy and rapid water discharge making little differences in water quality between stations surveyed. The number of taxa, dominance, diversity and richness of the entomofauna were exhibited stronger dependence to conductivity, TDS, hardness and chloride levels of the water during this season (Table 5). The insect fauna during this season were represented by individuals of order Ephemeroptera. Priyanka and Prasad (2014) had reported similar distribution pattern from the Kallar River. However, Ephemeroptera, during the present study was represented by *Caenis* sp., larvae of family Ceanidae and *Baetis* sp., larvae of Baetidae. The Odonata comprised of *Agriocnemis* sp., larva of Coenagrionidae, larvae of *Mnais* sp., and *Orthetrum* sp., were belong to the family Libellulidae and *Paragomphus* sp., larva of Gomphidae.

All the diversity indices of entomofauna except evenness index in the post-monsoon season were positively correlated to COD of the water (r>0.5) (Table 5). Conductivity and TDS level during this season found positively correlated (r=0.60 and r=0.78, respectively) only to evenness of macrobenthic insect fauna during this season. The number of taxa, number of individuals, diversity and richness were slightly correlated with the hardness of the water. However, the chloride content of water showed a weak correlation with diversity and distribution of aquatic entomofauna. BOD, pH, electrical conductivity (EC) and hardness of the water exhibited a positive correlation with benthic entomofauna except in their evenness of distribution. The aquatic insect groups encountered during this season were *Mnais* sp., *Matrona* sp. (Calopterygidae), *Libellago* sp. (Chlorocyphidae), *Cercion* sp., *Argiocnemis* sp., *Ceriagrion* sp. (Coenagrionidae), *Somatochlora* sp. (Corduliidae), *Melligomphus ardense* (Needham), *Trigomphis* sp., *Stylogomphus* sp. (Gomphide), *Copera marginipes* (Rambur) (Platycnemidae). Order Ephemeroptera in this season was represented by larvae of *Centrosptilum* sp., *Cleaon* sp., *Pseudocleon* sp., Caenis sp., *Hexagenia limbata* (Rambur), *Ephera* sp., Ephemerellidae *Habrophlebia* sp. (Leptophlebiidae). The larvae of *Chironomus* sp. (Chironomidae) and *Culicinae* sp. (Culicidae) of order Diptera indicate organic pollution (Czerniawska-Kusza, 2005; Al-Shami et al. 2010) were found during this season. The family Naucoridae during this season was represented only by larvae of *Plecoris* species.

Pre-monsoon and post-monsoon represented more diverse fauna and certain pollution tolerant families like Chironomidae and Culucinae. However, compared to the results of other lotic habitats composition of macrobenthic entomofauna in the present study varied significantly. Ambili and Reenamole (2013) studied benthic macroinvertebrates of Ayiroor River close to the longitude of Killi Ar recorded only 4 taxa. Similarly, Sheeba and Ramanujan, (2009) reported 28 species of macroinvertebrate fauna in Ithikkara River, of that only 12 were belong to the insect taxa. However, the present study could observe a fairly diverse composition of insect fauna in the upstream of Killi

Ar identifying lesser urbanization pressure at this stretch of river. In brief, entomofaunal composition changes with seasonal changes in water quality in the upstream segment of this stream. This observation is further substantiated by insect community distribution in Western Ghats (Subramanian and Sivaramakrishnan, 2005).

The presence of taxa viz; Coleoptera and Diptera are attributed to the prevalence of water pollution while such taxa were rare in the upstream segment of Killi Ar. Latha and Thanga, (2010) reported Dipteran dominance in the Veli and Kadinamkukam Lakes which are now at the risk of pollution. In addition, the intolerant taxa like Trichoptera were found few in all seasons during this study. Analysis showed that a considerable population of Hemiptera, Ephemeroptera and Odonata were occupied in upstream points during the post-monsoon season. Martin *et al.* (2000) identified a rich population of Hemipterans during the post-monsoon season in Tamiraparani River, South India substantiate the present findings. However, a high population density of Hemiptera regardless of the season was reported (Barman and Guptha, 2016). In contrast, the high density of Hemiptera in the present study could be due to their ability to live in hypoxic water environments. Bouchard (Bouchard, 2004) identified that Hemipteran can survive in low oxygen levels depending on their ability to absorb atmospheric oxygen. The study identified that benthic entomofauna in the upstream stretch of Killi Ar was determined by an interaction of both intrinsic habitat nature and extrinsic factors like water quality. A similar observation has been made in the study of the aquatic insect fauna of Western Ghats by Subramanian and Sivaramakrishnan (2005).

CONCLUSIONS

The environmental parameters were meaningfully linked to diversity and distribution of aquatic insects in the upstream segment of Killi Ar during this study. Diversity indices like dominance, diversity and richness of the insect fauna were positively correlated to water quality factors like BOD, DO, temperature, pH and chloride content. Seasonal changes in water quality were responsible for maintaining seasonality in distribution and diversity of entomofauna in Killi Ar. Since the results were appropriate to understand their association with physico-chemical parameters, the macro benthic entomofauna can be suitable for bio monitoring of the rivers. The findings of the present study were considered to be vital for the management of the water resources like Killi Ar which is an important lotic habitat traversing Thiruvananthapuram Corporation.

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