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Community Structure of Macrobenthic Fauna in Achenkovil River, Southern- Western Ghats, Kerala, India

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Abstract: A study on the water quality parameters and community structure of the macrobenthic fauna was carried out in the Achenkovil river basin, Kerala. Nine sampling sites were selected for the study and the macrobenthic fauna was collected using Van Veen Grab (0.025m2). Both the water and sediment samples were collected bimonthly and seasonally. Fourteen water quality parameters were analyzed to monitor the influence of water quality on the community structure of macrobenthos. The maximum mean value for DO and silicate was in station 1 (S1). The water temperature, BOD, turbidity, conductivity, TDS, salinity, alkalinity, hardness, pH, nitrate, and phosphate have their maximum value in the downstream stretches of the river. A total of 3563 macrobenthic individuals belonging to 8 orders, 32 families, 32 genera, and 32 species were collected and identified. Among the macrobenthic community, the order Ephemeroptera showed the maximum abundance (860 Ind/m^2) and minimum for Zygoptera (63 Ind/m^2). Station S1, part of a pristine forest region, is characterized by rich benthic diversity and abundance. The pollution-sensitive taxa such as Ephemeroptera, Plecoptera, and Trichoptera were the dominant members of the community structure in S1. Their presence is an indication of good water quality. The midstream and downstream segments of the river are facing severe anthropogenic stress. An increase in the abundance of pollution-tolerant organisms such as Chironomids in the midstream and downstream segments of the river is an indication of deteriorating water quality. The diversity, distribution, and abundance of the macrobenthic community were highly influenced by the variations in water quality due to various natural as well as anthropogenic impacts.

Keywords: Biogeochemical cycles, Diversity, Freshwater, Invertebrates, Species richness

Benthos plays a vital role in the functioning of an ecosystem (Iyagbaye et al 2017). They serve as the food source for most aquatic organisms. Freshwater sediments serve as the home for a diverse group of benthic invertebrates with rich diversity and abundance but their distribution is uneven which creates sampling difficulty. They decompose complex organic matter into simple absorbable forms, oxygenate the underlying sediments, and thus play an efficient role in biogeochemical cycles (Basu et al 2018). Interruptions among the complex sediment-dwelling benthos and associated food web sometimes cause a sudden change in the equilibrium setup of the environment (Poikane et al 2016). Thus, the species richness, diversity, abundance, distribution, and functional importance of benthic invertebrates remain unnoticed until unexcepted changes occur in the ecosystem. Anthropogenic activities play a negative role in the species richness of benthic macroinvertebrates (Mola and Gawad 2014). The structural assemblage of the macrobenthic community is very complex and includes a variety of organisms from microbes to phytobenthos and zoobenthos and covers different levels of the food web (Idowu and Funso 2019). The study on the macrobenthic community structure reveals differences in species composition, abundance, biomass, and distributional patterns in various aquatic ecosystems (Zabby and Hart 2006). Knowledge about diversity, abundance, richness, evenness, and community structure are important parameters to determine the natural or anthropogenic changes in the water body concerning time (Jun et al 2016). The macrobenthic fauna shows uneven distributional patterns in riverine ecosystems (Basu et al 2018). The physicochemical parameters influence the structural assemblage of the macrobenthic community (Zabby and Hart 2006). As they are slow-moving, they tend to remain in their original habitat with great acclimation potential (Sandin 2000). They can withstand changes in water quality and a high amount of pollution. High loads of pollution in the water body cause an increase in the number of tolerant species, thus increasing the abundance of particular species and decreasing the diversity and species richness. They serve as an efficient tool to evaluate water quality and are commonly used in biomonitoring programs. Thus, they are considered good bio-indicators for the environmental changes in any aquatic ecosystem. Abdel and Gawad (2019) observed that macrobenthic invertebrates are the most ideal indicators for biomonitoring and provide an ecological outline of the present status of the river. Similar studies on the influence of water quality parameters and the community structure of macrobenthos were carried out by several workers (Mophin-Kani and Murugesan (2014), Nautiyal et al 2017, Basu et al 2018, Kamal et al 2021, Mishra et al 2022, Priyanka and Prasad (2022), and Sekhar (2022)). No one has yet attempted to study the macrobenthic fauna of the Achenkovil river. The present study was carried out in the Achenkovil river to ascertain the composition and structural diversity of macrobenthic fauna, the environmental factors and anthropogenic impacts responsible for the community patterns.

MATERIAL AND METHODS

Study area: This study includes the Achenkovil river, Southern Western Ghats, Kerala, India. The river drains through highly varied geological formulations and covers the highland, midland and lowland physiographic provinces of the state. About 60% of the highland is occupied by dense forest, 5% by degraded forest and 10% is agricultural land. Nearly 40% of the Midland region is under double-crop paddy cultivation. The lowland region is a narrow strip of land along the West Coast and is occupied by 80% agricultural land (mixed agricultural/horticultural plantation) and 10% under double crop paddy cultivation. The rest of the area is occupied by water bodies. The study area experiences a tropical climate with three distinct seasons-premonsoon (February- May), monsoon (June-September) and postmonsoon (October- January). Floods are common in the midland and lowland regions during the monsoon months. In non-monsoon months, as the freshwater flow decreases, salinity intrusion occurs in the lowland tracks of the river making the river water saline. This adversely affects the biotic community and creates a lot of technical problems in this region.

Sampling sites: Samples were collected bimonthly and seasonally in premonsoon (February-May), monsoon (June-September), and postmonsoon seasons (October- January), early in the morning hours (06.00 -11.30 h) throughout the study period (2018-2020). The entire river body is divided into three segments- upstream with 9° 07' 39.53' N and 77° 07' 58.56' E with an elevation of 870 ft a.m.s.l, midstream- 9° 13' 59.37' N and 76° 40' 38.4' E with an elevation of 66 ft a.m.s.l, and downstream with 9° 19' 29.07' N and 76° 26' 54.31' E with an elevation of 6 ft a.m.s.l- with three stations in each segment of the river (Total 9 sampling sites along the entire stretch of the river) (Fig. 1).

Identification of macrobenthic fauna: Macrobenthic fauna was collected using Van Veen grab (0.025 m^2). Triplicate samples were taken for precision. The grab samples collected were sieved through a series of mesh sieves-3000 µm (3mm), 2000 µm (2 mm), 1000 µm (1mm), and 500 µm (0.5 mm) mesh and the sediments retained in the 0.5 mm sieve was washed, and carefully transferred to a white plastic tray and was sorted out. All the collected samples were preserved in 4% formalin for subsequent analysis. In the laboratory, the preserved sample was examined using a stereomicroscope (Magnus MSZ- BI LED) and identified using standard taxonomic literature- Young and Yule (2004), Dudgeon (1999), Thorp and Covich's Freshwater Invertebrates (2015), Merrit and Cummins (1996).

Physicochemical analysis: Water temperature (°C) was measured *in situ* by using a Mercury thermometer (with ± 0.1°C accuracies). The samples for DO and BOD were fixed with alkaline potassium iodide and manganous sulphate at the site itself. The water samples were then carried immediately to the laboratory for further analysis. The water samples were collected using clean polyethylene bottles and carried immediately to the laboratory for further analysis. DO (mg/l), BOD (mg/l), pH, turbidity (NTU), conductivity (µS/cm), salinity (ppt.), alkalinity (mg/l), hardness (mg/l), TDS (mg/l), phosphate (mg/l), silicate (mg/l) and Nitrate (mg/l) was carried out using standard references (APHA 2017).

Statistical analysis: Multivariate statistical analysis such as PCA was employed to study the variation in environmental parameters (PCA) and the relationship between macrobenthic fauna and environmental parameters were carried out using CCA. Community structure was assessed using biodiversity indices and Engelmann's scale. Biodiversity indexes and CCA were carried out using PAST (Version 4.09) software. PCA was carried out using SPSS (Version 22).

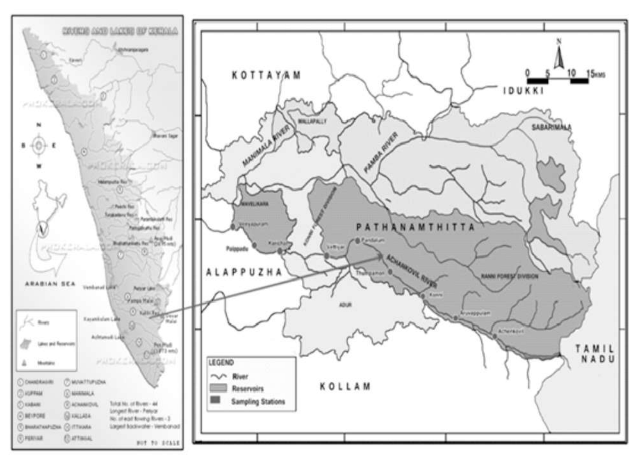

Fig. 1. Map showing the study sites (Stations S1 to S9) in the Achenkovil River basin, Kerala. The upstream sites include Achenkovil (S1), Aruvappulam (S2), and Konni (S3); Midstream includes Thumpamon (S4), Pandalam (S5), and Vettiyar(S6) and the Downstream includes Karichal (S7), Payippad (S8), and Veeyapuram (S9)

RESULTS AND DISCUSSION

Environmental variables: The variation in the environmental parameters was analyzed using the multivariate statistical technique (PCA) (Table 1 and 2). The PCA showed four principal components, which explained 77.98% of the total variance. PC1 explained 27.14% of the total variance and had a significant contribution from TDS, conductivity, salinity, and hardness with a strong positive loading value of >0.75. PC2 accounted for 20.28% of the total variance and has a strong positive correlation with BOD, DO, water temperature, and silicate. PC3 accounted for 16.53% of the total variance and had a strong positive correlation with depth, turbidity, phosphate, and nitrate. PC4 accounted for 14.04% of the total variance and had a strong positive correlation with pH and alkalinity (Table 3). Absolute loading value >0.75 is of strong significance and these parameters can be used to monitor the variations in water quality (Liu et al 2003).

Temperature is an important factor that plays a major role in the physical, chemical, and biological characteristics of water. The water temperature in the present study varied from 21.80°C to 30.20°C with the maximum mean value noted in S9 which may be due to high solar radiation, lack of

Table 3. Shows the variation in the environmental parameters analyzed using principal component analysis

Parameters	Components			
	1	2	3	4
Water temp.	0.179	0.756	0.217	0.376
Depth	-0.362	0.399	0.621	0.079
DO	-0.419	-0.76	0.283	0.076
BOD	-0.09	0.822	-0.094	0.209
pH	0.284	0.135	-0.102	0.778
Turbidity	0.271	-0.09	0.626	0.5
Conductivity	0.812	0.246	-0.05	0.372
Salinity	0.848	0.323	0.124	0.252
Alkalinity	0.265	0.259	0.052	0.763
Hardness	0.858	0.138	0.038	0.294
TDS	0.87	0.043	0.232	0.148
Phosphate	0.466	-0.07	0.751	-0.09
Silicate	-0.371	-0.74	0.053	-0.05
Nitrate	0.027	-0.18	0.865	-0.09
Eigen values	3.799	2.839	2.314	1.965
% of variance	27.14	20.28	16.53	14.04
Cumulative %	27.14	47.41	63.94	77.98

Table 1. Water quality parameters of Achenkovil river

Stations	Water temp. (°C)	Depth (m)	DO (mg/l)	BOD (mg/l)	Turbidity (NTU)	TDS (mg/l)	Conductivity (µS/cm)
S1	23.91 ±2.06	0.90±0.19	6.77±0.97	1.39±0.79	4.83±4.79	143.54±111.5	74.95±14.45
S2	25.26±1.55	1.32±0.81	6.48±0.97	1.65±0.67	5.04±2.99	118.38±43.80	64.13±13.24
S3	25.33±1.21	2.43±0.23	5.90±1.09	2.10±0.76	5.48±2.17	107.90±37.58	59.57±12.80
S4	26.23±1.10	3.49±0.20	6.16±0.92	2.20±0.64	5.52±2.71	104.81±41.70	66.89±14.29
S5	26.92±1.00	4.11±0.21	6.26±0.95	2.93±1.60	6.69±1.80	108.13±39.56	72.54±21.03
S6	26.99±0.79	3.19±0.35	5.90±1.07	2.90±1.64	6.96±2.25	126.78±40.50	75.94±19.08
S7	27.25±0.72	3.85±0.35	5.54±0.87	2.61±0.81	7.93±2.35	128.70±41.94	82.78±11.74
S8	28.10±0.99	3.15±0.22	5.25±1.13	2.94±0.60	8.58±2.79	250.59±127.7	173.60±167.13
S9	28.65±1.27	2.08±0.24	4.95±0.94	2.87±0.63	8.75±2.50	283.98±132.04	183.07±172.09

Table 2. Water quality parameters of Achenkovil river

Stations	Salinity (ppt.)	pH	Hardness (mg/l)	Alkalinity (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Silicate (mg/l)
S1	0	6.85±0.30	14.90±3.75	10.67±2.39	0.74±0.16	0.48±0.17	3.52±0.54
S2	0	6.74±0.19	15.40±3.01	10.93±2.42	0.92±0.16	0.49±0.14	2.73±0.54
S3	0	6.81±0.12	14.49±5.30	12.46±3.22	0.87±0.23	0.58±0.15	2.89±0.60
S4	0	6.78±0.18	17.34±3.46	11.86±2.87	0.92±0.22	0.66±0.17	3.12±0.74
S5	0	6.87±0.22	14.07±3.02	11.81±3.34	0.94±0.18	0.55±0.19	3.07±0.65
S6	0	6.87±0.36	14.15±2.50	12.40±2.50	0.99±0.21	0.60±0.20	2.46±0.34
S7	0.01±0.01	6.81±0.39	13.14±2.11	11.81±2.24	0.88±0.21	0.56±0.18	2.06±0.53
S8	0.26±0.16	6.94±0.35	30.50±23.09	14.37±3.56	1.01±0.17	0.80±0.24	2.05±0.45
S9	0.27±0.17	7.13±0.24	32.97±23.49	14.68±2.97	1.08±0.20	1.08±0.17	2.11±0.66

canopy cover, low rainfall, low water levels, and clear skies (Abilash and Mahadevaswamy 2021). The minimum mean water temperature was in S1, the headwater station has a thick canopy cover that prevents the direct heating of the surface water. The depth is in the range of 0.65m to 4.39m with maximum depth from S5. Sand mining by the locals residing near the river banks for house constructions may be a reason for an increase in depth. A high temperature causes a decrease in the DO level (in S9) which is a natural phenomenon, since warmer water was more easily saturated with oxygen and thus holds less DO (Yang et al 2021). The high DO in S1 may be due to water turbulence (Kannel et al 2007) resulting from the rugged topography of the river basin. The increase in pH value in S9 may be due to high photosynthetic activity (Craft et al 2018). The pH value shows a clear trend toward alkalinity which may be due to anthropogenic impacts, wastewater discharge and agricultural activities (Azouzi et al 2017). Heavy rain in the monsoon season causes surface runoff accompanied by sand, silt, clay, organic matter, etc. may be the reason for high turbidity in S9 during the monsoon season (Sanalkumar et al 2014). The mean turbidity was greater than the BIS permissible limit (5 NTU). An increase in turbidity is considered a limiting factor in the biological productivity of aquatic ecosystems (Mahajan and Billore 2014). Agricultural runoff resulting from heavy rainfall may be the reason for an increase in the value of nitrate and phosphate during the monsoon season (Varol et al 2012). The input of more silicious sediments along with surface runoff may be the reason for the high silicate content in the water body (Jaji et al 2007). The high BOD value noted in S8 may be due to low rainfall, low water flow, and high temperature (Girija et al 2007). The conductivity and salinity were maximum in S9. The intrusion of saline water from Kayamkulam lake into S8 and S9 during the premonsoon season may be the reason for high salinity and a corresponding increase in conductivity in the water body.

Macrobenthic community: The composition and distribution of macrobenthic fauna in the present study include a total of 3563 individuals belonging to 8 orders, 32 families, 32 genera, and 32 species (Table 4). The 8 orders include Ephemeroptera, Plecoptera, Zygoptera, Anisoptera, Coleoptera, Diptera, Hemiptera, and Trichoptera. The species composition of different orders of macrobenthic fauna revealed that the largest group was Ephimeroptera comprising 8 species, followed by 7 species of Coleoptera, 4 species each for Diptera, Hemiptera, Anisoptera. The order Ephemeroptera accounted for 24% of the total macrobenthic fauna and was the most dominant, diverse, and abundant group. This order was represented by 8 families. The second largest group was Coleoptera with 7 families, followed by Anisoptera, Diptera and Hemiptera with 4 families each, Trichoptera with 3 families and Plecoptera and Zygoptera with a single family. The least represented order was Zygoptera, which accounted for only 2% of the total macrobenthos studied (Fig. 2).

The abundance, relative abundance and dominance status of macrobenthic fauna studied in the Achenkovil river basin were calculated using Engelmann's scale (Table 4). The species *Notophlebia jobi, Caenis* sp., *Baetis* sp. of order Ephemeroptera, *Neoperla* sp., of order Plecoptera, *Chironomous* sp., *Atherix* sp., of order Diptera, *Micronecta* sp., of order Hemiptera, *Stylogomphus* sp., of order Anisoptera *Eubrinax* sp., *Cylloepus* sp., *Hydrophilus* sp., of order Coleoptera, *Economous* sp., *Chimarra* sp., *Hydropsyche* sp. of order Trichoptera (Relative abundance (RA%) range 3.2 to 10%) are the most abundant and sub-dominant species. *Dudgeodes* sp., *Sparsorythus gracillis, Afronurus kumbakkaraiensis, Torleya nepalica and Aethephemera nadiinae* of order Ephemeroptera, *Tabanus* sp. of order Diptera, *Microvelia douglasi, Lethocerus indicus, Nepa* sp. of order Hemiptera, *Euphae* sp. of order Zygoptera, *Anax* sp., *Corydalus* sp., *Crocothemis* sp. of order Anisoptera, *Agabus* sp. of order Coleoptera (RA % range from 1.1 to 3.1%) are the recedent species, *Tipula* sp.of order Diptera, *Rhyssemus* sp., *Hydrocanthus* sp.and *Hydrena* sp. of order Coleoptera (RA% less than 1%) are reported as sub-recedent species.

Canonical correspondence analysis: The relationship between the macrobenthic fauna and environmental variables (Fig. 3) was depicted using multivariate statistical analysis (CCA). The first canonical axis explained over 47.85% (Eigenvalue, 0.122) and the second 31.72% (Eigenvalue, 0.081) of the variation in the macrobenthic fauna data set. The Monte Carlo permutation test performed on the first two axes showed no significant differences. The CCA reveals that water quality parameters such as depth, water temperature, BOD, turbidity, TDS, conductivity, salinity, pH, hardness, alkalinity, nitrate, and phosphate show a positive correlation with macrobenthic groups such as Diptera and Anisoptera. The DO and silicate show a negative correlation with Ephemeroptera, Plecoptera, Hemiptera, Zygoptera, Coleoptera and Trichoptera in the first canonical axis. The second canonical axis revealed that water temperature, BOD, turbidity, TDS, conductivity, salinity, pH, hardness, alkalinity, nitrate, and phosphate shows a positive correlation with macrobenthic groups such as Plecoptera, Diptera, Hemiptera, Zygoptera, Coleoptera, Trichoptera whereas depth, DO and silicate shows a negative correlation with Ephemeroptera and Anisoptera. The studied physicochemical parameters have a strong influence on the community structure of macrobenthic fauna. From the CCA ordination plot, it is clear that the macrobenthos shows spatial variation concerning their environmental requirements. Dipterans commonly chironomids were one of the dominant taxa in natural (Copatti et al 2013) or non-natural environments (Hepp et al. 2010). Most of the members of EPT and Coleoptera are commonly known for their pollution-sensitive nature. They are absent from highly disturbed habitats.

The station-wise analysis reveals that the total number of taxa ranged from 4 (S9) to 32 (S1), individuals from 37 (S9) to 1461 (S1) Ind/m^2, dominance ranged from 0.043 (S3) to 0.661 (S9), Simpson from 0.339 (S9) to 0.957 (S3), Shannon from 0.73 (S9) to 3.28 (S3), Evenness from 0.44 (S8) to 0.86 (S3) and Margalef from 0.83 (S9) to 5.17 (S3) (Table 5). This study gave a reference state of the structural composition of the macrobenthic fauna of the Achenkovil river basin. Aquatic insects form the major group in the community structure of macrobenthos studied, and this is similar to the observations made by (Arimoro et al 2015). Abhilash and Mahadevaswamy (2021) observed that aquatic insects are generally considered the dominant macro-invertebrates in freshwater ecosystems. Spatio-temporal variations have a

Table 4. Relative abundance and dominance status of macrobenthic fauna in the Achenkovil river basin

Order	Family	Genus/Species	Abundance	Relative abundance	Status
Ephemeroptera	Leptophlebidae	*Notophlebia jobi*	171	4.80	Sub-dominant
	Caenidae	*Caenis* sp.	169	4.74	Sub-dominant
	Teloganodidae	*Dudgeodes* sp.	87	2.44	Recedent
	Baetidae	*Baetis* sp.	153	4.29	Sub-dominant
	Tricorythidae	*Sparsorythus gracillis*	74	2.08	Recedent
	Heptageniidae	*Afronurus kumbakkaraiensis*	94	2.64	Recedent
	Ephemerellidae	*Torleya nepalica*	65	1.82	Recedent
	Ephemeridae	*Aethephemera nadiinae*	47	1.32	Recedent
Plecoptera	Perlidae	*Neoperla*	175	4.91	Sub-dominant
Diptera	Chironomidae	*Chironomus* sp.	275	7.72	Sub-dominant
	Athericidae	*Atherix* sp.	125	3.51	Sub-dominant
	Tipulidae	*Tipula* sp.	34	0.95	Sub-recedent
	Tabanidae	*Tabanus* sp.	39	1.09	Recedent
Hemiptera	Notonectidae	*Micronecta* sp.	114	3.20	Sub-dominant
	Vellidae	*Microvelia douglasi*	87	2.44	Recedent
	Belostomatidae	*Lethocerus indicus*	98	2.75	Recedent
	Nepidae	*Nepa* sp.	75	2.10	Recedent
Zygoptera	Euphaeidae	*Euphae* sp.	63	1.77	Recedent
Anisoptera	Gomphidae	*Stylogomphus* sp.	290	8.14	Sub-dominant
	Aeshnidae	*Anax* sp.	78	2.19	Recedent
	Corydalidae	*Corydalus* sp.	39	1.09	Recedent
	Libellulidae	*Crocothemis* sp.	80	2.25	Recedent
Coleoptera	Dytiscidae	*Agabus* sp.	41	1.15	Recedent
	Psephenidae	*Eubrinax* sp.	183	5.14	Sub-dominant
	Elmidae	*Cylloepus* sp.	160	4.49	Sub-dominant
	Scarabaeidae	*Rhyssemus* sp.	20	0.56	Sub-recedent
	Hydraenidae	*Hydrena* sp.	16	0.45	Sub-recedent
	Hydrophilidae	*Hydrophilus* sp.	120	3.37	Sub-dominant
	Noteridae	*Hydrocanthus* sp.	26	0.73	Sub-Recedent
Trichoptera	Economidae	*Economous* sp.	142	3.99	Sub-dominant
	Philopotamidae	*Chimarra* sp.	175	4.91	Sub-dominant
	Hydropsychidae	*Hydropsyche* sp.	248	6.96	Sub-dominant

Table 5. Spatial variation of biodiversity indices in the Achenkovil river basin

Stations	Dominance _D	Simpson _1-D	Shannon _H	Evenness _e^H/S	Margalef
s1	0.045	0.955	3.23	0.79	4.254
s2	0.056	0.944	3.124	0.784	4.541
s3	0.043	0.957	3.288	0.864	5.179
s4	0.065	0.935	3.01	0.7	4.328
s5	0.118	0.882	2.704	0.622	4.122
s6	0.085	0.915	2.719	0.722	3.961
s7	0.094	0.906	2.551	0.713	3.416
s8	0.471	0.529	1.269	0.445	1.789
s9	0.661	0.339	0.73	0.519	0.831

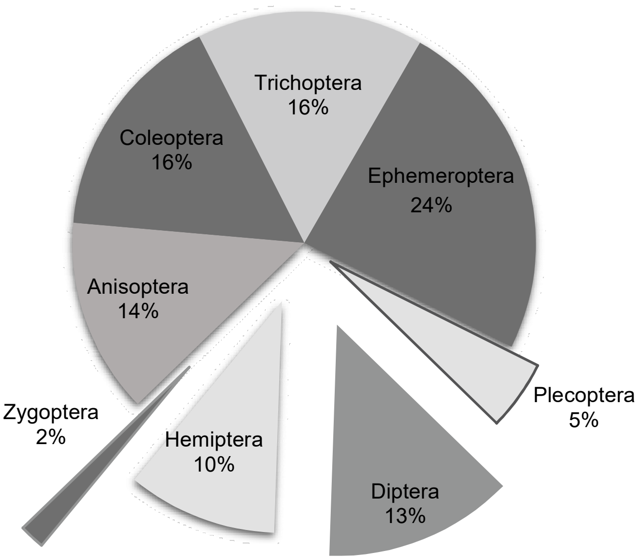

Fig. 2. Relative abundance of major orders of macrobenthic fauna studied

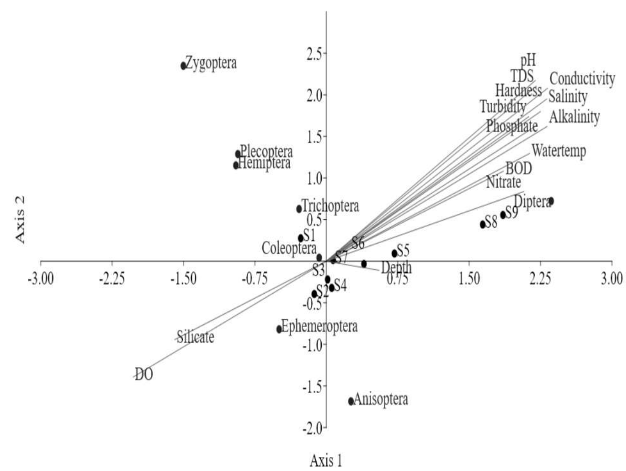

Fig. 3. Relationship between the macrobenthic fauna and the environmental parameters

strong influence on the community structure of macrobenthic fauna (Sasikala et al 2017). The structure and composition of biotic community change with the physicochemical and hydrobiological characteristics of the environment which is often reflected in the distribution, diversity and abundance pattern of species (Abhilash and Mahadevaswamy 2021). The Ephemeroptera had the highest number of species represented by 8 genera, accounting for 24% of the total macrobenthic fauna studied (Fig. 4). Leptophlebidae (19.88%) and Caenidae (19.65%) were the most abundant family among Ephemeroptera. The second largest group was Coleoptera (16%) with 7 families, followed by Trichoptera (16%), Anisoptera (14%), Diptera (13%), Hemiptera (10%), Coleopterans are abundantly seen in sites with good vegetation as it provides food and breeding places. They can also tolerate moderate levels of pollution (Popoola et al 2019). Chironomus are pollution tolerant and they dominated in sites with high turbidity, TDS, conductivity, and even low DO values. It can withstand hypoxic conditions (Popoola et al 2019). An increase in the number of Chironomus species is also an indication of anthropogenic stress . and are commonly used as bioindicators in water quality monitoring programs (Al- Shami et al 2010). The diversity and abundance of odonates in an area depend on the habitat heterogeneity formed due to the complexity of vegetation, the nature of the substrate, and physicochemical characteristics (Wijesooriya et al 2022). The Ephemeroptera shows higher species richness and abundance at the reference site and a reduction in species number and diversity towards the midstream and downstream stretch of the river. The abundance of some families of Ephemeroptera like Heptagenidae, Tricorythidae, Leptophlebiidae, Teloganodidae, etc indicates good water quality and the undisturbed forest habitat along the river banks and within the catchment in the reference site. *Baetis* and *Caenis* were present in the downstream segment of the river, as they can tolerate moderate levels of pollution. The decrease in the macrofaunal composition towards the midstream and downstream stretch of the river is an indication of pollution load and the corresponding deterioration of the water quality (Kumar et al 2012). Plecoptera and Trichoptera are sensitive to water quality degradation and occur only in clean and well-oxygenated water (Priyanka and Prasad 2014). They are abundant in the reference site (S1). Specific families within the Ephemeroptera, Plecoptera and Trichoptera (EPT taxa) help to monitor various types of disturbance in the water body (Abhijna et al 2013)). The spatial variation in the water quality status can be revealed from the values recorded for species diversity, richness, dominance and evenness indices. The highest values for Simpson, Shannon, Evenness and Margalef were noted in S3 and Dominance in S9. High dominance in S9 may be due to the disappearance of more sensitive taxa replaced with more tolerant species like Chironomous, thus reducing species richness and diversity (Copatti et al 2013). The highest diversity of macrobenthic fauna in the reference site may be due to the thick canopy cover that lowers the atmospheric and water temperature and provides diverse habitats for a variety of macrobenthic fauna leading to increased diversity. The Shannon index value for stations 5 to 9 and the Margalef index value for stations 8 and 9 were below three, which is an indication of the polluted water body. Similar reports were given by Kabir and Offioong (2016), in the Alaro stream, Ibadan. The low relative abundance of pollution-sensitive organisms, in the midstream and downstream segments, indicates that the river Achenkovil is already stressed across its reaches. However, water quality was more impacted during the rainy season, due to surface runoff. The CCA revealed that most taxa were sensitive to environmental changes. More sensitive macrobenthic fauna was in the upstream stations than in the midstream and downstream stations, as these species are favored by more DO levels and lower levels of conductivity, nitrate and phosphate. It is clear from the CCA plot that most of the Hemipterans are associated with high water temperature and less dissolved oxygen, indicating their less dependency on oxygen. Moreover, the Hemipterans possess additional respiratory structures such as plastron, siphon, etc. that help us to use atmospheric oxygen (Abhilash and Mahadevaswamy 2021).

CONCLUSION

The diversity, distribution pattern and abundance of macrobenthic fauna are highly influenced by environmental variables. Some species of macrobenthic fauna are pollution sensitive and some are pollution tolerant. So, their presence or absence can be used to predict water quality. To conclude, macrobenthic fauna has the potential to act as biological indicators of pollution status. Thus, keeping in mind the importance of the study, steps should be taken for the maintenance and conservation of freshwater ecosystems.

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