Eco. Env. & Cons. 29 (July Issue) pp. S15-S22
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ISSN 0971–765X

Special Issue on "Int. Conf. on Impact of Clim. Change on Aq. Life and Mtgn. Measures for a Sust. Blue Economy", 23-25 Nov, 2022, PG & Res. Dept. of Zoology, FMNC, Kollam, Kerala, India.

DOI No.: http://doi.org/10.53550/EEC.2023.v29isp2.003

Spatio-temporal variation of macrobenthic fauna and environmental parameters in Achenkovil River, Kerala, India

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ABSTRACT

The present study deals with the spatio-temporal variation of macrobenthic fauna and environmental parameters in Achenkovil River, Southern Western Ghats, Kerala. A bimonthly sampling was carried out from February 2019 to January 2020. Water samples for physico- chemical analysis was carried to the laboratory in clean polyethylene bottles. Macrobenthic fauna was collected using grabs, D- frame nets and handpicking methods. A total of 3563 individuals belonging to 8 orders, 32 families, 32 genus, and 32 species were identified. The most dominant order was Ephemeroptera followed by Coleoptera and *Trichoptera* and the least dominant was Zygoptera. The maximum number of macrobenthic fauna was observed in station S1(1461 Ind/m^2) and the least in station S9 (37 Ind/m^2). Seasonal analysis reveals that species richness is maximum during the post-monsoon season (1794 Ind/m^2) and minimum during the monsoon season (474 Ind/m^2). Environmental parameters play a major role in structuring the macrobenthic community. One-way ANOVA was used to analyse the seasonal variation of physico- chemical parameters. The spatial variation of water quality and the relationship between environmental variables and macrobenthic fauna was carried out using multivariate statistical analysis.

Key words: *Biomonitoring, Biodiversity indices, Freshwater, Invertebrates, Pollution*

Introduction

The ability of macrobenthic invertebrates to respond to different ecological conditions varies between species and hence, they can be used as bioindicators for water quality assessments in highly disturbed waterbodies (Sharma *et al.*, 2006). Macrobenthos are an inevitable part of aquatic ecosystems and are commonly used as biological indicators because of a set of distinct characteristics they show (Bae *et al.*, 2005). Their omnipresence and sedentary nature help to monitor spatial analysis of pollutants in the water body. Some macrobenthos has a longer lifespan compared to other freshwater organisms, the nature of the sediments they feed and thrive on varies constantly with space and time and with varying water quality conditions, etc. and this results in the accumulation of toxins in their body. This feature can be efficiently employed to monitor temporal changes in the waterbody (Deborde *et al.*, 2016). As the macrobenthos are visible to the naked eye, their morphological features aid in the ease of identification and evaluation of collected samples. An increase in population growth rate, industrialization, urbanization, inappropriate use of fertilizers for agricultural purposes, etc. fastens habitat degradation that finally results in the global decline of biodiversity and ecological functionality of freshwa-

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ter ecosystems (Deborde *et al.*, 2016). Nowadays water quality monitoring programs are implemented to assess the biological status of freshwater ecosystems and to sustain the human and ecological needs of freshwater. Traditional methods for assessing water quality are based on physicochemical parameters alone, and that seems to be insufficient in providing better results. So nowadays physicochemical parameters combined with biological monitoring was commonly employed that will provide a comprehensive evaluation of the overall condition of freshwater bodies (Heatherly *et al.*, 2007). To conserve the biodiversity of freshwater ecosystems it is important to determine how the macrobenthic fauna are influenced by abiotic factors (Medupin, 2020). Macrobenthic invertebrates are not commonly employed in tropical freshwater monitoring studies because of a lack of taxonomic knowledge of the faunal groups, seasonal variations, differences in community assemblage, etc. This study attempts to determine the spatial and temporal variations of macrobenthic fauna and water quality variables in the Achenkovil River, Kerala. Since there are no published data on the macrobenthic fauna of the Achenkovil River, this study serves as baseline data for the development of a biotic index for freshwater rivers. Macrobenthic invertebrates are employed for ecological river assessment studies in different parts of the world. But the use of macrobenthic fauna in India is still in its infancy. In Kerala the knowledge of riverine biodiversity is scanty and biomonitoring and conservation of rivers are not well developed. However, the assessment methods based on Macrobenthic invertebrates serve as efficient tools for water quality monitoring programs (Korte *et al.*, 2010), due to the increase in pollution and anthropogenic impacts in waterbodies, which are well reflected by the benthic communities.

Materials and Methods

Study area

The Achenkovil River is created towards the Southern tip of the peninsula by the confluence of the Rishimala, Pasukidamettu and Ramakkalteri Rivers originating from Devarmalai of Western Ghats (9°19′0" N 76°28′0" E). The length of this river is 120 km, the basin size is 1,484 km^2 and the average water flow is 2287 million cubic meters. 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 (Oct-January).

Sampling Methods

Study sites

Samples were collected bimonthly and seasonally in premonsoon (February – May), monsoon (June – September), and postmonsoon (October-January), early in the morning hours (06.00 - 11.30 h) throughout the study period (2019-2020). The entire river body is divided into three segments-upstream stations (S1, S2, S3) with 9° 07′ 39.53′ N and 77° 07′ 58.56′ E with an elevation of 870 ft above MSL, midstream (S4, S5, S6)- 9° 13′ 59.37′ N and 76° 40′ 38.4′ E with an elevation of 66 ft above MSL, and downstream stations (S7,S8, S9) with 9° 19′ 29.07′ N and 76° 26′ 54.31′ E with an elevation of 6 ft above MSL- with three stations in each segment of the river (Fig. 1), (total 9 sampling sites along the entire stretch of the river).

Macrobenthic fauna was collected using Van Veen grab (0.025m^2) (used during rainy or flood months), D-frame nets 500µm (used when water flow is slow) and handpicking methods (mostly in upstream stations). Triplicate samples were taken for precision. The grab samples collected were sieved through a series of mesh sieves-3000µm (3mm), 2000 µm (2 mm), 1000 µm (1mm), and 500µm (0.5 mm) mesh and the sediments retained in the 0.5mm sieve was washed, and the samples were sorted out. The samples in the D-frame net were transferred to a white plastic tray, and the macrobenthic fauna was sorted out. All the collected macrobenthicfauna were preserved in 80% ethanol for subsequent analysis. In the laboratory, the preserved sample was examined using a stereomicroscope (Magnus MSZ- BI LED) and identified using standard taxonomic literature.

The water samples collected for physico-chemical analysis were carried immediately to the laboratory for further analysis. Water temperature was noted with a mercury thermometer (with ± 0.1°C accuracies). Depth was noted with a manual metered rope with an adjustable bottom weight. DO, BOD, pH, turbidity, conductivity, TDS, alkalinity, hardness salinity, phosphate, silicate and nitrate were carried out using standard references (APHA 2012).

Fig. 1. Map showing the study sites in the Achenkovil River basin, Kerala

Statistical analysis

One-way ANOVA was carried out for analyzing the seasonal variation of environmental parameters. The spatial variation of environmental parameters and the relationship of environmental variables with the macrobenthic fauna was analyzed using multivariate statistical techniques(PCA& CCA). Relative abundance was calculated using excel 2019. Simpson_1-D, Shannon_H, Margalef index, Evenness_e^H/S, and Dominance index were carried out using PAST (version 4.09) software. one-way ANOVA and PCA were carried out using SPSS (version 22)

Results and Discussion

A total of 3563 individuals belonging to 8 orders, 32 families, 32 genera, and 32 species were identified (Table 1). The maximum number of individuals was noted in S1 (1461Ind/m^2 with a total no. of 32Taxa) and the minimum number of individuals was noted in S9 (37 Ind/$m^2$with only 4 Taxa). The highest values for Simpson_1-D (0.95), and Shannon_H (3.23) were noted in S1, Evenness_e^H/S (0.86) and Margalef's (5.17) in S3 and the lowest values for Simpson_1-D (0.34), Shannon_H (0.73) and Margalef index (0.83) were noted in S9 and Evenness_e^H/S (0.44) in S8. The number of species was not very high in S3, and the number of individuals was low when compared to other stations and this is the reason for the highest values for Eveness_e^H/S and Margalef index in S3 (Gamito, 2010). The most dominant order in S1 was Ephemeroptera followed by Trichoptera and Coleoptera and the least dominant was Zygoptera. Most species of Ephemeropterans are sensitive to environmental stress and their presence marked a relatively positive condition (Hamid *et al.,* 2017). The species richness and abundance of EPT (Ephemeroptera, Plecoptera & Trichoptera) in the upstream segments and their decline/absence in the downstream segments is a piece of clear evidence for deteriorating habitat and water quality (Masese *et al.,* 2009). In the downstream stretches of the river, the pollution-sensitive species were absent or few, and chironomids dominated in S5, S6, S7, S8 & S9. The presence of organic wastes increases the species number and relative abundance of tolerant taxa (Masese *et al.,* 2009). The spatial variation in the environmental parameters was analyzed using PCA which showed three principal components, which explained 89.17% of the total variance. PC1 explained 51.79% of the total variance and had a significant contribution from turbidity, TDS, conductivity, salinity, pH, phosphate, alkalinity, hardness with a strong positive loading value of >0.75, and a moderate correlation with water temperature and nitrate (>0.50- 0.75). PC2 accounted for 25.08% of the total variance and has a strong positive correlation with BOD, a strong negative correlation with DO, and a moderate negative correlation with silicate. PC3 accounted for 12.30% of the total variance and had a strong positive correlation with depth. 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). The highest mean values for water temperature (29.34 ±0.39), turbidity (8.36 ±1.87 NTU), TDS (224.5 ±81.72mg/l), pH (7.01 ±0.11), phosphate (1.14 ±0.15mg/l), alkalinity (14.59 ±2.71mg/l), hardness (32.43 ±27.47mg/l) was noted in S9, conductivity (228.9 ±88.4 µs/cm), salinity (0.27 ±0.15 ppt.) in S8. Chironomids dominated in S8 (68.00 %) and S9 (81.08%). The relationship between the environmental variables and macrobenthic fauna was analyzed using CCA (Fig. 2). However, the first canonical axis explained over 50.38% and the second 23.73% of the variation in the macrobenthic fauna data set. The Monte Carlo permutation test performed on the first two axes showed no significant differences ($p>0.05$). The *Agabus* sp., *Hydrena* sp. *(Hy)*, *Rhyssemus* sp. *(Rh)*, and *Hydrocanthus* sp. *(Hc)* show a negative correlation with BOD, turbidity, TDS, conductivity, salinity, water temperature and depth. Therefore, these species are good indicators of water quality because they are highly sensitive to acidic and alkaline environments (Barathy *et al.*, 2020). *Tipula* sp. *(Ti)* and *Tabanus* sp. *(Ta),* preferred deeper rivers as their abundances positively correlated with river depth. The sampling sites S5, S8 and S9 show a positive correlation with water temperature, turbidity, TDS, conductivity, salinity, pH, nitrate, phosphate, alkalinity and hardness. These sites (S5, S8 & S9) are severely affected by anthropogenic activities. The *Chironomus* sp. *(Cnm*), was tolerant and shows a positive correlation with sites S8 & S9 and the physicochemical parameters. So, they are indicators of poor water quality (Copatti *et al.*, 2013). The famous Ayappa Temple and Pandalam Palace are located at the bank of S5. Being a place of pilgrimage large number of devotes visit the place during Mandalakalam. The devotes and the locals use the waterbodies for various purposes like bathing, washing, garbage disposal and religious activities. When the water flow impedes during the dry month, stations S8 & S9 are facing saltwater intrusion from the Kayamkulam Lake. This hampers the biological diversity and results in the dominance of some tolerant taxa like chironomids. When water quality deteriorates the more sensitive species disappear and tolerant species dominate, thus reducing species richness and diversity (Copatti *et al.,* 2013).

Table 1. Shows the Order, Family, Genus/Species, and abbreviations used for the collected macrobenthic fauna from the Achenkovil river basin.

Order	Family	Genus/Species	Abbreviations used
Ephemeroptera	Leptophlebidae	*Notophlebiajobi*	*No.jo*
	Caenidae	*Caenis* sp.	*Ca*.sp.
	Teloganodidae	*Dudgeodes* sp.	*Du*.sp.
	Baetidae	*Baetis* sp.	*Ba*.sp.
	Tricorythidae	*Sparsorythusgracillis*	*S.gr.*
	Heptageniidae	*Afronuruskumbakkaraiensis*	*Af.ku*
	Ephemerellidae	*Torleyanepalica*	*To.ne.*
	Ephemeridae	*Aethephemeranadiinae*	*Ae.na.*
Plecoptera	Perlidae	*Neoperla*	*Np*.sp.
Diptera	Chironomidae	*Chironomus* sp.	*Cnm*.sp.
	Athericidae	*Atherix* sp.	*At*.sp.
	Tipulidae	*Tipula* sp.	*Ti*.sp.
	Tabanidae	*Tabanus* sp.	*Ta*.sp.
Hemiptera	Notonectidae	*Micronecta* sp.	*Mi*.sp.
	Vellidae	*Microveliadouglasi*	*Mv*.sp.
	Belostomatidae	*Lethocerus indicus*	*Le.in*
	Nepidae	*Nepa* sp.	*Ne*.sp.
Zygoptera	Euphaeidae	*Euphae* sp.	*Eu*.sp.
Anisoptera	Gomphidae	*Stylogomphus* sp	St.sp.
	Aeshnidae	*Anax* sp.	An.sp.
	Libellulidae	*Crocothemis* sp.	Cr. Sp.
Megaloptera	Corydalidae	*Corydalus* sp.	Co.sp.
Coleoptera	Dytiscidae	*Agabus* sp.	*Ag*.sp.
	Psephenidae	*Eubrinax* sp.	*Eb*.sp.
	Elmidae	*Cylloepus* sp.	*Cy*.sp.
	Scarabaeidae	*Rhyssemus* sp.	*Rh*.sp.
	Hydraenidae	*Hydrena* sp.	*Hy*.sp.
	Hydrophilidae	*Hydrophilus* sp.	*Hd*.sp.
	Noteridae	*Hydrocanthus* sp.	*Hy.sp.*
Trichoptera	Economidae	*Economous* sp.	*Ec*.sp.
	Philopotamidae	*Chimera* sp.	*Ch*.sp.
	Hydropsychidae	*Hydropsyche* sp.	*Hp*.sp.

The increase in temperature in the downstream stretches of the river can be attributed to the loss of riparian vegetation that results in the direct heating of the waterbody. A decrease in DO can be attributed to lower oxygen saturation at higher temperatures and an increase in organic decomposition (Kannan *et al.,* 2022). The intrusion of salt water, the influence of anthropogenic impacts, and higher instream and near stream activities such as laundry washing, bathing, cattle cleaning, agricultural activities, vehicle cleaning, and dumping of poultry waste are common in the downstream stretches of the river. These activities deteriorate the water quality and disturb the benthic fauna, as has been found in similar studies (Masese *et al.,* 2009; Malmqvist *et al.* 2002). A higher concentration of phosphate in the waterbody is an indication of 'poor' chemical status (James *et al.,* 2012). An increase in salt concentration increases the salinity, pH, turbidity, and conductivity. Besides this addition of organic matter, solid waste, a higher concentration of nutrients in the water, etc. causes an increase in salinity, turbidity, pH, conductivity, TDS, alkalinity and hardness (Qureshimatva *et al.,* 2015).

Abundant macrobenthic fauna including more environmentally sensitive organisms was found in S1 and S2. These sites had the lowest concentration of physicochemical variables and high dissolved oxygen levels. Such sites can be considered as 'sites with good ecological status (Medupin, 2020). Hence these sites can be considered reference sites to compare with other segments of the river. Higher subcatchment areas and urban covers were the features of stations S3 to S9, and these sites will be impacted by other factors such as silted banks and modified river channels. These factors impede the ability of the river to maintain its biodiversity (Brown, 2007). High richness in protected habitats and low richness in disturbed habitats were found in other works (Hepp *et al.,* 2010).

Seasonal analysis of environmental variables reveals significant differences for water temperature $F(2,24)=5.77, p=0.009$; turbidity $F(2,24)=21.20$, $p<0.0001$; silicate $F(2,24)=5.02$, $p=0.015$; phosphate $F(2,24)=4.21$, $p=0.027$; pH $F(2,24)=17.43$, $p<0.0001$; nitrate $F(2,24)=22.49$, $p<0.0001$; DO $F(2,24)=40.89$, $P<0.0001$; BOD $F(2,24)=19.21$, $p<0.0001$; alkalinity $F(2,24)=10.82$, $p<0.0001$. During these seasons the maximum mean values for temperature (29.65 ±1.13°C), pH (7.15 ±0.10), alkalinity (17.47 ±2.00 mg/l), were noted during the pre-monsoon season, DO (8.04 ±0.46 mg/l), turbidity (10.53 ±1.29 NTU), nitrate (1.43 ±0.16 mg/l), phosphate (1.26 ±0.23 mg/l), silicate (4.16 ±0.65 mg/l) were maximum during the monsoon season and BOD (3.25 ±0.48 mg/l) during the post-monsoon season.

The CCA reveals (Fig. 3) that *Athrix*sp. *(At.), Tipula*sp. *(Ti.), and Tabanus*sp. *(Ta.)* show a strong positive correlation with silicate, phosphate, nitrate, depth and DO while *Chironomus* sp. *(Cnm.)*, shows a strong correlation with phosphate, nitrate and depth. Studies have shown that Dipterans commonly chironomids as one of the dominant taxa in natural (Copatti *et al.,* 2013) or non-natural environments (Hepp *et al.,* 2010). *Neoperla* sp. *(Np.), Lethocerus indicus (Le.in), Nepa*sp. *(Ne.), Euphaea*sp. *(Eu.), Agabus* sp. *(Ag.), Hydrena* sp. *(Hy.), Economous* sp. *(Ec.), Chimarra* sp. *(Ch.), Hydropsyche* sp. *(Hp.)* shows a positive correlation with water temperature, BOD and hardness. *Notophlebiajobi (No.jo),*

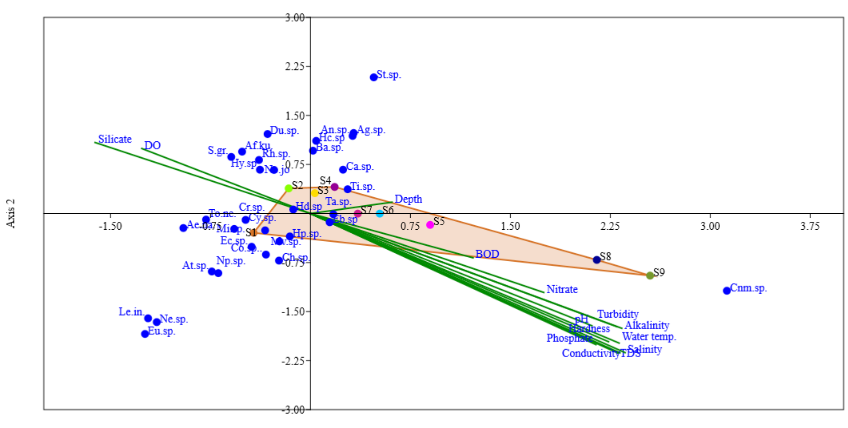

Fig. 2. CCA plot showing the spatial relationship between the macrobenthic fauna and the environmental parameters.

Caenis sp. *(Ca.)*, *Dudgeodes* sp. *(Du.)*, *Baetis* sp. *(Ba.)*, *Sparsorythusgracillis (S.gr.)*, *Afronuruskumbakkaraiensis (Af.)*, *Torleyanepalica (To.)*, *Aethephemeranadinae (Ae.na)*, *Rhyssemus* sp. *(Rh.)*, *Hydrophilus* sp. *(Hd)*, *Hydrocanthus* sp. *(Hc)* shows a negative correlation with turbidity, TDS, conductivity, salinity, pH and alkalinity. Most of the members of EPT and Coleoptera are commonly known for their pollution-sensitive nature. They are absent from highly disturbed habitats (Copatti *et al.*, 2013). *Micronecta* sp. (Mi.), *Microveliadouglasi (Mv.)*, *Anax*sp. *(An.)*, *Corydalus* sp. *(Co.)*, *Crocothemis*sp. *(Cr.)* shows a positive correlation with turbidity, TDS, conductivity, salinity, pH and alkalinity.

For any biological system, the simple and most useful method is assessing its species diversity. Species diversity is an efficient ecological tool and it helps to understand the relationship between species diversity and the nature of the environment (Dalia Susan *et al.*, 2014). The post-monsoon season witnessed the highest number of individuals 1794 Ind/m^2 and the lowest number of individuals was noted during the monsoon season 474 Ind/m^2. The highest values for Simpson_1-D (0.95), Shannon_H (3.23) and Evenness_e^H/S (0.79) index were seen during the post-monsoon season and Margalef's (4.54) during the monsoon season. The lowest values for Simpson_1-D (0.93), Shannon_H (3.01) and Evenness_e^H/S (0.70) were noted during the monsoon season and Margalef index (4.13) during the post-monsoon season.

The high atmospheric temperature and low intensity of rainfall may cause an increase in water temperature during the pre-monsoon season (Li *et al.*, 2014). The minimum mean water temperature was reported during the post-monsoon season in the headwater station. The headwater station has a thick canopy cover that prevents the direct heating of the surface water. The highest values noted for pH and alkalinity during the pre-monsoon season might be due to low-intensity rainfall and intrusion of salt water into the river (only in S8 & S9) from the kayamkulam Lake. Heavy rainfall accompanied by surface runoff, erosion carrying sand, silt,organic matter, the input of more silicious sediments, etc. results in an increase in turbidity, nitrate, silicate, and phosphate during the monsoon season (Jaji *et al.* 2007) Low rainfall, low water flow, high temperature, etc. results in a high BOD value during the post-monsoon season (Girija *et al.*, 2007). The maximum DO value observed during monsoon season may be the result of low water temperature, increased turbulence and oxygenation as a result of heavy rainfall (Alam *et al.*, 2007). The minimum mean values for DO (4.76 0.52 mg/l), nitrate (0.57 ±0.11 mg/l), phosphate (0.27 ±0.27 mg/l), and silicate (1.46 ±0.55 mg/l) were reported during the pre-monsoon season, BOD(0.76 ±0.31mg/l) in monsoon season, and water temperature (25.23 ±1.60 °C), turbidity(1.97 ±1.53 NTU), pH (6.49 ±0.12), alkalinity (8.08 ±2.31 mg/l), were minimum during the post-monsoon season. Higher temperature during the premonsoon season fastens microbial degradation of water contaminants and reduces oxygen satura-

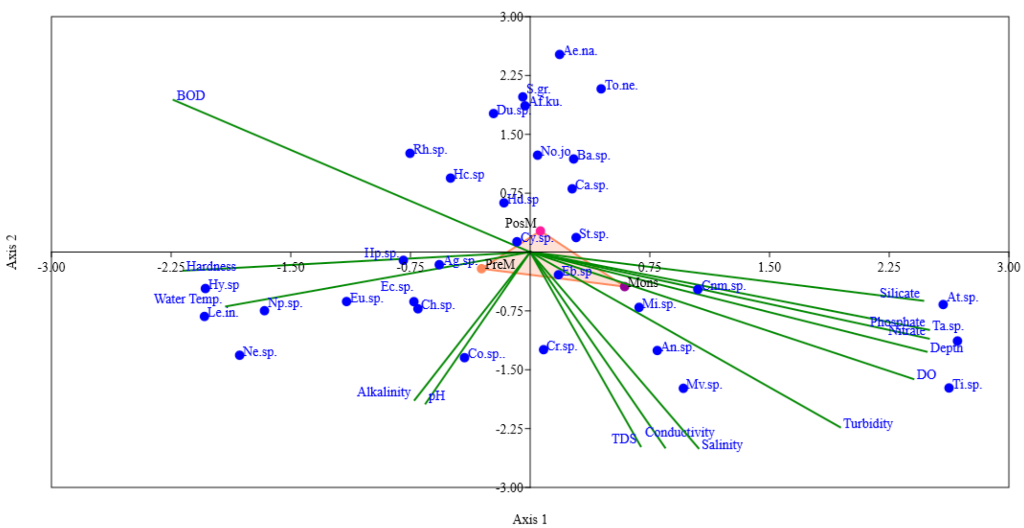

Fig. 3. CCA plot showing the temporal relationship between the macrobenthic fauna and the environmental parameters.

tion which may be a reason for low DO (Liu *et al.,* 2016). Multiple comparison test Tukey HSD also reveals a significant difference ($p<0.05$) between the post-monsoon and monsoon seasons. The nature of lower species diversity during monsoon season and highest species diversity during post-monsoon is following the early observations made in Sandspit beach (Farooq *et al.,* 2010). During the monsoon season, the midstream and downstream stretches of the Achenkovil River are receiving a high load of detrital sediments, organic matter and agricultural runoff. Moreover, the smaller number of other benthic fauna may be due to some ecological imbalance of certain factors that govern the abundance and distribution of macrobenthic faunal communities. The presence of Chironomus indicates the influence of pollution in the lower reaches of the river. Many of the dipterans inhabit heavily polluted water bodies with a wide range of tolerance (Abhijna *et al.*, 2013). During the pre-monsoon season, the water level in the Achenkovil River falls and water flow will get obstructed. This situation mainly creates problems in the lower stretches (S8 & S9) of the river due to the intrusion of salt water from Kayamkulam Lake. This hampers the biological diversity and water quality following the early observations made in Pondicherry Mangroves (Kumar *et al.*, 2013).

The presence and abundance of macrobenthic fauna help to indicate the relative degree of purity or pollution of water. The benthic fauna was, therefore studied because of their ubiquitous presence in all sorts of water and their potential in indicating the degree of pollution.

Conclusion

The present study on the spatio-temporal variation of macrobenthic fauna and water quality parameters of the Achenkovil River basin revealed the diversity, distribution and abundance of macrobenthic fauna concerning environmental parameters. Macrobenthic fauna was abundant in undisturbed habitats. Physico-chemical parameters play a major role in the distribution of macrobenthic fauna. 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.

Acknowledgements

We are grateful to the University Grants Commission, New Delhi for providing a Senior Research Fellowship (ID. No.365892) to the first author. We are also thankful to the Principal of St. Stephen's College, Pathanapuram for providing us with the necessary facilities to conduct the research work.

Conflict of interest

The authors have no conflict of interest

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