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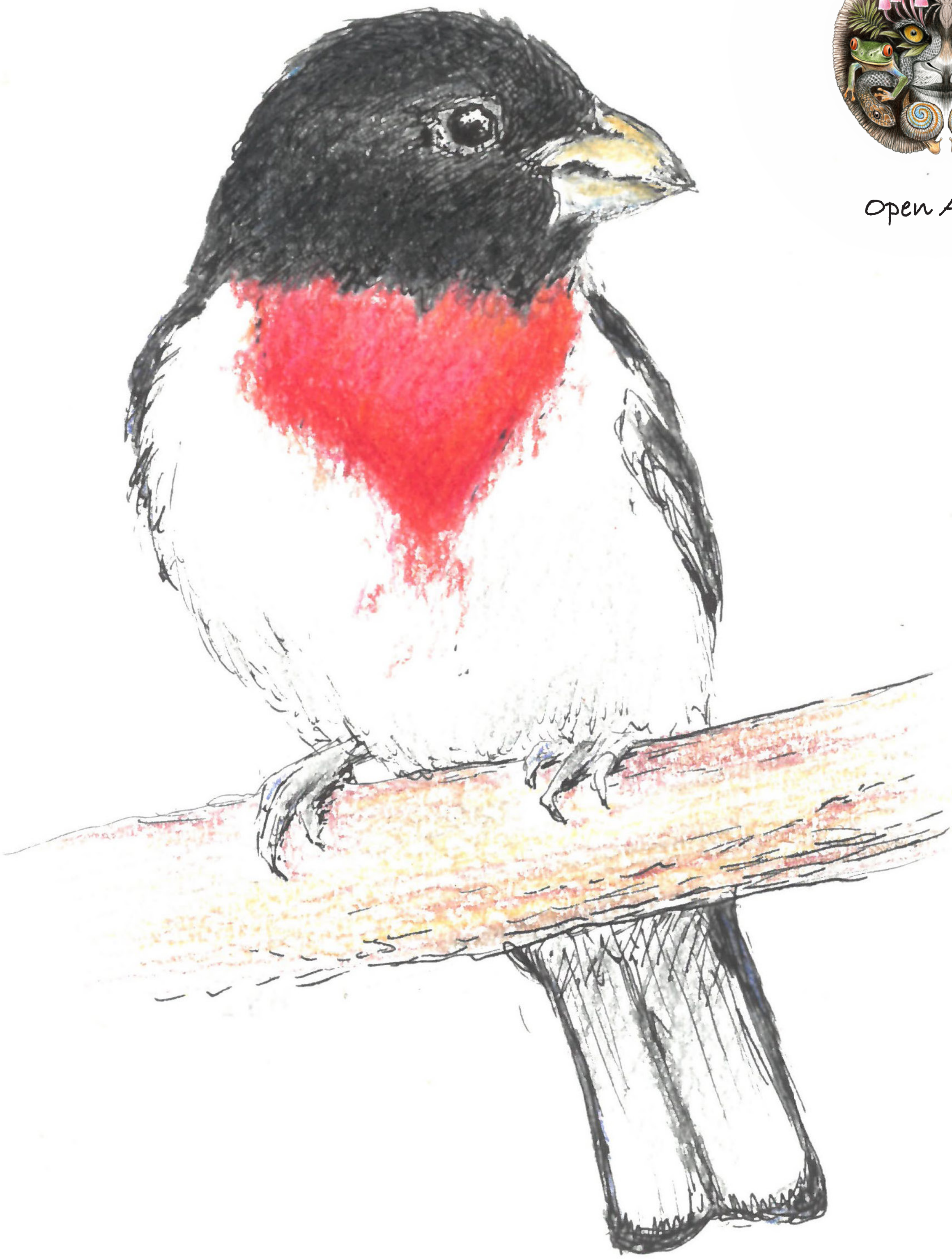

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Cover: Rose-breasted Grosbeak *Pheucticus ludovicianus*, pen & ink with colour pencil. © Lucille Betti-Nash.

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ARTICLE

Diversity and abundance of mayflies (Insecta: Ephemeroptera) in Achenkovil River, southern Western Ghats, Kerala, India

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Abstract: Freshwater insects like Ephemeroptera are more comprehensive and direct indicators of the biological impacts of pollution. During the study period (2018–2020), a total of 4,374 individuals of mayflies were collected and categorized under nine families, 27 genera, and 36 species. The family Leptophlebiidae was found dominant with 13 species. In the post-monsoon season, a higher species diversity of Ephemeroptera was noticed in the river's upstream section with a Shannon-Wiener index value of H' = 1.814. ANOVA revealed a significant difference ($p < 0.05$) except for Ephemeridae ($p > 0.05$). Protecting rivers requires a holistic approach and collaboration among stakeholders is essential for successful implementation.

Keywords: ANOVA, biodiversity indices, D-frame nets, ecosystem, exotic species, environmental parameters, freshwater, hemimetabolous, species richness, van veen grab.

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Author details: S. Sujitha is a research scholar. R. Sreejai is an assistant professor. His research interests are biodiversity and ecology. C. Selvakumar, is assistant professor. He has described 25 new species and two new genera of mayflies. He also established a DNA barcode for 40 species of mayflies. Currently, he is studying the phylogeny and phylogeography of mayflies in India.

Author contributions: SS carried out fieldwork and drafted the manuscript, SR carried out fieldwork with the first author and reviewed the manuscript, CS helped in the identification of mayflies and reviewed the manuscript.

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INTRODUCTION

Freshwater ecosystems and their valuable resources are inevitable for the existence of human life (Surachita et al. 2022). Environmental parameters like the geography of the river bed (Wallace et al. 1996), heavy rain, oxygen concentration, nutrients, water velocity, land use patterns, substrate type, and water temperature (Popielarz et al. 2007; Mishra & Nautiyal 2011, 2016) play a major role in structuring the diversity and distribution of freshwater ecosystems. However, freshwaters also face severe biodiversity depletion and extinction of species which makes them much more imperilled than terrestrial and marine species (Farooq et al. 2021). When environmental quality degrades, the species composition, richness, and abundance of specialist species decreases, and generalist species occupy the area, thereby decreasing biodiversity. This adversely affects the distribution pattern of highly sensitive, riverine species (Axelsson et al. 2011) which finally results in the elimination of numerous species before they are brought to the knowledge of science. The catchment-wide conservation of freshwater ecosystems, maintenance of historic river dynamics, biological control of invasive water plants, removal of exotic species, and conservation of location-specific factors such as river network connectivity can conserve species diversity. Moreover, the maintenance of the natural dynamics of freshwater systems is very important for improved vegetation and insect heterogeneity (Samways et al. 2020).

Ephemeroptera includes a small order of hemimetabolous insects with approximately 3,500 species, 450 genera, and 42 families distributed globally (Hamada et al. 2018). The Ephemeroptera of the Oriental region was represented by 390 species, 84 genera, and 20 families out of which four suborders, 15 families, 60 genera, and 204 species occur in the Indian subregion (Sivaramakrishnan et al. 2009). According to Vasanth et al. (2023), the Ephemeroptera of Indian Himalaya includes 10 families, 34 genera, and 89 species. The Ephemeroptera of India was represented by four suborders, 15 families, 59 genera, and 172 species (Sivaramakrishnan et al. 2020) and the Western Ghats of India alone comprises 13 families, 42 genera and 82 species (Sivaramakrishnan et al. 2020). After 2020, more than 60 new species of mayflies were described in India by various researchers (Balasubramanian & Muthukatturaja 2021; Martynov et al. 2021; Srinivasan et al. 2022; Kluge et al. 2022; Muthukatturaja & Balasubramanian 2022; Sivaruban et al. 2022; Vasanth et al. 2023).

Research hasn't explored the variety and spread of mayflies (Ephemeroptera) along the Achenkovil River basin's latitudinal and longitudinal gradients. Because mayflies are crucial for benthic community structure, understanding their ecology, distribution, and diversity in remote freshwater ecosystems would significantly improve our grasp of their functions.

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 (10.4147 N, 77.0136 E). It enriches the Pathanamthitta District of Kerala State. The length of this river is 128 km; the basin size is 1,484 km² and the average water flow is 2,287 MCM. The river drains through highly varied geological formulations and covers the highland, midland, and lowland physiographic provinces of the state. The study area experiences a tropical climate with three distinct seasons – pre-monsoon (February–May), monsoon (June–September.), and post-monsoon (October–January.).

Sampling Methods

Study sites

A reconnaissance survey was conducted in the Achenkovil River basin to identify sampling sites (refer to Figure 1). Samples were collected bimonthly and seasonally, specifically in the early morning hours (0600–1130 h) throughout the study duration (2018–2020). The river was divided into three segments—upstream, midstream, and downstream—each with three stations, totaling nine sampling sites along the entire river stretch. In the Upstream region, dense forest covers approximately 60% of the area, while 5% is occupied by degraded forest, and agricultural land accounts for 10%. Moving to the midstream region, double-crop paddy farming occupies 40% of the land. The downstream region is occupied by 80% agricultural land and 10% under double crop paddy cultivation.

The research region experiences a tropical and semi-arid climate, with an annual rainfall between 2,000 and 5,000 mm. It is affected by two distinct monsoon seasons: the south-west monsoon (June–September) and the north-west monsoon (October–December) (Prasad & Ramanathan 2005).

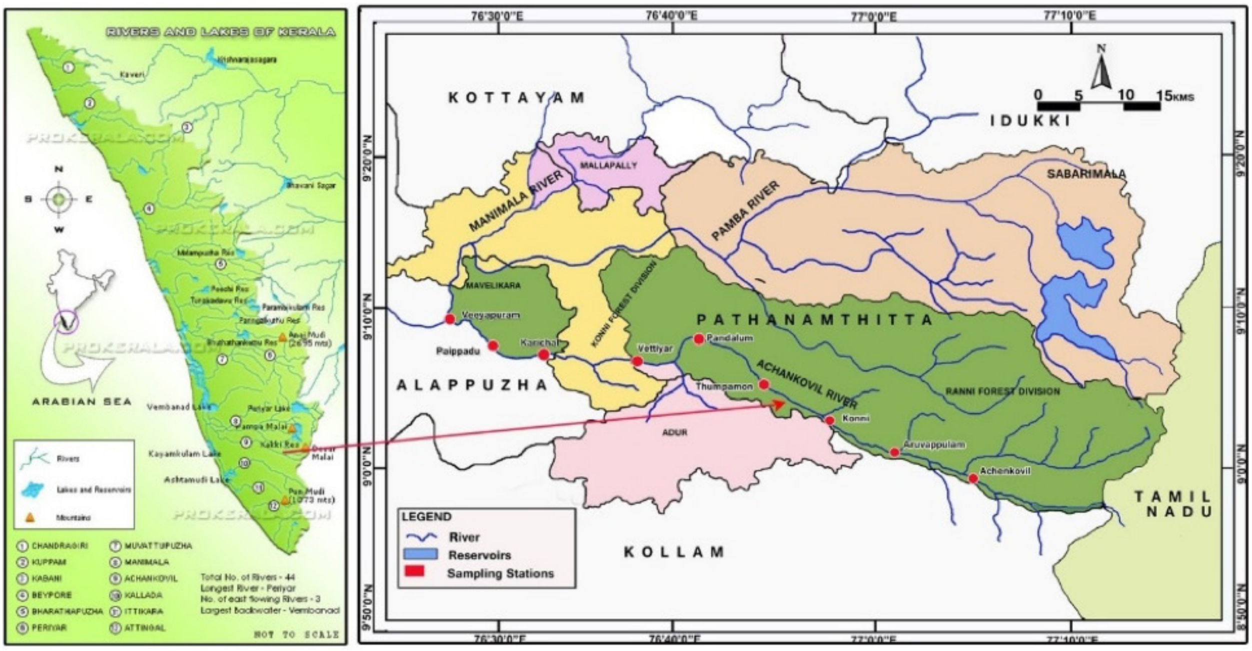

Figure 1. Map showing the study sites in the Achenkovil River Basin, Kerala.

Mayflies, were collected using Van Veen grab (0.025 m^2) (used during rainy or flood months), D-frame nets 500 µm (used when water flow is slow), and handpicking methods (mostly in upstream stations), within a depth ranged 0.65–4.39 m (Abdelsalam et al. 2013). To ensure accuracy, triplicate samples were collected. The grab samples were sieved through a 0.5 mm sieve and sorted for mayflies in a white plastic tray. Similarly, samples collected with a D-frame net were carefully sorted in a white plastic tray. All mayfly larvae were preserved in 80% ethanol for later analysis. In the laboratory, preserved samples were examined and identified using a stereomicroscope (Magnus MSZ- BI LED) and standard taxonomic literature, including works by Merrit & Cummins (1996), Dudgeon (1999), Yule & Sen (2004), Thorp & Covich (2015), and Selvakumar et al. (2019).

The water samples for physicochemical analysis were collected in clean polyethylene bottles. The temperature was recorded immediately after collection at the field itself with a mercury thermometer (with ± 0.1°C accuracies). The samples for Dissolved Oxygen (DO) & Biochemical Oxygen Demand (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. DO (mg/l), BOD (mg/l) were analyzed using Winkler's method, pH (pH meter), turbidity (NTU) by Nephelometric method, conductivity (µS/cm) using Systronics water analyzer 371, TDS (mg/l) by gravimetric method, and nitrate (mg/l) by spectrophotometric method (APHA 2012).

Data analysis

ANOVA was carried out to study the significant variations between the water quality parameters. Diversity was estimated using Shannon-Wiener, Evenness, and Margalef's indices. The commonness or the rarity of species was calculated using relative abundance. The diversity indices were calculated using PAST software (Version 4.09), (Hammer et al. 2001). The relative abundance was calculated using Excel 2011 and ANOVA using SPSS (Version 22).

RESULTS

Physico-chemical Parameters

The atmospheric and water temperatures ranged 23.1–34.9 °C and 22.9–30.9 °C, respectively, with the highest temperature recorded during pre-monsoon and lowest during post-monsoon season (Table 1). The pH ranged from 6.42–7.42. A good value of DO indicates a good and healthy ecosystem. The DO ranged 3.91–8.69 with the highest value (7.54 ± 0.72) recorded during monsoon, and the least during pre-monsoon season (5.67 ± 0.86). BOD is a measure of organic pollution in the water body and it ranges 0.44–3.91 mg/l with the highest value noticed during the post-monsoon (2.71 ±

Table 1. Mean seasonal variation of the physico-chemical parameters in Achenkovil River Basin, Kerala.

Parameters	Range		Seasons (Mean ± SD)			F value	*P*-value
	Minimum	Maximum	Pre-monsoon	Monsoon	Post-monsoon		
Atm. temp. (°C)	23.1	34.9	31.08 ±1.92	29.11 ± 1.78	28.55 ± 2.57	14.013	0.000 *P* <0.001
Water temp. (°C)	22.9	30.9	28.93 ±0.99	27.38 ± 1.26	27.18 ± 1.96	15.418	0.000 *P* <0.001
pH	6.42	7.42	6.98 ±0.18	6.85 ± 0.16	6.65 ± 0.17	31.741	0.000 *P* <0.001
DO (mg/l)	3.91	8.69	5.67 ±0.86	7.54 ± 0.72	5.87 ± 0.64	67.313	0.000 *P* <0.001
BOD (mg/l)	0.44	3.91	2.38 ±0.58	1.59 ± 0.46	2.71 ± 0.65	36.6	0.000 *P* <0.001
Turbidity (NTU)	0.74	12.62	4.99 ±1.29	8.58 ± 2.43	4.31 ± 1.74	53.511	0.000 *P* <0.001
Conductivity (µS/cm)	44.2	358.7	127.3 ±109.1	103.2 ± 33.94	108.4 ± 79.08	0.896	0.411 *P* >0.05
TDS (mg/l)	32.2	342.6	112.6 ±107.7	87.9 ± 34.19	87.49 ± 78.29	1.187	0.309 *P* >0.05
Nitrate (mg/l)	0.38	1.56	0.76 ±0.14	1.08 ± 0.20	0.87 ± 0.14	34.244	0.000 *P* <0.001

0.65) season.

The turbidity ranged 0.74–12.62 NTU with the highest value in monsoon (8.58 ± 2.43), and the least in post-monsoon season (4.31 ± 1.74). The conductivity of water depends mainly on the concentration of ions, and it ranged from 44.2–358.7 µS/cm with the highest value (112.6 ± 107.7) recorded during pre-monsoon, and the least value (103.2 ± 33.94) recorded during monsoon season. Natural sources are the contributors to TDS in the water body. The amount of TDS ranged 32.2–342.6 mg/l with the highest value (112.6 ± 107.7) recorded during pre-monsoon season. The value of nitrate varied 0.38–1.56 mg/l with the highest value (1.08 ± 0.20) noticed during monsoon and the lowest during pre-monsoon season (0.76 ± 0.14).

All the studied physicochemical parameters showed variations between seasons that are statistically significant ($p < 0.05$) (Table 2).

Species Richness

During the study period, a total of 36 species of mayflies under 27 genera belonging to nine families were identified (Table 2); out of which the major family Leptophlebidae constitutes 13 species with 1,279 Individuals(ind.)/m^2 in the upstream, 591 ind./m^2 in the midstream, and 80 ind./m^2 in the downstream. Family Caenidae was represented by *Caenis* sp. and *Clypeo caenis bisectosa* with maximum individuals (274 ind./m^2) in the upstream, 192 ind./m^2 in the midstream, and 34 ind./m^2 in the downstream segment. Leptophlebiidae, Caenidae, Baetidae, and Ephemeridae were present in all three segments of the river. The family Baetidae and Ephemeridae were represented by eight and two species, respectively. Teloganodidae (339 ind./m^2) and Tricorythidae (99 ind./m^2) were present only in the upstream stations. Heptageniidae (377 ind./m^2), Ephemerellidae (195 ind./m^2), and Prosopistomatidae (52 ind./m^2) were present in the upstream and also in the midstream with 98, 4, and 18 ind./m^2 respectively, but absent in the downstream stations. The seasonal variation in the distribution of major families except Ephemeridae shows maximum richness during post-monsoon followed by pre-monsoon and monsoon season.

The relative abundance of all species across different seasons at the three segments of the river is presented in Table 3. In the upstream segment, *Notophlebia* sp. exhibited the highest relative abundance (15.91%) during the monsoon, while *Teloganella indica* (0.07%) was the least abundant (0.07%) during the post-monsoon season. In the midstream segment, *Notophlebia ganeshi* dominated (19.55%) during the monsoon, with *Petersula courtallensis* and *Epeorus petersi* being the least dominant species, both reported during the pre-monsoon season. Similarly, in the downstream segment, *Caenis* sp. contributed the most (31.25%) during the monsoon, while *Tenuibaetis frequentus* was the least abundant (1.92%), reported during the pre-monsoon season.

In the Upstream segment (S1) of the river, higher species diversity of Ephemeroptera was observed during the post-monsoon season, with a Shannon-Wiener index value of H' = 1.814 (Figure 2). Maximum species richness and evenness were noted in the

Table 2. Checklist of mayflies in the Achenkovil River Basin.

Superfamily	Family	Genus and species
Prosopistomatoidea	Prosopistomatidae	*Prosopistoma indicum* Peters, 1967
Leptophlebioidea	Leptophlebiidae	*Choroterpes* (*Euthraulus*) *nambiyarensis* Selvakumar & Sivaramakrishnan, 2013
		Choroterpes (*Euthraulus*) *kalladaensis* Rekha, Anbalagan, Dinakaran, Balachandran & Krishnan, 2019.
		Choroterpes (*Euthraulus*) *nandini* Selvakumar & Sivaramakrishnan, 2015.
		Choroterpes petersi Tong & Dudgeon 2003
		Edmundsula lotica Sivaramakrishnan, 1985
		Indialis badia Peters & Edmunds, 1970
		Nathanella indica Sivaramakrishnan, Venkataraman & Balasubramanian, 1996
		Notophlebia ganeshi Kluge, 2014
		Notophlebia jobi Sivaramakrishnan & Peters, 1984
		Notophlebia sp.
		Petersula courtallensis Sivaramakrishnan, 1984
		Thraulus gopalani Grant & Sivaramakrishnan, 1985
Caenoidea	Caenidae	*Caenis* sp.
		Clypeocaenis bisetosa Soldan, 1978
Ephemerelloidea	Ephemerellidae	*Torleya nepalica* Allen and Edmunds, 1963
	Teloganodidae	*Derlethina tamiraparaniae* Selvakumar, Sivaramakrishnan & Jacobus, 2014
		Dudgeodes palnius Selvakumar, Sivaramakrishnan & Jacobus, 2014
Ephemerelloidea	Teloganodidae	*Dudgeodes bharathidasani* Anbalagan, 2015
		Dudgeodes sp. Sartori & Peters & Hubbard, 2008
		Teloganodes kodai Sartori, 2008
		Teloganella indica (Selvakumar, Sivaramakrishnan & Jacobus, 2014)
	Tricorythidae	*Sparsorythus gracilis* Sroka & Soldan, 2008
Ephemeroidea	Ephemeridae	*Ephemera* (*Aethephemera*) *nadinae* McCafferty and Edmunds, 1973
		Eatonigenia trirama McCafferty, 1973
	Heptageniidae	*Afronurus kumbakkaraiensis* Venkataraman & Sivaramakrishnan, 1989
		Epeorus petersi Sivaruban & Venkataraman & Sivaramakrishnan, 2013
		Thalerosphyrus flowersi Venkataraman and Sivaramakrishnan, 1987
	Baetidae	*Acentrella* (*Liebebiella*) *vera* Muller-Liebenau, 1982
		Indobaetis michaelohubbardi (Selvakumar, Sundar & Sivaramakrishnan, 2012)
		Baetis sp.
		Centroptella ornatipes Kluge 2021
		Centroptella (*Chopralla*) *ceylonensis* Müller-Liebenau 1983
		Cleon bicolor Kimmins, 1947
		Nigrobaetis paramakalyani Kubendran & Balasubramanian, 2015
		Tenuibaetis frequentus (Müller-Liebenau & Hubbard 1985)

post-monsoon, followed by the pre-monsoon and monsoon seasons. ANOVA analysis revealed a highly significant difference (p <0.001) for Leptophlebiidae, and Baetidae, and a significant difference (p <0.05) for Caenidae, Teloganodidae, Tricorythidae, Heptageniidae, Ephemerillidae, and Prosopistomatidae, while no significant difference was found for Ephemeridae (p >0.05) (Table 4). Spatial abundance was highest in the upstream segments, followed by the midstream and downstream segments. The ANOVA of abundance indicated significant differences both spatially and temporally (p <0.05) (Table 4).

DISCUSSION

Physico-chemical parameters play an important role in determining water quality and the distribution of biotic communities. The mean pH values of all seasons fall within the limits (6.5–8.5) as prescribed by BIS. The benthic macroinvertebrate including aquatic insects have a tolerance range to pH and most organisms can develop between 6.4–8.6 (Yorulmaz et al. 2021). Higher temperature during the pre-monsoon season fastens microbial degradation of water contaminants and reduces oxygen saturation which may be a reason for low DO (Liu et al. 2016). Heavy rainfall and cloudy sky in the monsoon season decrease the atmospheric temperature and thereby the water temperature, and

Table 3. Relative abundance of mayfly larvae at three segments in different seasons of the Achenkovil River Basin, Kerala.

	Family/Genus/Species	Upstream			Midstream			Downstream		
		PreM	Mons	PosM	PreM	Mons	PosM	PreM	Mons	PosM
A	**Leptophlebiidae**									
1	*Indialis badia*	0.28	1.26	0.26	4.13	6.77	2.86	5.77	8.33	7.14
2	*Choroterpes kalladensis*	6.83	5.78	3.30	10.00	8.27	9.54	9.62	4.17	14.29
3	*Choroterpes nambiyarensis*	3.51	7.23	2.64	10.87	6.77	6.68	-	-	-
4	*Choroterpes nandini*	4.17	6.51	2.31	-	-	-	-	-	-
5	*Choroterpes petersi*	2.27	1.63	3.04	-	-	0.95	-	-	-
6	*Edmundsula lotica*	7.88	9.58	1.78	13.26	7.52	8.78	5.77	2.08	7.14
7	*Nathanella indica*	0.09	-	0.13	3.04	6.02	3.63	9.62	10.42	4.76
8	*Notophlebia ganeshi*	3.22	5.06	4.49	6.09	19.55	7.63	5.77	12.50	2.38
9	*Notophlebia jobi*	4.27	5.24	5.61	3.26	4.51	4.58	17.31	2.08	9.52
10	*Notophlebia* sp.	7.59	15.91	6.86	3.48	4.51	2.48	11.54	12.50	4.76
11	*Petersula courtallensis*	1.71	1.63	2.51	0.22	-	0.38	-	-	-
12	*Thraulus gopalani*	0.19	-	0.40	0.43	1.50	0.57	-	-	-
B	**Caenidae**									
13	*Clypeocaenis bisetosa*	0.57	-	0.20	1.09	-	0.95	-	-	-
14	*Caenis* sp.	9.31	13.20	6.20	15.87	10.53	18.13	13.46	31.25	28.57
C	**Teloganodidae**									
15	*Teloganella indica*	0.38	-	0.07	-	-	-	-	-	-
16	*Teloganodes kodai*	5.60	1.63	9.70	-	-	-	-	-	-
17	*Dudgeodes bharathadasini*	0.28	-	0.53	-	-	-	-	-	-
18	*Dudgeodes* sp.	1.14	2.35	2.05	-	-	-	-	-	-
19	*Dudgeodes palnius*	0.47	0.36	0.59	-	-	-	-	-	-
20	*Derlethina tamiraparaniae*	0.38	3.61	0.79	-	-	-	-	-	-
D	**Baetidae**									
21	*Centroptella ceylonensis*	0.66	0.36	0.99	0.65	2.26	2.10	-	-	-
22	*Cloeon bicolor*	3.70	1.98	3.43	1.30	0.75	4.01	-	-	-
23	*Centroptella ornatipes*	1.04	1.63	0.86	0.87	1.50	1.34	-	-	-
24	*Indoaetis michaelohubbardi*	1.71	1.27	1.19	4.57	6.02	4.77	11.54	2.08	11.90
25	*Tenuibaetis frequentus*	3.70	0.90	3.10	4.13	3.76	3.44	1.92	4.17	-
26	*Baetis sp.*	1.90	1.45	0.79	0.43	0.75	0.57	-	-	-
27	*Acentrella vera*	0.76	0.54	0.13	1.09	-	1.53	3.85	-	-
28	*Nigrobaetis paramakalyani*	2.18	2.89	4.95	1.52	0.75	2.10	-	-	-
E	**Tricorythidae**									
29	*Sparsorythus gracilis*	7.12	0.90	4.69	-	-	-	-	-	-
F	**Heptageniidae**									
30	*Afronurus kumbakkaraiensis*	7.14	3.25	9.57	8.04	7.52	8.40	-	-	-
31	*Thalerosphyrus flowersi*	4.08	-	2.84	0.65	-	0.19	-	-	-
32	*Epeorus petersi*	1.04	0.36	2.64	0.22	-	0.38	-	-	-
G	**Ephemerellidae**									
33	*Torleya nepalica*	5.31	1.27	8.71	0.43	-	0.38	-	-	-
H	**Ephemeridae**									
34	*Ephemera* (*Aethephemera nadinae*)	1.42	1.27	0.66	2.61	0.75	1.72	3.85	10.42	9.52
35	*Eatoningenia trirama*	0.19	-	0.20	-	-	-	-	-	-
I	**Prosopistomatidae**									
36	*Prosopistoma indica*	1.90	0.90	1.78	1.74	-	1.91	-	-	-

PreM—Premonsoon | Mons—Monsoon | PosM—Post-monsoon.

Table 4. Spatial and seasonal abundance (Mean ± SD) in the number of species per family of mayflies in the Achenkovil River Basin.

Family	Upstream (Mean ± SD)			Midstream (Mean ± SD)			Downstream (Mean ± SD)			F value	*p*-value
	PreM	Mons	PosM	PreM	Mons	PosM	PreM	Mons	PosM		
Leptophlebiidae	221.5 ± 70.0	165.5 ± 109.6	252.5 ± 19.09	126.0 ± 59.39	43.50 ± 14.84	126.0 ± 26.87	17.00 ± 0.00	12.50 ± 10.60	10.50 ± 6.36	28.128	0.000 *P* <0.001
Caenidae	52.0 ± 24.04	36.5 ± 20.5	48.5 ± 2.12	39.0 ± 14.14	7.0 ± 1.41	50.0 ± 4.24	3.50 ± 2.12	7.50 ± 7.77	6.00 ± 4.24	12.877	*0.001* *P* <0.05
Teloganodidae	43.50 ± 28.99	22.0 ± 7.07	104.0 ± 26.87	-	-	-	-	-	-	12.902	*0.001* *P* <0.05
Baetidae	87.0 ± 29.69	30.5 ± 12.02	117.0 ± 4.24	33.50 ± 7.77	10.50 ± 2.12	52.0 ± 1.41	4.50 ± 2.12	1.50 ± 0.70	2.50 ± 3.53	23.002	0.000 *P* <0.001
Tricorythidae	11.50 ± 3.53	2.50 ± 2.12	35.50 ± 13.43	-	-	-	-	-	-	7.271	*0.008* *P* <0.05
Heptageniidae	64.50 ± 12.02	10.0 ± 1.41	114.0 ± 32.52	20.50 ± 0.70	5.00 ± 1.41	23.50 ± 6.36	-	-	-	11.158	*0.002* *P* <0.05
Ephemerellidae	28.0 ± 21.21	3.50 ± 4.94	66.0 ± 57.98	1.0 0 ± 00	-	1.0 ± 1.41	-	-	-	4.175	*0.040* *P* <0.05
Ephemeridae	8.50 ± 3.53	3.50 ± 2.12	6.50 ± 6.36	6.0 ± 2.82	0.50 ± 0.70	4.50 ± 0.70	1.0 ± 1.41	2.50 ± 3.53	2.0 ± 2.82	3.07	*0.081* *P* >0.05
Prosopistomatidae	10.0 ± 5.65	2.50 ± 3.53	13.50 ± 3.53	4.0 ± 2.82	-	5.0 ± 2.82	-	-	-	11.064	*0.002* *P* <0.05

PreM—Premonsoon | Mons—Monsoon | PosM—Post-monsoon.

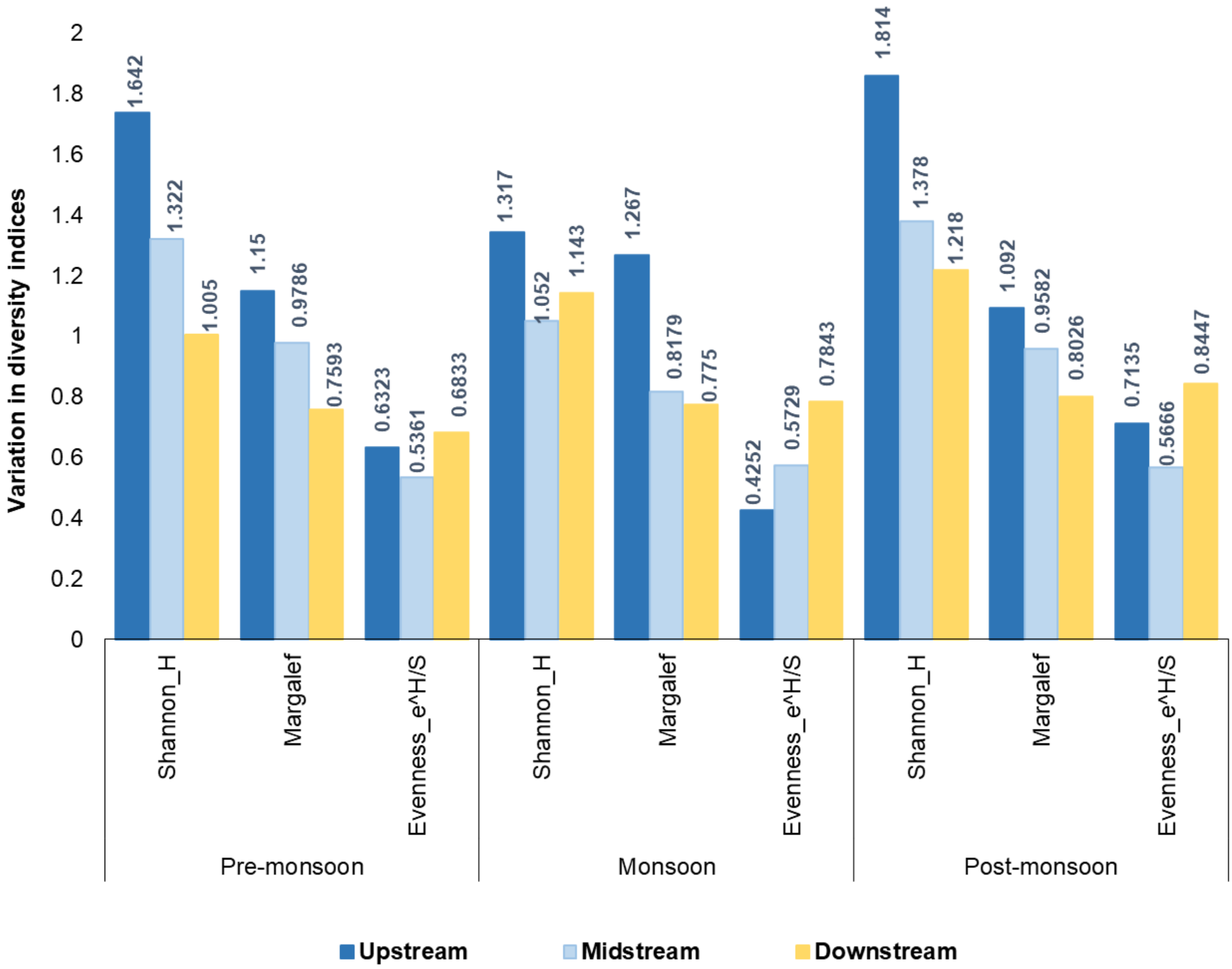

Figure 2. Spatial and seasonal variation of biodiversity indices in the Achenkovil River Basin, Kerala.

increase the turbulence, oxygenation, and DO level in the water body (Alam et al. 2007). BIS standard value for BOD is 2mg/l, which is exceeded up to 2.71±0.65 in the present investigation during the post-monsoon season. The biodegradation of organic matter and the impact of anthropogenic activities may contribute to a rise in BOD (Virha et al.2011). The permissive limit of turbidity is 5 NTU, which is exceeded to a small extent in the present study during the monsoon season. The turbid waters tend to fasten the growth of pathogenic microorganisms (Farahbaksh & Smith 2002) and thus hamper the quality of the drinking water. A sudden increase in conductivity indicates pollution in the water body (Gupta et al. 2009). The value of conductivity falls within the limits as prescribed by BIS (400µS/cm^2). An increase in both TDS (BIS limit, 500mg/l) and conductivity is toxic and a stressor to the mayfly community (Barathy et al. 2020). The main source of nitrate (BIS limit, 45mg/l) in the monsoon season is due to surface runoff carrying agricultural waste, fertilizers, domestic waste, etc. Rainwater itself contributes substantially to the supply of nitrates.

The record of 36 species of mayflies coming under 27 genera and 9 families in the present study from the Achenkovil River basin is the first report of the diversity and abundance of mayfly larvae (Ephemeroptera). In the present study, the diversity indices differ between seasons probably due to different seasonal changes and uneven geomorphological features of the river basin, as geomorphological heterogeneity plays a major role in determining species richness (Nichols et al. 1998). Habitat diversity influences the structure and composition of macro-benthic invertebrates. The different microhabitats present in the rocky substratum of the upstream segment of the river are home to diverse biotic communities. Studies reveal that thick canopy cover regulates water temperature and overall quality of water in the river and promotes the occurrence of macro-benthic invertebrates and provides favourable habitat (Bose et al. 2021).

The midstream and the downstream segments are facing severe anthropogenic pressures, such as the destruction of riparian forests, river regulation, and bank deterioration for agricultural purposes, which adversely affect the mayfly community structure (Ramulifho et al. 2020). During pre-monsoon season, the water level in the river falls and flow gets obstructed, as a result, saltwater intrusion from Kayamkulam Lake occurs in the downstream segment of the river. This adversely creates a lot of problems for salt-sensitive organisms. Protecting rivers requires a holistic approach, including watershed management, riparian buffer zones, water quality monitoring, restoration projects, and community engagement. Enforce regulations on pollution and unsustainable practices, manage floodplains, and integrate river protection into planning. Collaboration among stakeholders is essential for successful implementation.

CONCLUSION

Mayflies serve as water quality indicators, so monitoring their diversity and abundance provides insights into the river's ecological health. This work acts as a model ecosystem for biomonitoring studies and offers consistent data on the current state of the water quality and temporal variations in relation to the mayfly community structure in the Achenkovil River basin.

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