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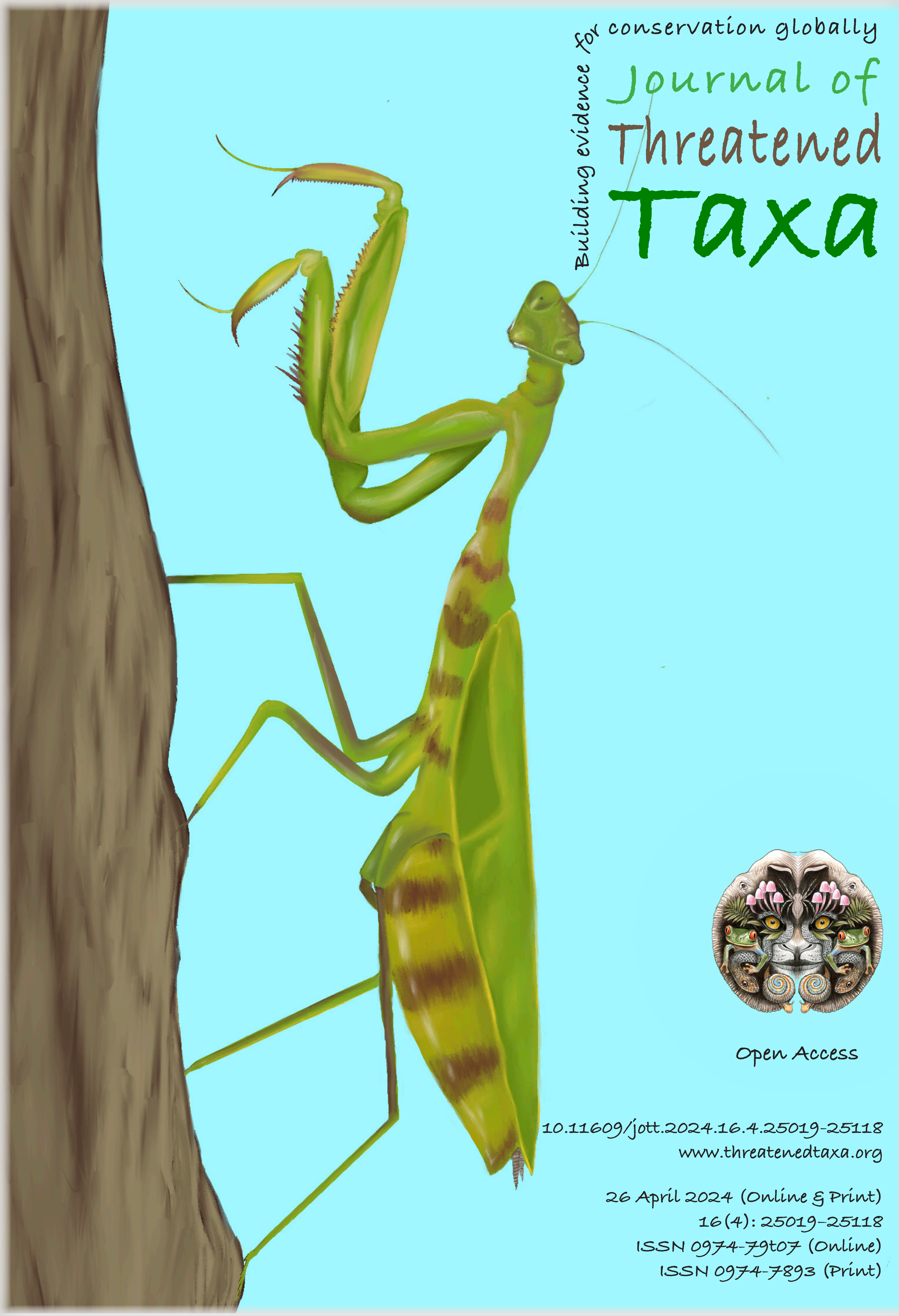

Open Access

10.11609/jott.2024.16.4.25019-25118
www.threatenedtaxa.org

26 April 2024 (Online & Print)
16(4): 25019-25118
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

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Cover: A gravid praying mantis just before she laid her ootheca—digital art on procreate. © Aakanksha Komanduri.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 April 2024 | 16(4): 25082–25088

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.7690.16.4.25082-25088

#7690 | Received 02 October 2021 | Final received 16 September 2023 | Finally accepted 11 March 2024

COMMUNICATION

Aquatic insects as bioindicators of stream water quality - a seasonal analysis on Western Ghats river, Muthirapuzha, in central Kerala, India

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Abstract: This study was conducted to assess the water quality of Muthirapuzha River, Idukki using aquatic insects as bioindicators. Insects were collected on a seasonal basis from February 2014 to January 2015 from 12 sampling stations. Insects were sampled using standard collection methods and were identified up to family level. A total of 3,278 individuals belonging to seven orders and 37 families were collected during the study period. The greatest number of taxa was represented by order Ephemetroptera during monsoon (27%) and post-monsoon (25%), while Diptera (22.7%) dominated the pre-monsoon season. Shannon-Weiner diversity index, Simpson dominance index, and Margalef's richness index was highest at post-monsoon. The EPT score in Muthirapuzha was for normal waters, however, pre-monsoon values were lowest, indicating pollution load during this period. Hilsenhoff's family biotic index (HFBI) was used to estimate the status of organic pollution along the river based on representative families of aquatic entomofauna; values were highest at pre-monsoon season. The overall organic water quality level in the Muthirapuzha was good to fair based on this study.

Keywords: Biomonitoring, diversity indices, EPT scores, Hilsenhoff's family biotic index, macro-invertebrates, Margalef's richness index, Munnar, Muthirapuzha River, Periyar River, Shannon Weiner diversity index, Simpson dominance index.

Editor: R. Ramanibai, University of Madras, Chennai, India. **Date of publication:** 26 April 2024 (online & print)

Citation: Harinagaraj, M., L. Joseph & V.S. Josekumar (2024). Aquatic insects as bioindicators of stream water quality - a seasonal analysis on Western Ghats river, Muthirapuzha, in central Kerala, India. *Journal of Threatened Taxa* 16(4): 25082–25088. https://doi.org/10.11609/jott.7690.16.4.25082-25088

Funding: The Higher Education Department, Government of Kerala, Thiruvananthapuram.

Competing interests: The authors declare no competing interests.

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Author contributions: MH—data collection and manuscripts preparation. LJ—correction of manuscripts, language check. VSJ—conceptual support, Identification of macroinvertebrates, correction of final draft.

Acknowledgements: Financial assistance from Govt. of Kerala to Harinagaraj M is gratefully acknowledged. Authors are thankful to the Mar Ivanios College administrations for the library and laboratory support.

INTRODUCTION

Rivers provide fresh water for agricultural, industrial and domestic needs (Ridoutt et al. 2010; Sunil et al. 2010) that can create enormous environmental pressures, including pollution leading to deteriorated water quality adversely affecting aquatic life (Kamboj & Kamboj 2019; Sinha et al. 2020). Biological communities provide a faithful reflection of environmental conditions, since they are continually exposed to them (Rosenberg & Resh 1993). Water quality changes are directly reflected by aquatic fauna, which can be assessed to measure the health of their ecosystems (Mulani et al. 2009; Saxena & Singh 2020). This approach is widely exploited as a reliable technique for assessing point and non-point sources of pollution of water bodies via biomonitoring protocols. Benthic macroinvertebrates representing different visible aquatic phyla exhibit a relatively wide range of response to chemical and physical water quality stressors like pH, temperature, dissolved oxygen, organic pollutants, heavy metals and sediments that can serve as a biological indicator of water pollution (Marzelai et al. 2008). Latha & Thanga (2010) identified macroinvertebrates as useful bioindicators in estuaries. Stream insect communities were suggested for aquatic biomonitoring protocol by Morse et al. (1994) and Subramanian & Sivaramkrishnan (2005). Diversity of aquatic insects is relatively easy to measure for assessing the health status of streams, and many biomonitoring studies are reported from southern Indian rivers (Sheeba & Ramanujan 2009; Priyanka & Prasad 2014). Stream entomofauna were targeted in Killi Ar, an urban river of Trivandrum corporation area, to assess the pollution status of the stream (Dinesh et al. 2017).

Many tools are employed in biological monitoring to assess the quality of water resources (Buss et al. 2003). The effective use of these tools leads to a better understanding of aquatic organisms that influence on biotic index results, and occurrence of bioindicators (Czerniawska-Kusza 2005). Distribution of bioindicator taxa is influenced by hydrological characteristics, nutrient supply, substrate type, predation pressure and natural or anthropogenic disturbances, in addition to variation in water quality, that makes these biotic indices important tools for evaluate the health of water ecosystems (Silveira et al. 2004). Comparative analyses of biotic indices are now available to determine which index best reflects ecosystem health (Gonçalves & Menezes 2011). William Hilsenhoff formulated family-level (Hilsenhoff 1988) versions of a biotic index, and tabulated interpretive criteria based on known sensitivities of arthropod taxa to organic enrichment (i.e., sewage pollution). This has been widely used in to characterize the health of freshwater streams (Reynoldson & Metcalfe-Smith 1992; Hu et al. 2007).

The river Periyar, the longest river in Kerala State (PWD 1974; CESS 1984) is considered to be the life line of central Kerala. Muthirapuzha River, the major tributary of the Periyar, forms the main drainage system south of Anamudi. This river is the major water resource of five panchayath in Devikulam Taluk of Idukki District. The Muthirapuzha watershed includes Kannan Devan Tea plantations along with Eravikulam National Park, and forms the highest watershed of the Western Ghats. Munnar Township, one of major tourist destinations in Kerala, extends along the banks of this stream. Thus this river is experiencing active anthropogenic pressure chiefly due to tourism and agricultural activities. In this study we undertook a rapid assessment of the status of this river utilizing a biomonitoring protocol targeting aquatic insects as bioindicators for stream water quality.

MATERIALS AND METHODS

Study area

The Muthirapuzha is located at 10.172–9.951 ^{0}N & 77.077–76.983 ^{0}E (Figure 1). It originates from Umaya Mala near Anamudi Peak and flows through Deikulam, Munnar, Pallivasal, Vellathooval and Konnathadi panchayths of Devikulam and Udumbanchola of Idukki District, and joins the Periyar River at Panamkutti, covering a distance of 34 km.

Macroinvertebrate analysis

Macroinvertebrates were sampled once every four months from February 2014 to January 2015 at twelve selected stations on the Muthirapuzha to capture seasonal variations. A D-frame aquatic net (0.5 mm mesh) was used to collect benthic organisms present in a 10 m^2 area (Hellawell 1986). After each jab and sweep, the net was rinsed in a sieve bucket (250 µm mesh) to collect all the macroinvertebrates. Samples were washed, separated through three sieves (2 mm, 1 mm, and 0.3 mm), transferred to glass bottles after labeling and preserved in 5% formalin in the field immediately after each collection. Each animal was then brush picked, preserved in 4% formalin, sorted and identified in the laboratory according to Edmondson (1992) and Pennak (1978). Aquatic insects were counted and identified using a stereo microscope (Headz-HD600D) with the help of standard keys (McCafferty 1983; Morse et al. 1994

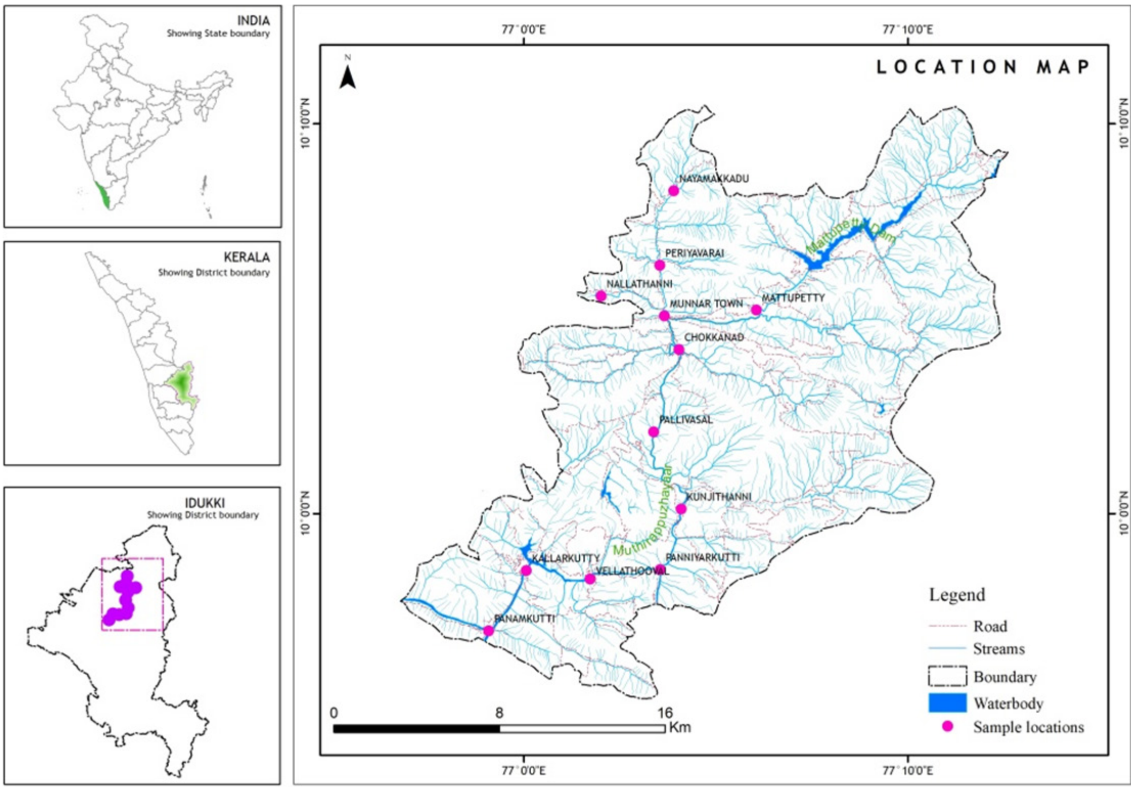

Figure 1. Sampling stations of river Muthirapuzha.

& Yong & Yule 2004) up to the family level. Taxonomic indices used for analyses of aquatic insects include Shannon-Weiner diversity index, Simpson dominance index, Margalef richness index (Shannon & Weiner 1963; Simpson 1949; Margalef 1958; Pielou 1966) and Hilsenhoff's Family Biotic Index (HFBI) (Hilsenhoff 1988) to estimate the level of organic pollution. Biodiversity indices were calculated using PAST ver. 1.34 software (Hammer et al. 2005).

RESULTS AND DISCUSSION

The present study identified 55 taxa represented by 37 families belonging to eight orders among the 3,278 total aquatic insects collected during the study period in pre-monsoon, monsoon, and post-monsoon seasons. Table 1 shows the overall numbers of insects collected during the sampling period. The number of individuals found in the pre-monsoon season was 1,313, 270 in monsoon, and 1,695 post monsoon. The greatest numbers of taxa were represented by order Ephemeroptera in monsoon (27%) and post-monsoon (25%), while Diptera (22.7%) dominated in pre-monsoon. The overall analysis of aquatic insects indicated that the most abundant taxa were Ephemeroptera (22%), followed by, Odonata (18.5%), Diptera (18%), Trichoptera (11%), Hemiptera (10%), Coleoptera (9.7%), and Plecoptera (7.9%) (Figure 2).

The biological indices of aquatic insects computed for 12 sampling sites are represented in Table 2, 3, & 4. Shannon-Weiner diversity index for pre monsoon season ranged between 3.807–3.211 and were found to be maximum at station 2 and minimum at station 10. During monsoon it was highest at station 1 (3.266) and lower index value was reported in station 10 (2.306). Shannon-Weiner diversity index was varying between 3.752 and 3.428; these values are represented in stations 1 and 10, respectively. Simpson dominance index also showed similar relation and varied from 0.974 to 0.943 in pre-monsoon. Maximum dominance index was found in station 2 and minimum in station 10. Index values were between 0.956 to 0.879 in monsoon and 0.972 to 0.948 in post- monsoon seasons. Margalef's richness index showed comparatively low value in monsoon season and the lowest value (2.954) was identified from station 6, Chokkanadu which is an urbanized site and higher (7.452) in station 1, Nayamakkadu near the origin of stream. Richness index was higher in pre-monsoon and post-monsoon seasons compared to monsoon. In

Table 1. Aquatic insects collected from river Muthirapuzha over different seasons (2014–15).

ORDER	FAMILY	PRM*	MON**	POM***
Diptera	Simuliidae	33	2	39
	Chironomidae	155	10	129
	Culicidae	68	20	52
	Tipulidae	42	5	38
Hemiptera	Nepidae	20	3	16
	Velliidae	19	3	19
	Hydrometridae	9	7	26
	Belostomatidae	12	2	27
	Gerridae	85	13	66
Ephemeroptera	Ephemeridae	34	9	53
	Heptageniidae	24	11	68
	Leptohyphidae	64	14	108
	Caenidae	94	16	110
	Ephemerellidae	18	3	25
	Baetidae	27	20	63
Plecoptera	Perlidae	94	14	151
Odonata	Coenagrionidae	114	3	125
	Chlorocyphidae	24	3	31
Odonata	Eupaeidae	25	2	25
	Calopterygidae	17	0	17
	Lestidae	7	2	13
	Platystictidae	13	0	15
	Cordullidae	7	0	7
	Gomphidae	43	6	39
	Aeshnidae	22	5	43
Megaloptera	Corydalidae	17	4	30
Trichoptera	Helicopsychidae	27	8	47
	Hydropsychidae	11	15	46
	Glossosomatidae	18	1	26
	Polycentropodidae	6	4	21
	Leptoceridae	21	31	80
Coleoptera	Haliplidae	10	7	17
	Hydrophildae	68	11	55
	Gyrinidae	14	12	33
	Dytiscidae	51	4	35

PRM*—Pre-monsoon | MON**—Monsoon | POM***—Post-monsoon

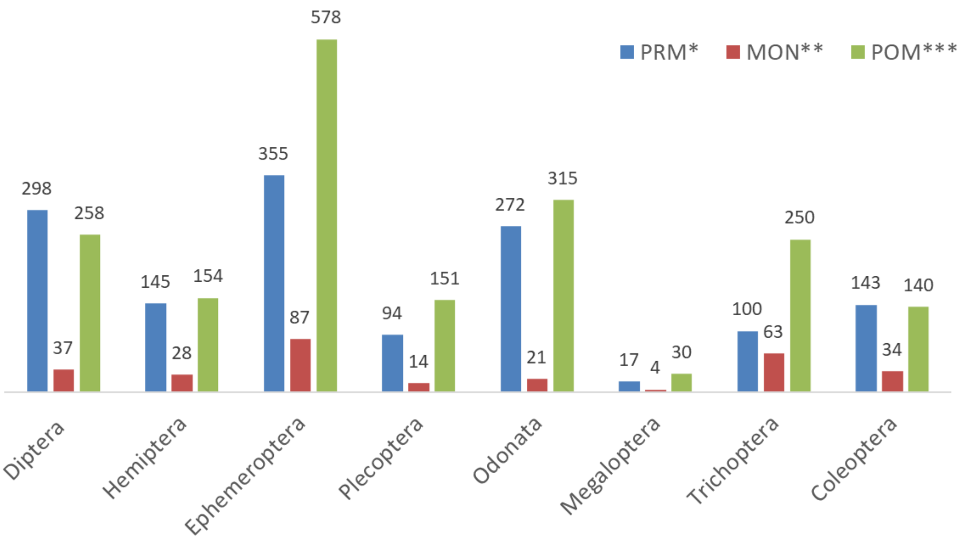

Figure 2. Aquatic insects collected from river Muthirapuzha during 2014–15.

pre-monsoon the maximum Margalef richness index was found in station 2 (10.98) and minimum in station 11 (7.015). In post-monsoon season the richness index varied from 10.08 to 7.856, respectively from station 2 and station 9. Highest taxonomic indices were observed in post-monsoon season.

Among aquatic insects, Ephemeroptera, Plecoptera, and Trichoptera (EPT) have a great role in low and medium order stony cobble streams. The percentage of EPT in river Muthirapuzha during the study period was represented in Table 5. These organisms are sensitive to environmental perturbations and occur in clean and well oxygenated waters. Therefore, EPT assemblages are frequently considered to be good indicators of water quality (Rosenberg & Resh 1992; Priyanka & Prasad 2014), EPT is widely used for the measure of health of

Table 2. Biodiversity indices of aquatic insects in pre-monsoon season (2014–15).

Stations	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Taxa_S	46	53	50	48	43	39	39	37	32	33	31	30
Individuals	132	114	128	151	149	135	100	114	81	77	72	60
Simpson_1-D	0.969	0.974	0.968	0.956	0.954	0.947	0.962	0.964	0.956	0.949	0.955	0.953
Shannon_H	3.647	3.807	3.652	3.49	3.369	3.261	3.451	3.452	3.298	3.211	3.242	3.223
Margalef	9.216	10.98	10.1	9.368	8.393	7.747	8.252	7.601	7.054	7.367	7.015	7.083

Table 3. Biodiversity indices of aquatic insects in monsoon season (2014–15).

Stations	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Taxa_S	30	23	23	15	12	9	14	14	12	12	12	12
Individuals	49	33	30	22	19	15	18	22	17	21	20	18
Simpson_1-D	0.956	0.949	0.951	0.922	0.903	0.871	0.92	0.905	0.899	0.879	0.89	0.901
Shannon_H	3.266	3.061	3.078	2.626	2.406	2.119	2.582	2.5	2.395	2.306	2.346	2.399
Margalef	7.452	6.292	6.468	4.529	3.736	2.954	4.498	4.206	3.883	3.613	3.672	3.806

Table 4. Biodiversity indices of aquatic insects in post-monsoon season (2014–15).

Stations	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Taxa_S	55	55	52	48	45	41	44	42	38	41	40	41
Individuals	228	212	182	170	141	147	118	105	111	102	90	89
Simpson_1-D	0.972	0.966	0.965	0.971	0.953	0.959	0.958	0.956	0.948	0.96	0.955	0.957
Shannon_H	3.752	3.668	3.649	3.683	3.402	3.416	3.486	3.434	3.248	3.481	3.409	3.42
Margalef	9.946	10.08	9.8	9.151	8.891	8.015	9.013	8.81	7.856	8.649	8.667	8.911

fresh water ecosystem (Wallace & Jackson 1996).

In this study the percentage of EPT was very high in sampling stations 1, 2, & 3 in three sampling seasons. But it was gradually decreased in the middle and lower streams of river Muthirapuzha. Especially the middle sampling sites representing Munnar Township and nearby inhabited area exhibit a very low percentage of EPT level. This clearly indicates that the water quality was badly affected by pollution related activities at this stretch of river. The percentage of EPT in lower stream varied from station to station which means that each sampling stations were under different types of pollution stress mainly due to anthropogenic and tourism related activities along the river, Muthirapuzha. The overall mean percentage of EPT score indicated that the pre-monsoon season was polluted in nature compared to the other two seasons (Figure 3)

Hilsenhoff family biotic index (HFBI) is one of the most effective bio monitoring tool in stream ecology and is used to assess the level of organic pollution in water bodies (Hilsenhoff 1988). HFBI of river Muthirapuzha (Table 6) categorizes the water quality based on the families identified from 12 stations along this river. Water quality grade according to HFBI index is shown in table 7. HFBI indicated that the water quality varies in each sampling station ranging from excellent to fairly poor and the degree of organic pollution was comparatively low in Muthirapuzha. Based on this study the water of Muthirapuzha could be classified into four categories using the HFBI, 'excellent', 'very good', 'good', and 'fair'. The HFBI values were higher in pre-monsoon and lower during monsoon seasons indicating the organic loading during pre-monsoon.

When classifying water quality during monsoon, the HFBI index gave scores of 'excellent' to 'good', however, station 11 was under some organic pollution (Table 6) otherwise the overall water quality was very good during this period. During post-monsoon season the HFBI ranged 3.78–5.34 which indicated the water quality in between very well to fair (Table 6). Station 5, 6, 8, 11, & 12 came under 'fairly substantial pollution likely' (Table 7) during this season. Finally in pre-monsoon HBFI

Table 5. Percentage of EPT in river Muthirapuzha (2014–15).

Stations	PRM*	MON**	POM***
1 - Nayamakkadu	42.73	33.84	46.18
2 - Periyavarai	45.74	47.61	48.56
3 - Mattupetty	46.05	30.61	45.56
4 - Nallathanni	22.7	15.21	28.78
5 - Munnar Town	20.68	15.55	23.78
6 - Chokkanadu	15.95	21.42	27.21
7 - Pallivasal	27.78	54.57	36.87
8 - Kunjithanni	31.13	44.82	39.59
9 - Panniyarkutti	27.47	32.14	42.95
10 - Vellathooval	24.09	55.17	36.71
11- Kallarkutti	29.67	24.32	41.07
12 - Panamkutti	25	56.1	46.28
Mean	**29.91**	**35.93**	**38.62**

PRM*—Pre-monsoon | MON**—Monsoon | POM***—Post-monsoon

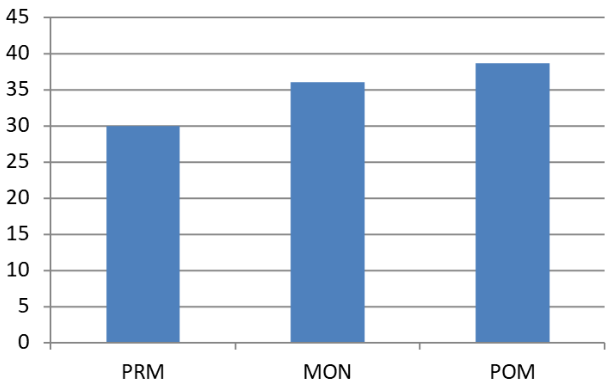

Figure 3. Mean percentage of EPT in river Muthirapuzha (2014–15).

Table 6. Hilsenhoff family biotic index of river Muthirapuzha (2014–15).

Stations	PRM	MON	POM
S1 (Nayamakkadu)	3.78	3.22	3.99
S2 (periyavarai)	4.33	3.45	3.78
S3 (Mattupetty)	4.51	3.37	4.12
S4 (Nallathanni)	5.29	3.57	4.34
S5 (Munnar Town)	5.75	3.8	5.19
S6 (Chokkanadu)	5.8	3.78	5.34
S7 (Pallivasal)	5.21	3.6	4.92
S8 (Kunjithanni)	5.33	4.18	5.13
S9 (Panniyarkutti))	5.3	4.23	4.83
S10 (Vellathooval)	4.82	4.4	5.04
S11 (Kallarkutti)	5.12	4.54	4.61
S12 (Panamkutti)	5.41	3.38	4.94

PRM*—Pre-monsoon | MON**—Monsoon | POM***—Post-monsoon

Table 7. Hilsenhoff family biotic index for water quality grades.

HFBI	Water quality	Degree of organic pollution
0.00–3.75	Excellent	Organic Pollution Unlikely
3.76–4.25	Very Good	Possible Slight Organic Pollution
4.26–5.00	Good	Some Organic Pollution Probable
5.01–5.75	Fair	Fairly Substantial Pollution Likely
5.76–6.50	Fairly Poor	Substantial Pollution Likely
6.51–7.25	Poor	Very Substantial Pollution Likely
7.26–10.00	Very Poor	Severe Organic Pollution Likely

was comparatively higher with the other two seasons; the water quality values come under the categories of 'very good' to 'fairly poor'. Sampling stations 5 and 6 reported 'substantial pollution likely' (Table 6, 7) during this period. It may be noted that these sampling stations are representing the Munnar township segment of the stream. 'Poor' and 'very poor' water qualities were not reported at any sampling stations during the course of sampling period.

According to the HFBI, overall water quality was very good in monsoon, good in post monsoon and fair in pre-monsoon seasons (Figure 3). Though the sampling points were located within populated area except the first three, the HFBI did not reflect obvious anthropogenic pressure on this river. Munnar Township and some small towns are located in the middle and lower reaches of river Muthirapuzha, which reported 'fairly poor' status of water at these stretches but the overall water quality falls between very good to fair scale of HFBI. Present study shows a temporal variation in bioassessment of Muthirapuzha River that influence the judgment of the sites. Studies shows temporal variations in bioassessment based on benthic macroinvertebrates (Linke et al. 2001; Nukeri et al. 2021). Substrate heterogeneity as well as land use changes are generally the determinants of the macroinvertebrate distribution along streams (Semwal & Mishra 2019). Spatio-seasonal flux of benthic macroinvertebrate assemblages as indicators of water quality in a coastal basin of southern Chile was assessed by applying HFBI (Fierro et al. 2012). River Muthirapuzha seems sensitive to anthropogenic activities due to tourism as indicated by the macroinvertebrate community based biotic index.

CONCLUSION

River Muthirapuzha one of the major tributary of river Periyar, a mountain stream originated and flow through the higher elevations of Western Ghats. There are 33 small and large streams contribute water to river Muthirapuzha at various stretches. The taxonomic indices of aquatic insects collected from this river established a clear view of level of stream health. The season-wise analysis of taxonomic Indies indicated that the water quality was good on monsoon season and comparatively higher pollution in other two seasons. The EPT scores indicated average water quality in the river, except at the middle stream sampling sites, the anthropogenic pressure due to tourism activates affects the water quality in this area. The study identified the water quality of the river Muthirapuzha varied seasonally at every sampling station, and the overall water quality was good based on HFBI category, although pollution load was evident in pre-monsoon season.

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NAAS rating (India) 5.64

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Journal of Threatened Taxa

OPEN ACCESS

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

www.threatenedtaxa.org

April 2024 | Vol. 16 | No. 4 | Pages: 25019–25118
Date of Publication: 26 April 2024 (Online & Print)
DOI: 10.11609/jott.2024.16.4.25019-25118

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