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Substratum Texture as a Key Determinant of Macrozoobenthic Community Structure Along the Longitudinal Gradient of River Jhelum, Kashmir Himalaya

Khalida Hassan*
*Corresponding Author: khalidahassan123@gmail.com
Orcid ID: https://orcid.org/0000-0001-7197-0512

Department of Zoology Govt. Degree College for Women, Pulwama- Jammu and Kashmir- India

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Abstract

Substrate characteristics are among the most important physical factors governing the distribution, abundance, and diversity of benthic macroinvertebrates in lotic ecosystems. The present study investigated the influence of substratum texture on the spatial distribution and community composition of macrozoobenthos along the longitudinal gradient of River Jhelum, Kashmir Himalaya. Sampling was conducted at twelve sites representing the upper, middle, and lower stretches of the river during December 2020 to April 2021. Macrozoobenthic organisms were collected using a Surber sampler in coarse substrata and an Ekman's dredge in fine sediments, while substrate composition was determined using the Wolman pebble count method. A total of 42 taxa belonging to the phyla Arthropoda, Annelida, and Mollusca were recorded. Coarse substrata dominated by boulders, cobbles, and gravel in the upper reaches supported the highest taxonomic diversity and were characterized by pollution-sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa, accounting for nearly 65% of the arthropod assemblage. In contrast, the middle and lower stretches, dominated by sandy, silty, and clayey sediments, exhibited greater abundance of pollution-tolerant oligochaetes and dipteran larvae, particularly *Chironomus* spp. Functional feeding group analysis revealed collector-gatherers as the dominant group in downstream reaches, whereas scrapers and shredders were largely confined to the upper stretch. The observed changes in macrozoobenthic assemblages closely reflected longitudinal variations in substrate texture, habitat complexity, and increasing anthropogenic disturbances. The findings demonstrate that substrate composition strongly regulates benthic community structure and highlight the usefulness of macrozoobenthos as reliable bioindicators for ecological assessment and conservation of Himalayan river ecosystems.

Introduction

Freshwater rivers are dynamic ecosystems that support diverse biological communities while providing essential ecological services such as nutrient cycling, fisheries production, irrigation, and drinking water. Among the biological communities inhabiting river ecosystems, benthic macroinvertebrates constitute an important component because they occupy a central position in aquatic food webs and facilitate the transfer of energy between primary producers and higher trophic levels, including fishes. Aylagas et al. (2018) .Benthic macroinvertebrates are widely recognized as reliable bioindicators because of their relatively sedentary nature, differential tolerance to environmental disturbances and prolonged life cycles, making them suitable indicators of river health and ecological integrity (Siraj *et al*., 2010; Hussain and Pandit, 2012; Strayer and Dudgeon, 2010; Geist, 2011; Sabha *et al*., 2022).Owing to their differential tolerance to environmental disturbances, and prolonged life cycles, macrozoobenthic organisms are widely recognized as reliable indicators of river health and water quality.

The composition and distribution of benthic macroinvertebrate communities are influenced by a complex interaction of physicochemical and habitat variables. Among these, substrate texture is considered one of the primary determinants of benthic habitat quality. Substrate heterogeneity strongly influences habitat stability, food resources, refuge availability and colonization opportunities for benthic fauna, thereby regulating community composition and biodiversity (Buhl-Mortensen *et al*., 2010; Jones *et al*., 2012; Mathers *et al*., 2017).It directly influences, current velocity, oxygen exchange, refuge availability and reproductive habitats. Coarse substrates such as boulders, cobbles, and gravel generally provide stable habitats that support diverse assemblages of pollution-sensitive taxa, Numerous investigations have demonstrated that coarse substrates, such as boulders, cobbles, and gravel, favour pollution-sensitive taxa, particularly members of the orders **Ephemeroptera, Plecoptera, and Trichoptera (EPT)**, whereas fine sediments generally support pollution-tolerant oligochaetes and chironomids (Akamagwuna et al., 2019; do Amaral et al., 2019).In contrast, fine sediments consisting of sand, silt, and clay are frequently associated with higher organic matter accumulation and are commonly dominated by pollution-tolerant taxa, including oligochaetes and chironomid larvae.

The River Continuum Concept proposes that biological communities undergo predictable longitudinal changes from headwaters to downstream reaches in response to natural variations in habitat characteristics, energy sources, and substrate composition. (Thorp *et al*., 2010; Doretto *et al*., 2020) Although numerous studies have evaluated macrozoobenthic diversity in Himalayan rivers (Pandit, 2017; Harrison *et al*., 2018) relatively few have specifically examined the influence of substrate characteristics on macrozoobenthic community organization along the longitudinal gradient of River Jhelum. Considering the increasing anthropogenic pressures associated with urbanization, agricultural runoff, and habitat modification, understanding substrate–macrozoobenthos relationships has become essential for river conservation and biomonitoring. Similar observations have been reported from River Jhelum and other Himalayan streams where increasing anthropogenic disturbances have significantly altered benthic community structure (Hassan *et al*., 2014; Rather *et al*., 2016; Khanday *et al*., 2021; Sofi *et al*., 2022).

River Jhelum is the principal drainage system of the Kashmir Valley and receives water from several tributaries before discharging into Wular Lake. The river exhibits substantial variation in geomorphology, hydrology, substrate composition, and land-use patterns along its course, providing an ideal natural gradient for investigating benthic community dynamics. These environmental gradients significantly influence habitat heterogeneity and the ecological integrity of the river ecosystem.

Therefore, the present study was undertaken to evaluate the influence of substratum texture on the spatial distribution and community composition of macrozoobenthos along different stretches of River Jhelum. Specifically, the study aimed to (i) characterize substrate composition along the river continuum, (ii) assess spatial variations in macrozoobenthic diversity and abundance, (iii) examine changes in functional feeding groups across different substrate types, and (iv) evaluate the usefulness of macrozoobenthic assemblages as indicators of ecological health in River Jhelum.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted along the longitudinal gradient of the River Jhelum, the principal river system of the Kashmir Valley, India India (Rather et al., 2016; Khanday et al., 2021), originating from the Verinag Spring (33°32′ N, 75°14′ E) at an altitude of approximately 1,866 m above mean sea level, the river traverses the Kashmir Valley before entering Wular Lake. Along its course, the river exhibits marked variations in geomorphology, hydrology, land use, and substrate characteristics, making it suitable for evaluating spatial changes in benthic macroinvertebrate communities.

Based on altitude, channel morphology, bottom substrate, and physicochemical characteristics, the river was divided into three longitudinal sections: upper, middle, and lower stretches.The map of sampling sites is shown in Figure 1 and Geographical coordinates of sampling sites has been depicted in Table 1.

The **upper stretch** (1,865–1,793 m a.s.l.) comprised four sampling sites (U1–U4) located in the headwater region near Verinag. This section was characterized by swift-flowing water and coarse substrates dominated by boulders, cobbles, pebbles, and gravel.

The **middle stretch** (1,598–1,590 m a.s.l.) extended from Anantnag to Lasjan and included four sampling sites (M1–M4). Compared with the upper reach, this section exhibited greater channel width and depth, with sandy and muddy substrates predominating.

The **lower stretch** (1,588–1,581 m a.s.l.) extended from Habbakadal to Shilvath and consisted of four sampling sites (D1–D4). This reach receives considerable anthropogenic inputs from urban settlements and sewage drains and is characterized primarily by fine sediments comprising sand, silt, and clay.

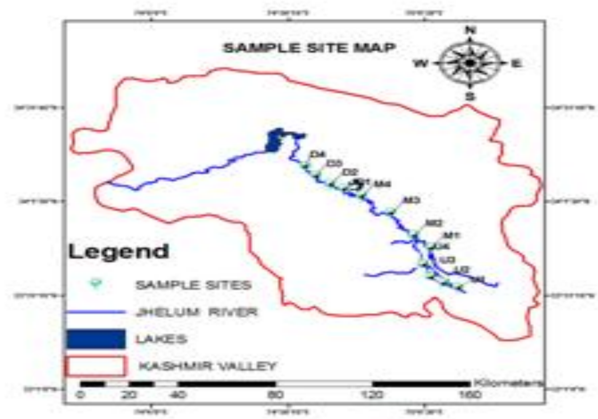

Fig.1. Map Showing Sampling sites

Site	Altitude (m a.s.l.)	Latitude	Longitude	Plant Flora
Zone 1	1865	33°32'17"N	75°14'26"E	Pinus sp., Cedrus sp., Silver fir, Picea, Potamogeton crispus, Salix sp., Juglans regia, Ceratophyllum demersum, Erigeron canadensis, mosses
Zone II	1597	33°50'13"N	75°03'39"E	Populus sp., Salix sp., Cannabis sativa, Alternanthera sessilis and Robinia pseudoacacia
Zone III	1582	34°09'16"N	74°42'12"E	Salix sp., Cannabis sativa, Populus sp.

Table 1: Geographical coordinates with plant description at the three longitudinal zones

2.2 Sampling Design

Field investigations were conducted from December 2020 to April 2021. Twelve representative sampling sites were selected to encompass the longitudinal environmental gradient of the river. At each site, three replicate samples were collected during each sampling occasion to ensure representative estimation of macrozoobenthic assemblages.

2.3 Collection of Macrozoobenthos

Macrozoobenthic organisms were collected using sampling techniques appropriate for the prevailing substrate conditions.

At sites with coarse substrates, a **Surber sampler** covering an area of **1,600 cm²** was employed. The substrate enclosed within the frame was disturbed manually to dislodge benthic organisms, which were subsequently carried by the current into the attached collecting net.

At sites dominated by soft sediments, an **Ekman's dredge (16 × 15 cm)** was used to collect benthic samples. Three replicate dredge samples were collected from each site. The collected sediments were sieved through graded mesh sieves (2.0, 1.0, and 0.5 mm) to separate macroinvertebrates from sediment particles.

The retained organisms were transported to the laboratory, sorted manually using forceps under illuminated trays, and preserved in **5% buffered formalin** until identification.

2.4 Identification of Macrozoobenthic Fauna

Macrozoobenthic organisms were identified to the lowest possible taxonomic level using standard taxonomic keys and identification manuals, including those of Pennak (1978), Edmondson (1959), Brinkhurst (1971), McCafferty (1981), and Milligan (1997). Organisms were examined using both stereozoom and compound microscopes.

The abundance of each taxon was expressed as **individuals m^{-2}** using standard density calculations.

2.5 Substrate Analysis

Bottom substrate composition was determined using the **Wolman Pebble Count Method** (Wolman, 1954). At each sampling site, at least 100 randomly selected substrate particles were measured across the wetted channel. Particle sizes were classified according to the **Wentworth sediment classification** into boulders, cobbles, pebbles, gravel, sand, and silt/clay fractions.

For fine sediments (particle diameter <2 mm), sediment texture was determined using the texture-by-feel method. Relative proportions of different substrate categories were calculated for each sampling site.

2.6 Functional Feeding Groups

Macrozoobenthic taxa were classified into functional feeding groups following the classification proposed by Merritt and Cummins (1996). The identified taxa were categorized as:

- Collector-gatherers
- Collector-filterers
- Scrapers (grazers)
- Shredders
- Predators

The proportional abundance of each functional feeding group was determined for each sampling site to evaluate trophic organization along the river continuum.

2.7 Statistical Analysis

Macrozoobenthic abundance and community composition were compared among the upper, middle, and lower stretches of the River Jhelum. Relative abundance (%) of major taxonomic groups and functional feeding groups was calculated for each sampling site. Spatial variations in macrozoobenthic assemblages were interpreted in relation to substrate composition and habitat characteristics.

3. RESULTS

3.1 Composition of Macrozoobenthic Communities

A total of **42 macrozoobenthic taxa** belonging to three phyla—**Arthropoda, Annelida, and Mollusca**—were recorded from the River Jhelum during the study period. Arthropoda was represented by **23 taxa**, including 21 insect taxa and one taxon each of Crustacea (*Gammarus pulex*) and Arachnida (*Hygrobatoidea* sp.). Annelida comprised **12 taxa**, whereas Mollusca was represented by **seven taxa**. Similar macrozoobenthic composition has been reported from Himalayan freshwater ecosystems by Siraj *et al*. (2010) and Hassan *et al*. (2014).

Overall, Annelida constituted the dominant component of the macrozoobenthic assemblage (**56.4%**), followed by Arthropoda (**41.6%**) and Mollusca (**1.8%**). However, considerable spatial variation in taxonomic composition was observed among the three river stretches.

3.2 Longitudinal Variation in Macrozoobenthic Assemblages

The upper stretch exhibited the highest taxonomic diversity and was dominated by Arthropoda, which contributed **90.5%** of the total macrozoobenthic fauna, followed by Annelida (**8.7%**) and Mollusca (**0.7%**). In contrast, the middle and lower stretches were dominated by Annelida, contributing **62.9%** and **77.9%**, respectively. Arthropoda declined to **35.0%** in the middle stretch and **19.5%** in the lower stretch, while Mollusca showed a gradual increase downstream (**1.9–2.5%**).

Among arthropods, members of the **Ephemeroptera–Plecoptera–Trichoptera (EPT)** group constituted nearly **65%** of the arthropod community in the upper stretch, whereas dipteran larvae, particularly *Chironomus* spp., predominated in the middle and lower reaches.

3.3 Functional Feeding Groups

Macrozoobenthic taxa were classified into five functional feeding groups following Merritt and Cummins (1996), consistent with functional trait approaches adopted by Statzner et al. (2004). Collector-gatherers were the dominant feeding group throughout the river, contributing **77.1%** of the total assemblage. Their relative abundance increased markedly downstream, ranging from **44.2–50.8%** in the upper stretch to approximately **90–98%** in the middle and lower stretches.

Predators constituted **11.6%** of the assemblage and showed a decreasing trend downstream. Scrapers (**7.2%**) and shredders (**5.5%**) were largely restricted to the upper stretch, while collector-filterers (**1.5%**) were absent from the upper reach and occurred only in the middle and lower stretches.

These patterns indicate a gradual shift in trophic organization from coarse-substrate headwaters to fine-sediment downstream reaches.

3.4 Substrate Characteristics

Distinct spatial differences in substrate composition were observed among the three river stretches. The upper stretch was characterized by coarse substrates comprising boulders, cobbles, pebbles, and gravel, with cobbles forming the dominant substrate category. Sand and silt occurred in relatively low proportions.

The middle and lower stretches were dominated by sand, silt, clay, and mud, reflecting reduced flow velocity and increased sediment deposition. Fine sediment accumulation was particularly pronounced at downstream sites affected by urban settlements and agricultural runoff.

3.5 Influence of Substrate on Macrozoobenthic Distribution

Macrozoobenthic distribution closely corresponded with substrate characteristics along the river continuum. Coarse substrates supported greater taxonomic richness and higher proportions of pollution-sensitive EPT taxa, whereas fine sediments favored pollution-tolerant oligochaetes, chironomid larvae, and molluscs.

The transition from coarse particulate organic matter in the upper reaches to fine particulate organic matter downstream was accompanied by a shift in dominant functional feeding groups from scrapers and shredders to collector-gatherers. These observations indicate that substrate composition strongly regulates habitat availability and trophic organization of benthic communities in River Jhelum

	U1	U2	U3	U4	M1	M2	M3	M4	D1	D2	D3
Collector-Gatherer	47.3	45.9	50.8	44.2	86.5	90.4	98.1	95.5	89.2	90.9	95.5
Collector-Filterer	0.0	0.0	0.0	0.0	1.5	2.3	0.9	2.1	0.7	1.9	1.5
Predator	28.0	26.1	31.5	27.2	11.7	7.3	1.0	2.4	10.1	7.1	2.8
Grazers(Scrapers)	14.5	16.3	5.8	17.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Shredder	10.3	11.6	11.9	10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2

Table 2: Abundance (%) of macroinvertebrates functional feeding groups at different sites of River Jhelum

Table 3: List of macroinvertebrates recorded during investigation

Phylum	Class	Taxa
Annelida	Oligochaeta	1.*Limnodrilus hoffmeister*
		2.*Limnodrilus udekemainus*
		3.*Tubifex tubifex*
		4.*Lumbriculus* variegates
		5.*Pristina* sp
		6.*Aeolosoma* sp
		7.*Nais* sp
		8.*Branchiura sowerbyii*
	Hirudinaria	1.*Erpobdella octoculata*
		2.*Placobdella montifera*
		3.*Placobdella hollensis*
		4.*Glossiphonia complanata*
Arthropoda	Crustacea	1.*Gammarus pulex*
	Arachnida	1.*Hygrobatoidea*
	Insecta	1.*Baetis* sp.
		2.*Baetilla* sp
		3.*Epeorus* sp
		4.*Caenis* sp
		5.*Rhyacophila obscura*
		6.*Rhyacophila basalis*
		7.*Limnephilus* sp
		8.*Lepidostoma* sp
		9.*Neumora* sp
		10.*Perilidae* sp
		11.*Elimidae* sp.
		12.*Dytiscus* sp.
		13.*Gomphus* sp
		14.*Chironomus* sp
		15.*Diamesinae* sp
		16.*Procladius* sp
		17.*Tabanus* sp
		18.*Simulium* sp
		19.*Culex*
		20.*Psychoda* sp
		21.*Bezzia* sp
Mollusca	Gastropoda	1.*Gyraulus* sp
		2.*Lymnaea ovata*
		3.*Lymnaea stagnalis*
		4.*Lymnaea auricularia*
		5.*Planorbis* sp
	Pelecypoda	1.*Corbicula* sp
		2.*Sphaerium* sp

4. DISCUSSION

The present investigation clearly demonstrates that substrate texture is a major determinant of macrozoobenthic community organization in River Jhelum. Similar relationships between substrate composition and benthic assemblages have been reported from Himalayan rivers and other freshwater ecosystems worldwide (Jones *et al*., 2012; Mathers *et al*., 2017; Wang *et al*., 2019).These findings support the hypothesis that substrate heterogeneity plays a fundamental role in structuring benthic communities in Himalayan river ecosystems.

A total of **42 macrozoobenthic taxa** belonging to Arthropoda, Annelida, and Mollusca were recorded during the study, indicating considerable benthic diversity within the River Jhelum. However, the composition of these assemblages varied markedly among the upper, middle, and lower reaches. The upper stretch was dominated by arthropods, particularly Ephemeroptera, Plecoptera, and Trichoptera (EPT), whereas the downstream reaches exhibited increasing dominance of oligochaetes and dipteran larvae. Similar longitudinal shifts in macrozoobenthic assemblages have been reported in Himalayan rivers and other temperate lotic ecosystems, where environmental gradients regulate species distribution and community composition.

The predominance of EPT taxa in the upper reaches can be attributed to the presence of coarse substrates consisting of boulders, cobbles, gravel, and pebbles. Such substrates provide greater habitat stability, increased surface area for periphyton growth, and interstitial spaces that serve as refugia against current velocity and predation. In addition, these habitats are characterized by well-oxygenated water and relatively low organic pollution, conditions that favour pollution-sensitive aquatic insects. The high abundance of

EPT taxa therefore indicates comparatively good ecological status in the headwater region of the River Jhelum.

In contrast, the middle and lower stretches were characterized by sandy, silty, and clayey substrates associated with reduced flow velocity and increased accumulation of organic matter. In contrast, the middle and lower stretches were characterized by sandy, silty, and clayey substrates associated with reduced flow velocity and increased accumulation of organic matter. These environmental conditions favoured the proliferation of oligochaetes and chironomid larvae, which are widely recognized as tolerant of nutrient enrichment and organic pollution. The increasing abundance of these taxa downstream suggests progressive habitat modification resulting from urbanization, domestic sewage discharge, agricultural runoff, and sediment deposition. Similar downstream shifts towards pollution-tolerant oligochaetes and chironomids have also been reported by Meena et al. (2019), Sabha et al. (2022), and Chakraborty et al. (2022). Furthermore, these findings agree with those of Akamagwuna et al. (2019), do Amaral et al. (2019), and Sofi et al. (2022), who reported greater abundance of pollution-sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa in heterogeneous coarse-substrate habitats, emphasizing the importance of substrate heterogeneity in maintaining benthic biodiversity and ecological integrity.The increasing abundance of these taxa downstream suggests progressive habitat modification resulting from urbanization, domestic sewage discharge, agricultural runoff, and sediment deposition. Similar downstream shifts towards pollution-tolerant oligochaetes and chironomids have also been reported by Meena *et al*. (2019), Sabha *et al*. (2022) and Chakraborty *et al*. (2022).

The observed changes in functional feeding groups further illustrate the ecological consequences of substrate variation. Collector-gatherers dominated the middle and lower stretches, whereas scrapers and shredders were largely confined to the upper reaches. This pattern is consistent with the **River Continuum Concept**, which predicts downstream changes in energy sources and trophic organization. Headwater streams typically receive coarse particulate organic matter derived from riparian vegetation, favouring shredders and scrapers, whereas downstream reaches contain higher proportions of fine particulate organic matter that support collector-gatherers and collector-filterers. The predominance of collector-gatherers in downstream sites therefore reflects increased organic matter deposition and changing habitat conditions. These trophic shifts are in agreement with the River Continuum Concept (Thorp *et al*., 2010; Doretto *et al*., 2020).

The transition from coarse to fine substrates was also associated with a decline in taxonomic diversity and an increase in pollution-tolerant taxa. Fine sediment deposition reduces habitat complexity by filling interstitial spaces between larger substrate particles, thereby limiting suitable microhabitats for many aquatic insects. Sediment accumulation also decreases oxygen penetration into benthic habitats and modifies food resources available to macroinvertebrates. Consequently, substrate degradation may substantially alter ecosystem functioning and reduce biological integrity.

Macrozoobenthic assemblages are increasingly used worldwide as reliable indicators of freshwater ecosystem health because they integrate environmental conditions over extended periods. Unlike physicochemical parameters, which provide only a snapshot of water quality, benthic macroinvertebrates reflect the cumulative effects of multiple environmental stressors. The present study confirms that shifts in community composition and functional feeding groups effectively indicate ecological changes associated with substrate alteration and anthropogenic disturbances. These findings support the incorporation of macrozoobenthic monitoring into long-term river assessment programmes for the Kashmir Himalaya.

Overall, the study demonstrates that substrate texture exerts a strong influence on macrozoobenthic diversity, abundance, and functional organization along the longitudinal gradient of the River Jhelum. Conservation of heterogeneous substrate habitats, together with effective management of sediment inputs and pollution sources, will be essential for maintaining ecological integrity and biodiversity in this important Himalayan river system. Increasing anthropogenic disturbances including urbanization, sewage discharge and agricultural runoff have been recognized as major drivers of benthic community degradation in River Jhelum and other Himalayan rivers (Rather *et al*., 2016; Khanday *et al*., 2021; Sofi *et al*., 2022).

5. CONCLUSION

The present study demonstrates that substrate texture is a fundamental determinant of macrozoobenthic community structure and ecological integrity along the longitudinal gradient of the River Jhelum, Kashmir Himalaya. Coarse substrates dominated by boulders, cobbles, and gravel in the upper reaches supported diverse assemblages characterized by pollution-sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa, reflecting favourable habitat conditions and good ecological status. In contrast, the middle and lower reaches, dominated by sand, silt, and clay, were characterized by increased abundance of pollution-tolerant oligochaetes and dipteran larvae, indicating habitat degradation associated with sediment deposition and anthropogenic disturbances. Functional feeding groups also exhibited predictable longitudinal shifts, with scrapers and shredders confined mainly to the headwaters, whereas collector-gatherers dominated downstream reaches, consistent with the River Continuum Concept. These findings highlight the strong influence of substrate composition on habitat heterogeneity, trophic organization, and benthic biodiversity. The study further confirms the value of macrozoobenthic assemblages as reliable bioindicators for assessing freshwater ecosystem health and monitoring environmental change. Conservation of heterogeneous substrate habitats, together with effective management of sediment inputs, urban effluents, and agricultural runoff, is essential for maintaining the ecological integrity and biodiversity of the River Jhelum and other Himalayan river ecosystems.

Bibliography

Siraj, S., Yousuf, A.R., Bhat, F.A. and Parveen, M. 2010. The ecology of macrozoobenthos in Shallabugh wetland of Kashmir Himalaya, India. Eco. Nat. Environ. 2(5): 84-91.

Meena, D.K., Lianthuamluaia, L., Mishal, P., Swain, H.S., Naskar, B.K., Saha, S. and Das, B.K. 2019. Assemblage patterns and community structure of macrozoobenthos and temporal dynamics of eco-physiological indices of two wetlands in lower Gangetic plains under varying ecological regimes: A tool for wetland management. Ecological Engineering. 130: 1-10.

Aylagas, E., Borja, Á., Muxika, I. and Rodríguez-Ezpeleta, N. 2018. Adapting metabarcoding-based benthic biomonitoring into routine marine ecological status assessment networks. Ecological Indicators. 95: 194-202.

Chakraborty, S., Bhattacharya, T., Singh, G. and Maity, J.P. 2014. Benthic macroalgae as biological indicators of heavy metal pollution in marine environments: A biomonitoring approach for pollution assessment. Ecotoxicology and Environmental Safety. 100: 61-68.

Akamagwuna, F.C., Mensah, P.K., Nnadozie, C.F. and Odume, O.N. 2019. Evaluating the responses of taxa in the orders Ephemeroptera, Plecoptera and Trichoptera (EPT) to sediment stress in the Tsitsa River and its tributaries, Eastern Cape, South Africa. Environmental Monitoring and Assessment. 191(11): 664.

do Amaral, P.H.M., de Almeida Gonçalves, E., da Silveira, L.S. and da Gama Alves, R. 2019. Richness and distribution of Ephemeroptera, Plecoptera and Trichoptera in Atlantic forest streams. Acta Oecologica. 99: 103441.

Hassan, K., Yousuf, A.R., Zargar, U., Jamila, I. and Rehman, M. 2014. Distributional pattern of macroinvertebrates across River Jhelum in Kashmir Valley. International Journal of Fisheries and Aquatic Studies. 1(6): 113-120.

Sabha, I., Hamid, A., Bhat, S.U. and Islam, S.T. 2022. Water quality and anthropogenic impact assessment using macroinvertebrates as bioindicators in a stream ecosystem. Water, Air, and Soil Pollution. 233(9): 387.

Sofi, M.S., Hamid, A., Bhat, S.U., Rashid, I. and Kuniyal, J.C. 2022. Biotic alteration of benthic macroinvertebrate communities based on multispatial-scale environmental variables in a regulated river system of Kashmir Himalaya. Ecological Engineering. 177: 106560.

Buhl-Mortensen, L., Vanreusel, A., Gooday, A.J., Levin, L.A., Priede, I.G., Buhl-Mortensen, P., Gheerardyn, H., King, N.J. and Raes, M. 2010. Biological structures as a source of habitat heterogeneity and biodiversity on the deep ocean margins. Marine Ecology. 31(1): 21-50.

Thorp, J.H., Thoms, M.C. and Delong, M.D. 2010. The riverine ecosystem synthesis: Toward conceptual cohesiveness in river science. Elsevier, Amsterdam.

Doretto, A., Piano, E. and Larson, C.E. 2020. The River Continuum Concept: Lessons from the past and perspectives for the future. Canadian Journal of Fisheries and Aquatic Sciences. 77(11): 1853-1864.

Hussain, Q.A. and Pandit, A.K. 2012. Macroinvertebrates in streams: A review of some ecological factors. International Journal of Fisheries and Aquaculture. 4(7): 114-123.

Rather, M.I., Rashid, I., Shahi, N., Murtaza, K.O., Hassan, K., Yousuf, A.R. and Shah, I.Y. 2016. Massive land system changes impact water quality of the Jhelum River in Kashmir Himalaya. Environmental Monitoring and Assessment. 188(3): 185.

Khanday, S.A., Bhat, S.U., Islam, S.T. and Sabha, I. 2021. Identifying lithogenic and anthropogenic factors responsible for spatio-seasonal patterns and quality evaluation of snow melt waters of the River Jhelum Basin in Kashmir Himalaya. Catena. 196: 104853.

Pandit, M.K. 2017. *Life in the Himalaya: An Ecosystem at Risk*. Harvard University Press, Cambridge.

Chakraborty, A., Saha, G.K. and Aditya, G. 2022. Macroinvertebrates as engineers for bioturbation in freshwater ecosystem. Environmental Science and Pollution Research. 29(43): 64447-64468.

Jones, J.I., Murphy, J.F., Collins, A.L., Sear, D.A., Naden, P.S. and Armitage, P.D. 2012. The impact of fine sediment on macroinvertebrates. River Research and Applications. 28(8): 1055-1071.

Mathers, K.L., Rice, S.P. and Wood, P.J. 2017. Temporal effects of enhanced fine sediment loading on macroinvertebrate community structure and functional traits. Science of the Total Environment. 599: 513-522.

Wang, S., Zhang, Q., Yang, T., Zhang, L., Li, X. and Chen, J. 2019. River health assessment: Proposing a comprehensive model based on physical habitat, chemical condition and biotic structure. Ecological Indicators. 103: 446-460.

Strayer, D.L. and Dudgeon, D. 2010. Freshwater biodiversity conservation: Recent progress and future challenges. Journal of the North American Benthological Society. 29(1): 344-358.

Geist, J. 2011. Integrative freshwater ecology and biodiversity conservation. Ecological Indicators. 11(6): 1507-1516.

Harrison, I., Abell, R., Darwall, W., Thieme, M.L., Tickner, D. and Timboe, I. 2018. The freshwater biodiversity crisis. Science. 362(6421): 1369

Statzner, B., Dolédec, S. and Hugueny, B. 2004. Biological trait composition of European stream invertebrate communities: Assessing the effects of various trait filter types. Freshwater Biology, 49: 1467–1485.