Journal of Threatened Taxa

Building evidence for conservation globally

www.threatenedtaxa.org

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

COMMUNICATION

The distributional pattern of benthic macroinvertebrates in a spring-fed foothill tributary of the Ganga River, western Himalaya, India

Vijay Prakash Semwal & Asheesh Shivam Mishra

26 September 2019 | Vol. 11 | No. 12 | Pages: 14511–14517
DOI: 10.11609/jott.4648.11.12.14511-14517

Communication

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

PLATINUM OPEN ACCESS

The distributional pattern of benthic macroinvertebrates in a spring-fed foothill tributary of the Ganga River, western Himalaya, India

Vijay Prakash Semwal [1] & Asheesh Shivam Mishra [2]

[1] Department of Zoology, Government Post Graduate College New Tehri, Tehri Garhwal, Uttarakhand 249001, India.
[2] Department of Zoology, Nehru Gram Bharati (Deemed to be University) Prayagraj, Uttar Pradesh 221505, India.
[1] vpsemwal75@gmail.com, [2] shivam_a2000@yahoo.co.in (corresponding author)

Abstract: Benthic macroinvertebrates play important ecosystem roles in the cycling and outflow of nutrients. The benthos transforms organic detritus from sedimentary storage into dissolved nutrients that can be mixed into overlying waters and used by rooted plants (macrophytes) and algae (phytoplankton) to enhance primary productivity. This study examined the distribution pattern of benthic macroinvertebrates in a lesser Himalayan foothill stream from the headwaters (2,200m) to mouth (375m). Five stations (S1 to S5) were established along the 43-km course of the stream. Samples were collected at bi-monthly intervals from January to December 2009. The total density of the benthic macroinvertebrate community increased with decreasing altitude and differed significantly among stations. Dominant orders were Diptera at S1 (Simulidae, 27%) & S5 (Chironomidae 24%), Trichoptera at S2 (Limnephilidae 16%) & S3 (Hydropsychidae 9.9%), and Ephemeroptera (Heptageniidae 9.2%) at S4. Principal component analysis revealed that the characteristic taxa were Simulidae at S1, Limnephildae at S2, Hydropsychiidae, Rhyacophilidae, Tipulidae, Perlodidae, Dryopidae & Notonectidae at S3, Heptageniidae at S4, and Chironomidae, Siphlonuridae, & Agrionidae at S5. Cluster analysis showed one large cluster comprising S1 and S2 as sub-groups with resemblance to S3-S4, and S5 as an outlier. The similarity between the stations S3-S4 was attributed to similar land-use pattern (agriculture) and stream order (II Order), while S1 and S2 were slightly similar due to partial similar forest type (oak forest at S1, pine-oak forest at S2) and stream order. At S5, however, the considerable change in forest type (mixed forest) land-use and stream order (III Order) caused S5 as an outlier in cluster. The variations in the abundant and characteristics taxon at different stations were attributed to change in substratum and land-use patterns.

Keywords: Ganga, lesser Himalaya, altitudinal variation, dominants, Diptera, Trichoptera.

बेन्थिक मैक्रोइनवेटेब्रेट पारिस्थितिकी तंत्र की साइकिल चलाने और पोषक तत्वों के बहिर्वाह में महत्वपूर्ण भूमिका निभाता है। बैन्थोस कार्बनिक डिटर्जेंट को तलछटी भंडारण से विघटित पोषक तत्वों में बदल देता है जो प्राथमिक उत्पादकता को बढ़ाने के लिए जड़ वाले पौधों (मैक्रोफाइट्स) और शैवाल (फाइटोप्लांकटन) द्वारा पानी में मिलाया जा सकता है। इस अध्ययन में हेडवटर्स (2,200□) से मुंह (375□) तक कम हिमालयी तलहटी की धारा में बेन्थिक मैक्रोइनवेटेब्रेट के वितरण पैटर्न की जांच की गई। धारा के 43 किलोमीटर के रास्ते में पांच स्टेशन (□1 से □5) स्थापित किए गए थे। जनवरी से दिसंबर 2009 के बीच द्वि-मासिक अंतराल पर नमूने एकत्र किए गए थे। मैक्रोइंटरवेटेबेट समुदाय की कुल घनत्व कम ऊंचाई के साथ बढ़ी और स्टेशनों के बीच काफी भिन्नता थी। □1 पर डिप्टेरा (27%) और एस 5 (चिरोनोमिदे 24%), एस 2 पर त्रिचोप्टेरा (लिम्फिलिडीडे 16%) और एस 3 (हाइड्रोप्सिसिडे 9.9%), और एफिमेरोप्टेरा (हेप्टेनिजाइडे 9.2%) एस 4 प्रमुख टैक्सा थे। प्रधान घटक विश्लेषण से पता चला है कि एस 1 में सिमुल्डे, एस 2 में लिम्नेफिल्डे, हाइड्रोप्सिइकिडे, रिहाकोफिलिडे, टिपुलिडी, पेर्लोडिदे, ड्रायोपीडे और एस 3 में हिरोपेनेडी, चिरोनिडा और चिरोनिडिडा में विशेषत टैक्सा थे। क्लस्टर विश्लेषण में □3 और □2 के एक बड़े क्लस्टर को □3-□4, और □5 के एक समानता के साथ उप-समूह के रूप में दिखाया गया है। □3-□4 स्टेशनों के बीच समानता को समान भूमि-उपयोग पैटर्न (कृषि) और स्ट्रीम ऑर्डर (□□ ऑर्डर) के लिए जिम्मेदार ठहराया गया था, जबकि □1 और □2 आंशिक समान वन प्रकार (□1 में ओक वन, पाइन-ओक वन के कारण समान थे) □2 पर और स्ट्रीम ऑर्डर □5 में, हालांकि, वन प्रकार (मिश्रित वन) भूमि-उपयोग और धारा क्रम (□□□ ऑर्डर) में काफी बदलाव से क्लस्टर में बाहरी रूप से □5 का कारण बना। विभिन्न स्टेशनों पर प्रचुर और विशेषताओं वाले टैक्सों में बदलाव को सब्सट्रेटम और लैंड-यूज़ पैटर्न में बदलाव के लिए जिम्मेदार ठहराया गया था।

DOI: https://doi.org/10.11609/jott.4648.11.12.14511-14517 | **ZooBank:** urn:lsid:zoobank.org:pub:275D813E-ECB2-4D8A-9C6B-CCF91CF3B564

Editor: Tomáš Ditrich, University of South Bohemia in Ceske Budejovice, Czech Republic. **Date of publication:** 26 September 2019 (online & print)

Manuscript details: #4648 | Received 21 October 2018 | Final received 09 July 2019 | Finally accepted 15 August 2019

Citation: Semwal, V.P. & A.S. Mishra (2019). The distributional pattern of benthic macroinvertebrates in a spring-fed foothill tributary of the Ganga River, western Himalaya, India. *Journal of Threatened Taxa* 11(12): 14511–14517. https://doi.org/10.11609/jott.4648.11.12.14511-14517

Funding: None.

Competing interests: The authors declare no competing interests.

For **Author details** & **Author contribution** see end of this article.

Acknowledgements: The authors acknowledge the academic support granted by Prof. H.R. Singh, former Vice Chancellor, University of Allahabad, and former professor & head Prof. J.P. Bhatt, Department of Zoology & Biotechnology, H.N.B. Garhwal University, Srinagar, Uttarakhand, India.

INTRODUCTION

Benthic macroinvertebrates are important components of aquatic communities, where they can be found in sediment and accumulated leaves, and in association with macrophytes between rocks, interacting with a wide range of environmental conditions (Moretti & Callisto 2005; Würdig et al. 2007). Community species distributions vary with water characteristics (Pereira & De Luca 2003; Silveira et al. 2006). Benthic organisms are sensitive to the habitat characteristics and substratum (Buss et al. 2004; Mishra & Nautiyal 2016), water temperature (Camargo & Voelz 1998; Mishra & Nautiyal 2011), pH (Sandin & Johnson 2004), electrical conductivity (Buss et al. 2002), riparian vegetation (Silveira et al. 2006), sedimentation (Smith & Lamp 2008), and land-use (Collier et al. 2000; Kratzer et al. 2006; Nautiyal et al. 2017). Thus they can be used as indicators of the functional status of rivers (Jiang et al. 2011; Mishra & Nautiyal 2013a).

In the lesser Himalayan region, benthic macroinvertebrates have been investigated in glacier and spring fed rivers/streams (Rundle et al. 1993; Ormerod et al. 1994; Singh et al. 1994; Nautiyal 1997; Julka et al. 1999; Kannel et al. 2007; Nesemann et al. 2011; Mishra et al. 2013c; Nautiyal et al. 2013; Nautiyal & Mishra 2014). Few studies have examined the foothill[1] region of western Himalaya, where streams often have springs as their source. We studied a spring-fed stream in the foothill region (Fig. 1a) that flows into the Ganga at Shivpuri, 15km upstream of Rishikesh. The rapids between Shivpuri and Rishikesh are a popular water-rafting zone, and the stream is under severe anthropogenic stress owing to extensive use of its banks for night camping. In the middle and upper reaches stress comes from water extraction for agriculture. Our study of benthic macroinvertebrate fauna is intended to help detect environmental changes in the stream due to human activity in the vicinity.

MATERIALS AND METHODS

Study Area

Most foothill streams that discharge into the Ganga between Shivpuri and Rishikesh are steep and short, and many dry up in summer. Hiyunl Nadi is a perennial stream with a 43km course that was chosen as a representative of a foothill stream. There are a number of streams of moderate length but in the Doon Valley and not the hills except for Song that drains eastern Doons. The Kho is one such like Hiyunl but not of this kind. The Hiyunl flows down from an elevation of 2,400m north-west direction and meets the Ganga River at 375m. By virtue of this it exhibits a rapid transition from alpine to sub-tropical conditions. Bemunda Gad, Pilri Gad, and Chamol Gad are its prominent tributaries. The Hiyunl basin lies between 30.258–30.440 ^{0}N and 78.708–75.084 ^{0}E, covering an area of 167.50km^2 (Table 1, Fig. 1b) that is rich in limestone (Kumar et al. 2017). There is some confusion regarding its name: Henval in headwaters (toposheet 53 J/7; https://zenodo.org/record/1216911) and Hiyunl in its lower stretch (toposheet 53 J/8; https://zenodo.org/record/1216913). Some studies carried out on the Ganga River between Devprayag and Haridwar have conveniently called it Henval, and another local name is Huinl (NH 44-5, Series U502).

Sampling

Five stations were selected in the stream on the basis of variation in land-use type (forest and/or agriculture). Sampling was performed at bi-monthly intervals from January 2010 to December 2010 (Table 1). Samples were taken from area of 0.09m^2 with respect to habitat type (20 samples per station). The standard methods for sampling (Singh & Nautiyal 1990; Nautiyal & Mishra 2013b) and identification (Burks 1953; Pennak 1953; Edmunds et al. 1976) were adopted. Family level counts were performed to obtain abundance (as %). Significant difference in density between stations was determined using the Mann–Whitney (U) test, and among the stations using the Kruskal–Wallis (H) test (PAST software http://nhm2.uio.no/norlex/past). Principal Component Analysis (PCA) was used to determine the characteristic taxa at each station (CANOCO ver 4.5; ter Braak & Smilauer 2002).

RESULTS AND DISCUSSION

Physicochemical characteristics varied among stations. The air (4–42^{o}C) and water temperature (3–25^{o}C) increased from S1 to S5 as did dissolved oxygen (7.4–12.5 mgl^{-1}), pH (6.8–7.3), conductivity (80–350 µS^{-1}), and current velocity (0.1–0.48msec^{-1}).

The total mean density of macroinvertebrates increased from S1 to S5, with significant differences observed between successive stations (Table 1). Singh &

[1] The **foothills** of a mountain or a range of mountains are the lower hills or mountains around its base).

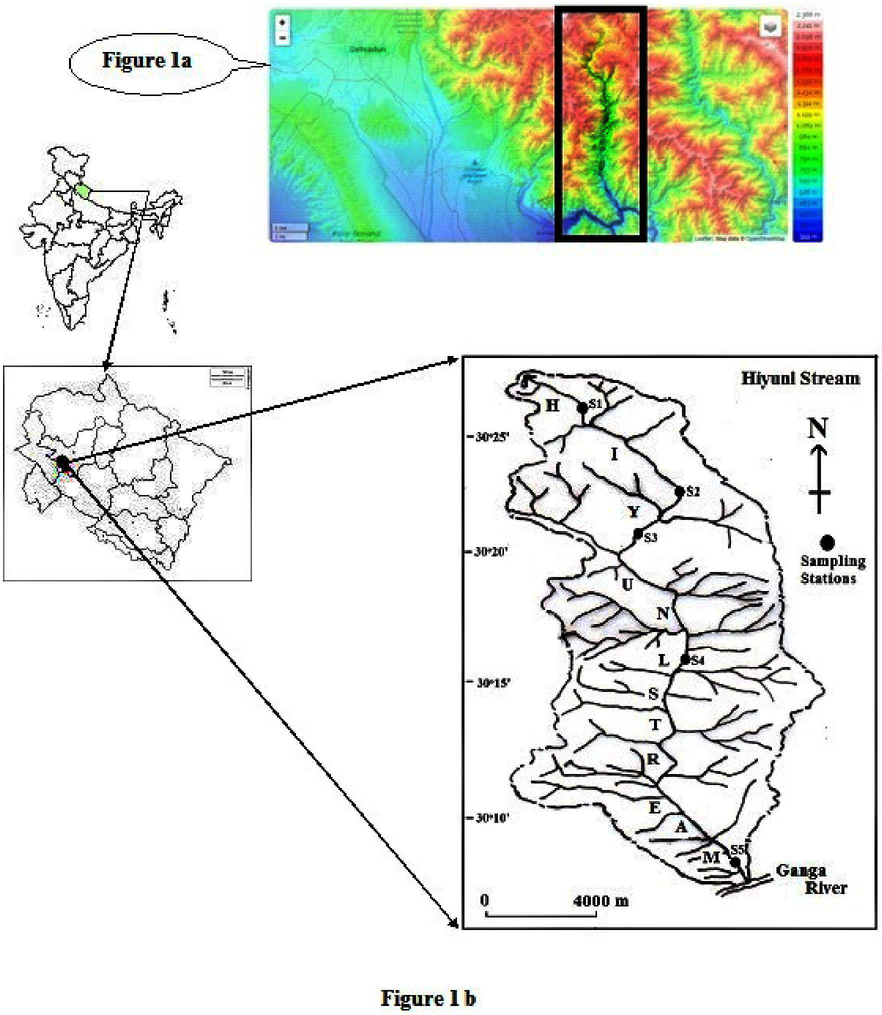

Figure 1a&b. a—Terrain map to show location of the Hiyunl Stream in foothills. Flat terrain at Rishikesh extending towards Haridwar and Dehradun while high rise lesser Himalayan mountains to right with elevation reaching over 2,400m even in foothills. b—Location of Uttrakhand in India and of Hiyunl Stream in Uttrakhand. The sampling stations (S1 to S5) are indicated in the map via black circle.

Nautiyal (1990) suggested that density increased in the mouth zone of the Himalayan river Bhagirathi. In central Indian rivers, the density also increased in the mouth zone of Paisuni River (Mishra & Nautiyal 2011) but decreased in Tons (Mishra & Nautiyal 2013b). The sudden decline of density at S4, however, was attributed to the dumping of waste materials into the river from road construction, which caused habitat loss and fragmentation resulting in a decline in the benthic macroinvertebrate community. The decline is also attributed to anthropogenic activity such as extraction of water for agriculture (Mishra & Nautiyal 2013b).

Taxonomic composition

Diptera (81%) was dominant at S1, Trichoptera at S2 (75%), S3 (80.7%) and S4 (54.5%). At S5 Ephemeroptera (69.3%) was dominant. The composition of other taxa varied at each station (Table 2). Diptera, Trichoptera and Ephemeroptera dominated the assemblages from S1 to S5. Odonates and annelids exhibited a similar profile, though their share was low in the community. Diptera declined abruptly from S1 to S2, and increased from S3 to S5. The communities differed structurally primarily on account of proximity to a snow line of approximately 150km aerial length, with high gradients in mountain streams. At the family level, Simulidae was the most abundant taxon at S1 followed by Limnephilidae, while Limnephilidae and Hydropsychidae were dominant at S2 and S3, respectively. Heptageniidae and Chironomidae were dominant at S4 and S5, respectively (Fig. 2). The share of Simulidae decreased from S1 to S5, while Chironomidae increased from S1 to S5. Trichopterans were dominant in the headwater section of the Garhwal Himalayan spring-fed streams (Nautiyal et al. 2015) and

Table 1. Geographical co-ordinates of the sampling station in different forest types in H Hiyunl Stream (nadi). Total density (mean, SE) at different stations in Henwal River. Density is calculated from 15 quadrants data at each station. Kruskal-Wallis test (H-test) and Mann-Whitney tests (U-test) determined significant differences in mean densities (indiv. m^{-2}) among and between the stations in the Hiyunl Stream.

Henwal Station	Khuret (S1)	Kurialgaon (S2)	Nagani (S3)	Jajal (S4)	Shivpuri (S5)
Forest	Oak Forest	Pine-Oak Forest	Agriculture	Agriculture	Mixed Forest
Stream Order	I	II	III	III	III
Distance from Source (Km)	6	11	21	29	43
Latitude (°N)	30.390	30.356	30.320	30.304	30.137
Longitude (°E)	78.325	78.336	78.325	78.344	78.391
Altitude (m)	2,200	1,571	1,400	1,200	375
Substrate type	C,P,PMB, St	LMB	C,PMB,St	LMB,C,P,G,St	C, P,G,St
Total Mean Density ±SE (Indiv.m^{-2})	542.36± 15.18	617.49± 15.31	649.62± 16.80	588.07 ±19.66	754.54± 39.88
Final p value (U-test)	S1-S2 0.003653	S2-S3 0.06448	S3-S4 0.02122	S4-S5 =0.0004915	S1-S5= 2.3E-05
Final p value (H-test)	S1-S5=2.312E-06				

C—Cobble | P—Pebble | PMB—Prismatic maturing boulder | LMB—Large maturing boulder | G—Gravel | St—Silt.

Table 2. Percentage composition of benthic macroinvertebrate community in Hiyunl Stream.

Station	E	T	D	P	C	O	N	L	M
S1	3.3	5.27	**81.43**	5.0	2.0	00	1.0	2.0	00
S2	11.05	**75.00**	10.52	3.43	00	00	00	00	00
S3	6.63	**80.79**	3.58	00	4.0	5.0	00	00	00
S4	18.79	**54.51**	20.69	00	3.5	1.5	1.1	00	00
S5	**69.29**	6.29	22.85	00	00	00	00	00	1.57

E—Ephemeroptera | T—Trichoptera | O—Odonata | L—Lepidoptera | D—Diptera | P—Plecoptera | C—Coleoptera | N—Neuroptera | M—Mollusca.

in headwater zone of Vindhyan spring-fed river Paisuni (Mishra & Nautiyal 2011). In the spring-fed Himalayan streams, Ephemeroptera was dominant taxon in the Khanda Gad (Kumar 1991) and the Gaula in the Kumaun region (Sunder 1997).

The benthic macroinvertebrate assemblages also varied at S1 (Simulidae-Limnephilidae), S2 (Limnephilidae-Hydropsychidae), S3 (Hydropsychidae-Baetidae), S4 (Heptageniidae-Hydropsychidae), and S5 (Chironomidae-Heptageniidae). This variation was attributed mainly to substratum, forest type and altitude. Simuliade was dominant in Oak forest at S1 while Limnephilidae was dominant in Pine-Oak forest at S2 (Table 1). Nautiyal et al. (2015) also observed similar pattern in the streams/rivers of Uttarakhand Himalaya. Corkum (1992) and Sivaramakrishnan (2005) also reported the impact of forest type on assemblage pattern. The dominance of Hydropsychidae, Heptageniidae, and Chironomidae at S3, S4, S5, respectively, indicated impact of agricultural land-use and substratum, also

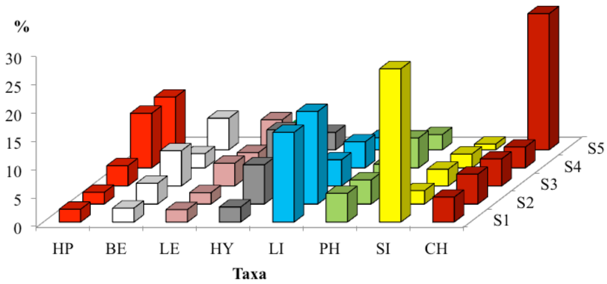

Figure 2. Taxonomic composition of the benthic macroinvertebrate fauna (>1%) at various stations in the Hiyunl Stream. CH—Chironomidae | HP—Heptageniidae | HY—Hydropsychidae | LP—Leptophlebiidae | LI—Limnephelidae | PH—Philopotamidae | SI—Simulidae.

evident in central Highlands rivers (Mishra & Nautiyal 2013b, 2016).

Functionally, the river continuum concept (Vannote et al. 1980) also supports the distribution pattern of invertebrate fauna, as predators (Simulidae)

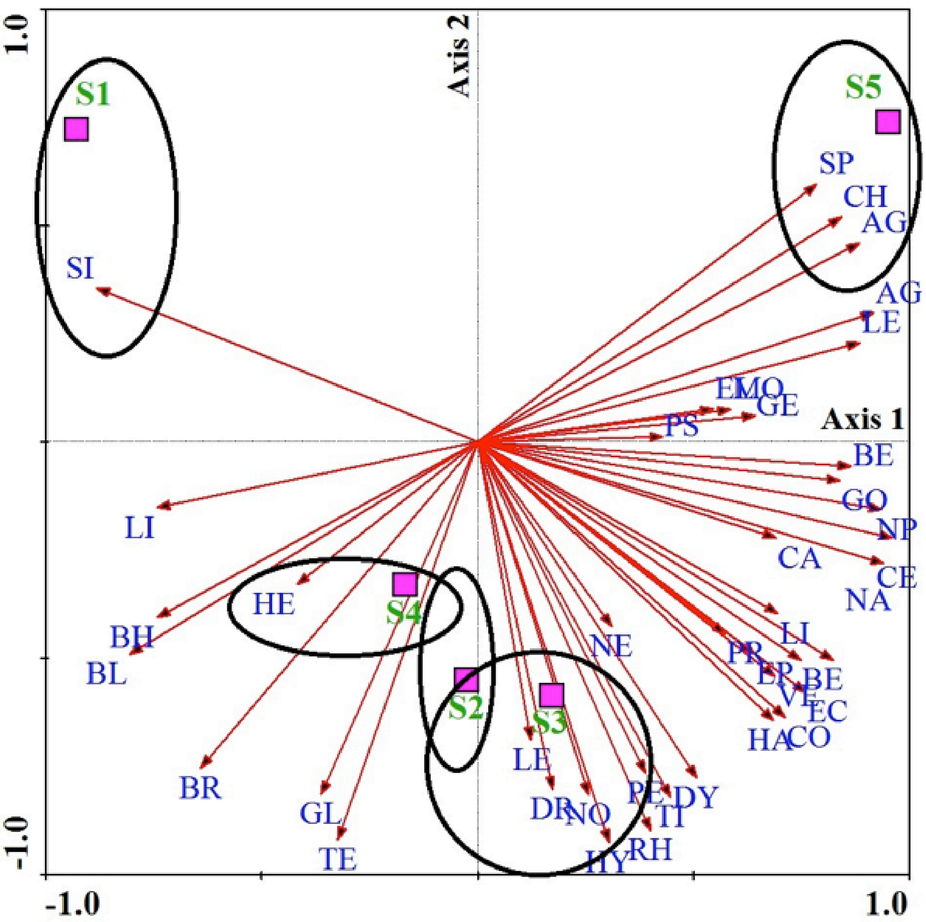

Figure 3. Principal component analysis (PCA): the ordination indicates the characteristic taxa (in circle) through graphical presentation between the taxon (arrows) and station (filled square) in the Hiyunl Stream. The taxa close to the station are characteristic of that station and encircled. HE—Heptageniidae | BA—Baetidae | EP—Ephemerellidae | LE—Leptophlebidae | CA—Caenidae | SP—Siphlonuridae | EC—Ecdyonuridae | HY—Hydroosychidae | LI—Limnephilidae | GL—Glossosomatidae | LP—Leptoceridae | PH—Philopotamidae | BR—Brachycentridae | PSY—Psychomyiidae | RH—Rhyacophilidae | SI—Simulidae | BL—Blepharoceridae | TE—Tendipedini | CH—Chironomidae | PY—Psychodidae | LT—Leptidae | TI—Tipulidae | PE—Perlodidae | PR—Perlidae | CHL—Chloroperlidae | NE—Nemouridae | DR—Dryopidae | HD—Hydrophilidae | EL—Elmidae | HA— Haliplidae | PS—Psephenidae | DY—Dytiscidae | SA—Sialidae | CO—Corixidae | NA—Naucoridae | GE—Gerridae | VE—Vellidae | NP—Nepidae | NO—Notonectidae | BE—Belostomatidae | AGN—Agrionidae | GO—Gomphdae | CE—Coenagridae | CHP—Chlorocyphidae | AG—Agridae | LD—Lipidoptera | MO—Mollusca.

were abundant at S1, followed by collectors at S2 (Limnephilidae) and S3 (Hydropsychidae), scrappers (Heptageniidae) at S4, and collectors (Chironomidae) at S5.

Cluster analysis revealed highest similarity between S3 and S4 as compared to other stations as both the stations were functionally similar (gathering collectors) because of common land-use pattern (agriculture) and stream order (Table 1). The distance between these two stations was c. 8km. These two stations were more similar to S2 and then S1. S5 was noticeably different from all of them (Fig. 3). The similarity among the stations in cluster analysis is also evident in the PCA (Fig. 4) as the circle of S2, S3 and S4 were close to each other and closer to S1 rather than S5.

Characteristic taxa: principal component analysis (PCA)

The eigen values for PCA axis 1 (λ_1=0.501) and 2 (λ_2=0.293) explained cumulative variance in taxonomic composition and taxon-environmental relationships in the stream and caused 5.01% and 29.3% variation in the taxon-site relationship, respectively. The characteristic benthic macroinvertebrate taxa differed at S1, S2, S3, S4 and S5, Simulidae was characteristic taxa at S1, while Limnephildae taxa at S2. Hydropsychiidae, Rhyacophilidae, Tipulidae, Perlodidae, Dryopidae, and Notonectidae were characteristic at S3. Heptageniidae was characteristics at S4, while Chironomidae, Siphlonuridae, and Agrionidae were characteristic taxa at S5 (Fig. 3). Functionally, filtering collector was dominant at S1, shredder at S2, gathering collectors-

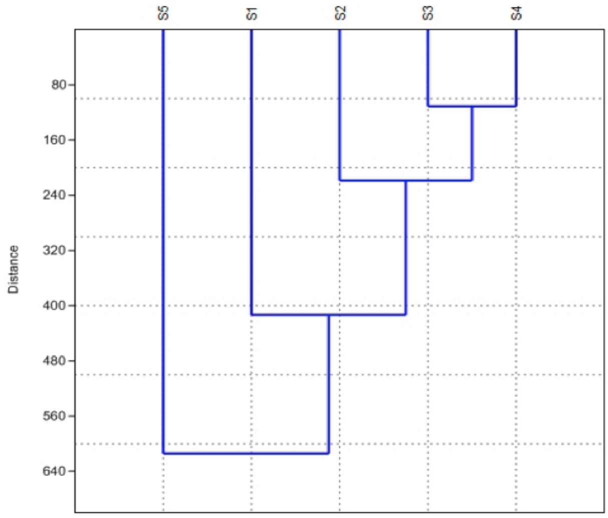

Figure 4. Cluster analysis indicated the similarity among the stations based on linkage distance among the stations.

predators at S3, scraper at S4, and gathering collectors-predators at S5.

The variation in the characteristic taxa at S1, S2, S3, S4, and S5 was attributed to difference in substrate heterogeneity (Table 1) and forest type (S1—oak forest, S2—oak-pine forest, S5—mixed forest). The land-use type (agriculture), however, was similar at S3 and S4. Functionally, the stream was heterotrophic as the gathering and filtering collectors prevailed, attributed to presence of fine particulate organic matter (FPOM) from agricultural land in the lower section of the stream as also observed in the central Indian rivers (Mishra & Nautiyal 2013a). Agriculture is both extensive and intensive in this lower stretch of the stream and anthropogenic influences hence become a prominent factor because of fertilizer and other inputs. The impact of agriculture and habitation was also observed on the distribution of benthic macroinvertebrate fauna in Himalayan rivers (Mishra et al. 2013; Nautiyal et al. 2015) and central Indian rivers (Mishra & Nautiyal 2013a). Vannote et al. (1980) suggested that the longitudinal or continuum models predict that invertebrate assemblages will change along the length of rivers as evident in the present study.

CONCLUSION

The present study indicated that the mean density of benthic macroinvertebrates increased along the stream (except S4), and differed significantly between and among the stations. The taxonomic composition and function of invertebrate fauna varied along the stream length indicated the impact of substrate heterogeneity and land-use type. At some stations, however, the functional composition was observed to be similar with other stations. Thus, the present study indicated the variations in the taxa along the stream.

REFERENCES

Burks, B.D. (1953). The Mayflies or Ephemeroptera of Iilinois. *Bulletin of the Illinois State Laboratory of Natural History* 26: 1–215.

Buss, D.F., D.F. Baptista, J.L. Nessman & M. Egler (2004). Substrate specificity environmental degradation and disturbance structuring macroinvertebrate assemblages in neotropical streams. *Hydrobiologia* 518(1): 179–188.

Buss, D.F., D.F. Baptista, M.P. Silveira, J.L. Nessimian & L.F.M. Dorville (2002). Influence of water chemistry and environmental degradation on macroinvertebrates assemblages in a river basin in south-east Brazil. *Hydrobiologia* 481(1–3): 125–136.

Camargo, J.A. & N.J. Voeiz (1998). Biotic and abiotic changes along the recovery gradient of two impounded rivers with different impoundment use. *Environmental Monitoring and Assessment* 50(2): 143–158.

Collier, K.J., B.J. Smith, J.M. Quinn, M.R. Scarsbrook, N.J. Halliday, G.F. Croker & S.M. Parkyn (2000). Biodiversity of stream invertebrate faunas in a Waikato hill-country catchment in relation to land use. *New Zealand Entomologist* 23: 9–22.

Corkum, L.D. (1992) Relationship between density of macroinvertebrate and detritus in the rivers. *Arch fur Hydrobiologia* 239: 149–166

Edmunds, G.F., S.L. Jensen & L. Berner (1976). *The may flies of north and central America*. University Minnesota Press, Mineapalis, 330pp.

Jiang, X., J. Xiong, Z. Xie & Y. Chen (2011). Longitudinal patterns of macroinvertebratefunctional feeding groups in a Chinese river system: A test for river continuum concept (RCC). *Quaternary International* 244: 289–295.

Julka, J.M., H.S. Vasistht & B. Bala (1999). Distributions of aquatic insects in a small streams in north west Himalayas, Indian. *Journal of Bombay Natural History Society* 96(1): 55–63.

Kratzer, E.B., J.K. Jackson, D.B. Arscott, A.K. Aufdenkampe, C.L. Dow, L.A. Kaplan, J.D. Newbold & B.W. Sweeney (2006). Macroinvertebrate distribution in relation to land use and water chemistry in New York City drinking-water-supply watersheds. *Journal of North American Benthological Society* 25(4): 954–976.

Kumar, N. (1991). Ecological studies on the macrozoobenthic communities of some Hill streams of the Alaknanda river system. D.Phil. Thesis H N B Garhwal University, Srinagar (Garhwal), 216pp.

Kumar A., A. Bhardwaj, P. Kumar and H. Padaliya (2017). Delineation of Micro-Watershed using Geo-Spatial Techniques. Suresh Gyan Vihar University. *International Journal of Environment, Science and Technology* 3(2): 14–34

Mishra, A.S. & P. Nautiyal (2011). Factors governing longitudinal variation in benthic macroinvertebrate fauna of a small Vindhyan River in central highlands ecoregion (central India). *Tropical Ecology* 52(1): 103–112.

Mishra, A.S. & P. Nautiyal (2013a). Functional composition of benthic macroinvertebrate fauna in the plateau rivers, Bundelkhand, central India. *Journal of Threatened Taxa* 5(13): 4752–4758. https://doi.org/10.11609/JoTT.o3226.4752-8.

Mishra, A.S. & P. Nautiyal (2013b). Longitudinal distribution of benthic macroinvertebrate assemblages in a central highlands river, the Tons (central India). *Proceedings of the National Academy of Sciences (Biological Sciences)* 83(1): 47–51. http://doi.org/10.1007/s40011-012-0083-4

Mishra, A.S. & P. Nautiyal (2016). Substratum as determining factor for the distribution of benthic macroinvertebrate fauna in a river ecosystem. *Proceedings of the National Academy of Sciences (Biological Sciences)* 86(3): 735–742. https://doi.org//10.1007%2Fs40011-015-0520-2

Mishra, A.S., **P. Nautiyal & V.P. Semwal (2013c)** Distributional patterns of benthic macroinvertebrate fauna in the glacier fed rivers of Indian Himalaya. *Our Nature* 11(1): 36–44.

Moretti, M.S. & M. Callisto (2005). Bio-monitoring of benthic macroinvertebrates in the middle Doce River watershed. *Acta Limnologica Brasiliensia* 17(3): 267–281.

Nautiyal, P. (1997). Migratory phenomenon of the endangered Himalayan Mahseer *Tor putitora* in relation to the Ecology of the river Ganga, Final Technical Report of Research Project No. 14/28/92-submitted to the Ministry of Environment Forests New Delhi under Man & Biosphere Program.

Nautiyal, P. & A.S. Mishra (2013) Variations in benthic macroinvertebrate fauna as indicator of land use in the Ken River, central India. Journal of Threatened Taxa 5(7): 4096–4105; https://doi.org/10.11609/JoTT.o3211.4096-105

Nautiyal, P. & A.S. Mishra (2014) Large scale distributional Patterns of benthic macroinvertebrate fauna in the Himalayan streams. pp. 181–187. In: Gupta, N. & D.K. Gupta (eds.) *Environment and Biodiversity*. Narendra Publishing House, Delhi.

Nautiyal, P., R. Nautiyal, V. P. Semwal, A S. Mishra, J. Verma, D.P. Uniyal, M. Uniyal & K.R. Singh (2013). Ecosystem health indicators in the Ganga Basin (Uttarakhand, India): Biodiversity, spatial patterns in structure and distribution of benthic diatoms, macro-invertebrates and ichthyofauna. *Aquatic Ecosystem Health & Management* 16(4): 362–373.

Nautiyal, P., A.S. Mishra & V.P. Semwal (2015). Spatial distribution of benthic macroinvertebrate fauna in mountain streams of Uttarakhand**,** India, pp. 31–51. In: Rawat, M., S. Dookia & C. Sivaperuman (eds.) *Aquatic Ecosystem: Biodiversity, Ecology and Conservation*, Springer. https://doi.org/10.1007/978-81-322-2178-4_4

Nautiyal P., A.S. Mishra, J. Verma & A. Agrawal (2017). River ecosystems of the central highland ecoregion: spatial distribution of benthic flora and fauna in the plateau rivers (tributaries of the Yamuna and Ganga) in central India. *Aquatic Ecosystem Health & Management* 20(1–2): 43–58. https://doi.org/10.1080/14634988.2017.1296324

Nesemann, H., G. Sharma & R.K. Sinha (2011). Benthic macro-invertebrate fauna and "marine elements" sensu annandale (1922) highlight the valuable Dolphin habitat of river Ganga in Bihar – India. *Taprobanica* 3(1): 18–30.

Ormerod, S.J., S.D. Rundle, S.M. Wilkinson, G.P. Daly, K.M. Dal & I. Juttner (1994). Altitudinal trends in the diatoms, bryophytes, macroinvertebrates and fish of a Nepalese river system. *Freshwater Biology* 32: 309–322.

Pennak, R.W. (1953). Fresh water Invertebrates of the United States, 2nd Edition. John Wiley & Sons, New York, 512–733pp.

Pereira, D. & S.J. De Luca (2003). Benthic macroinvertebrates and the quality of the hydric resources in Maratá Creek basin (Rio Grande do Sul, Brazil). *Acta Limnologica Brasiliensia* 15(2): 57–68.

Rundle, S.D., A. Jenkins & S.J. Ormerod (1993). Macroinvertebrate communities in streams in the Himalaya, Nepal. *Freshwater Biology* 30: 169–180

Sandin, L. & R.K. Johnson (2004). Local, landscape and regional factors structuring benthic macroinvertebrate assemblages in Swedish streams. *Landscape Eco*logy 19(5): 501–514.

Silveira, M.P., D.F. Buss, J.L. Nessimian & D.F. Baptista (2006). Spatial and temporal distribution of benthic macroinvertebrates in southeastern Brazilian river. *Brazilian Journal of Biology* 66(2B): 623–632.

Singh, H.R. & P. Nautiyal (1990). Altitudinal changes and the impact of municipal sewage on the community structure of macrobenthic insects in the torrential reaches of the river Ganges in the Garhwal Himalaya (India). *Acta Hydrobiologica* 32: 407–421.

Singh, H.R., P. Nautiyal, A.K. Dobriyal, R.C. Pokhriyal, M. Negi, V. Baduni, R. Nautiyal, N.K. Agrawal, P. Nautiyal & A. Gautam (1994). Water quality of river Ganga (Garhwal Himalaya). *Acta Hydrobiologica* 36(1): 3–15.

Smith, R.F. & W.O. Lamp (2008). Comparison of insect communities between adjacent headwater and main-stem streams in urban and rural watersheds. *Journal of North American Benthological Society* 27(1): 161–175.

Sivaramakrishnan, K.G., V.K. Sridhar & S. Marimuthu (1995) Spatial patterns of benthic macroinvertebrate distribution along river Kaveri and its tributaries (India). *International Journal of Ecology and Environmental Science* 21: 141–161.

Sunder, S. (1997). Biotic communities of Kumaon Himalaya river - The Gaula - 1. Macro-benthic invertebrates. *Proceedings of the National Academy of Sciences (Biological Sciences) 67*(*B*) *II*: 157–167.

ter Braak, C.J.F. & P. Smilauer (2002). *CANOCO Reference Manual and Canodraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5).* Microcomputer Power (Ithaca, NY, USA).

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell & C.E. Cushing (1980). The river continuum concept. *Canadian Journal of Fisheries & Aquatic Sciences* 37: 130–137.

Wurdig, N.L., C.S.S. Cenzano & D.M. Motta (2007). Macroinvertebrate communities structure in different environments of the Taim Hydrological System in the state of Rio Grande do Sul, Brazil. *Acta Limnologica Brasiliensia* 19(4): 57–68.

Internet Resources

https://zenodo.org/record/1216911#.XQdBErz7S01. Publication date: June 7, 1965. https://doi.org/10.5281/zenodo.1216911

https://zenodo.org/record/1216913#.XQdAWLz7S00. Publication date: June 6, 1967. https://doi.org/10.5281/zenodo.1216913

Author details: Dr. Vijay Prakash Semwal, Assistant Professor, Major contributions: Research on Benthic macroinvertebrate fauna in the Himalayan rivers/streams. Dr. Asheesh Shivam Mishra, Assistant Professor & Head, performing research on distribution and population ecology of diatom, benthic macroinvertebrate and fish in Central Highlands & Himalayan rivers/streams. Expertise on Environmental Flow studies on the river Ganga and its tributaries, Environmental Impact Assessment (HEP).

Author contribution: VPS data collection from the study area & identify the taxa. ASM worked on data analysis using various softwares and manuscript writing, graphs, and map preparation.

Journal of Threatened Taxa

www.threatenedtaxa.org

PLATINUM OPEN ACCESS

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

September 2019 | Vol. 11 | No. 12 | Pages: 14471–14630
Date of Publication: 26 September 2019 (Online & Print)
DOI: 10.11609/jott.2019.11.12.14471-14630

Article

Communications

Short Communications

Notes

Response & Reply

Partner

صندوق محمد بن زايد
للمحافظة على
الكائنات الحية
The Mohamed bin Zayed
SPECIES CONSERVATION FUND

Member

FJN

Publisher & Host

WILD
ZOOREACH
Threatened Taxa