COMMUNICATION

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THE DISTRIBUTIONAL PATTERN OF BENTHIC MACROINVERTEBRATES IN A SPRING-FED FOOTHILL TRIBUTARY OF THE GANGA RIVER, WESTERN HIMALAYA, INDIA

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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 9.3%), and Ephemeroptera (Heptageniidae 9.2%) at S4. Principal component analysis revealed that the characteristic taxa were Simulidae at S1, Hydropsychidae at S3, and Chironomidae 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) 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.
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 (Morett & 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 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°N and 78.708–75.084°E, covering an area of 167.50km² (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 US02).

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 0.09m² 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°C) and water temperature (3–25°C) increased from S1 to S5 as did dissolved oxygen (7.4–12.5 mg/l), 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 &
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. Odonata 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
Macroinvertebrates in a foothill tributary of Ganga River
Semwal & Mishra

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.

<table>
<thead>
<tr>
<th>Henwal Station</th>
<th>Khuret (S1)</th>
<th>Kurialgaon (S2)</th>
<th>Nagani (S3)</th>
<th>Jajal (S4)</th>
<th>Shivpuri (S5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>Oak Forest</td>
<td>Pine-Oak Forest</td>
<td>Agriculture</td>
<td>Agriculture</td>
<td>Mixed Forest</td>
</tr>
<tr>
<td>Stream Order</td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>III</td>
<td>III</td>
</tr>
<tr>
<td>Distance from Source (Km)</td>
<td>6</td>
<td>11</td>
<td>21</td>
<td>29</td>
<td>43</td>
</tr>
<tr>
<td>Latitude (°N)</td>
<td>30.390</td>
<td>30.356</td>
<td>30.320</td>
<td>30.304</td>
<td>30.137</td>
</tr>
<tr>
<td>Longitude (°E)</td>
<td>78.325</td>
<td>78.336</td>
<td>78.325</td>
<td>78.344</td>
<td>78.391</td>
</tr>
<tr>
<td>Altitude (m)</td>
<td>2,200</td>
<td>1,571</td>
<td>1,400</td>
<td>1,200</td>
<td>375</td>
</tr>
<tr>
<td>Substrate type</td>
<td>C,P,PMB, St</td>
<td>LMB</td>
<td>C,PMB,St</td>
<td>LMB,C,P,G,St</td>
<td>C, P,G,St</td>
</tr>
<tr>
<td>Total Mean Density ±SE (Indiv. m⁻²)</td>
<td>542.36± 15.18</td>
<td>617.49± 15.31</td>
<td>649.62± 16.80</td>
<td>588.07± 119.66</td>
<td>754.54± 39.88</td>
</tr>
<tr>
<td>Final p value (U-test)</td>
<td>0.0365</td>
<td>0.06448</td>
<td>0.02122</td>
<td>0.0004915</td>
<td>2.36-05</td>
</tr>
<tr>
<td>Final p value (H-test)</td>
<td>S1-S5=2.312E-06</td>
<td>S1-S2=0.003653</td>
<td>S2-S3=0.06448</td>
<td>S3-S4=0.02122</td>
<td>S4-S5=0.0004915</td>
</tr>
<tr>
<td>C—Cobble</td>
<td>P—Pebble</td>
<td>PMB—Prismatic maturing boulder</td>
<td>LMB—Large maturing boulder</td>
<td>G—Gravel</td>
<td>St—Silt.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Station</th>
<th>E</th>
<th>T</th>
<th>D</th>
<th>P</th>
<th>C</th>
<th>O</th>
<th>N</th>
<th>L</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>3.3</td>
<td>5.27</td>
<td>5.13</td>
<td>5.0</td>
<td>2.0</td>
<td>00</td>
<td>1.0</td>
<td>2.0</td>
<td>00</td>
</tr>
<tr>
<td>S2</td>
<td>11.05</td>
<td>75.00</td>
<td>10.52</td>
<td>3.43</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>S3</td>
<td>6.63</td>
<td>80.79</td>
<td>3.58</td>
<td>00</td>
<td>4.0</td>
<td>5.0</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>S4</td>
<td>18.79</td>
<td>54.51</td>
<td>20.69</td>
<td>00</td>
<td>3.5</td>
<td>1.5</td>
<td>1.1</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>S5</td>
<td>69.29</td>
<td>6.29</td>
<td>22.85</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>0.15</td>
<td>00</td>
</tr>
</tbody>
</table>


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. Simulidae 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 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)
were abundant at S1, followed by collectors at S2 (Limnephilidae) and S3 (Hydropsychidae), scrapers (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 ($\lambda_1=0.501$) and 2 ($\lambda_2=0.293$) explained cumulative variance in taxonomic composition and taxon-environmental relationships in the stream and caused 50.1% 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 Limnephilidae 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...
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.

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


Internet Resources

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.
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