**Relationship between macrobenthos and abiotic characteristics of river Alaknanda in a stretch from Chamoli to Devprayag in Garhwal Himalayan region of Uttarakhand, India**

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**Abstract**
Macrobenthos is the best water quality indicator for ecosystem health assessment. The present study aimed to examine the interrelationship between macrobenthos and different water quality parameters of the river Alaknanda at Garhwal Himalaya. Four demarcated sampling zones viz. zone-A (Chamoli to Nandprayag), zone-B (Karanprayag to Rudraprayag), zone-C (Rudraprayag to Srinagar) and zone-D (Srinagar to Devprayag) were taken from its approximately 170 km long stretch during 2016-2018. River water characteristics were analyzed for the important parameters viz. substratum, water temperature (WT), water velocity, pH, electrical conductivity (EC), total dissolved solids (TDS), calcium (Ca), and magnesium (Mg) using standard methods. The results indicated that the river water velocity was the highest 1.02 m/s at zone-C, TDS of 114.19 mg/l was maximum at zone-A, and Ca and Mg were recorded highest 23.17 mg/l and 5.44 mg/l at zone-A and zone-B, respectively. All abiotic parameters (pH, EC, TDS, DO, Ca and Mg) were recorded to be below BIS/WHO limits. A total of 27 macrobenthos taxa belonging to the five orders such as Coleoptera (6 ind./m²), Diptera (5 ind./m²), Ephemeroptera (8 ind./m²), Hemiptera (4 ind./m²), and Odonata (4 ind./m²) were recorded. Macrobenthos represented an important relationship between the water current and water temperature. The lowest number was reported at zone-C due to the river's high water velocity (1.02 m/s). The changes like biota loss, presence of some pollution indicator species (Cloeon sp., Bateis sp., Ephememer sa sp.) at zone-C, in sediment structure of habitat were due to the anthropogenic activities on the riverbank of different zones. The study will help in the conservation of macrobenthos diversity of the river Alaknanda.

**Keywords:** Abiotic characteristics, Alaknanda river, Anthropogenic factors, Biotic characteristics, Macrobenthos

**INTRODUCTION**
Macroinvertebrates are bottom dwellers, act as the best water quality indicator for a freshwater ecosystem. The macro-benthos fauna uses as the best bioassessment measure (Kumar et al., 2017). Benthic aquatic macroinvertebrates are sensitive indicators of environmental changes in streams because they express long-term water and habitat quality changes rather than instantaneous conditions (Johnson et al., 2017). Macrobenthos play an important role in food web. These are the favourite food for fish and waterfowls. They transfer energy from trophic level one to trophic level two in the form of food (Sharma and Rawat, 2009). Macrobenthos are small aquatic fauna which is quite difficult to identify. These aquatic organisms are smaller in size, found in all over the world’s aquatic ecosystem. Despite the fewer studies on macrobenthos, some species are lost due to habitat degradation, a few remain undiscovered (Singh, 1998). Aquatic biodiversity plays
an important role in an aquatic ecosystem. The river water quality changes the species confirmation, abundance, and productivity of biotic components in a water ecosystem (Mishra et al., 2009). The variety of aquatic habitats, such as leaf debris, rock surfaces, backwaters, plant surfaces, sediments, sands, logs, pebbles, and gravel, are present in the Garhwal region to aquatic biota. Benthic invertebrates observations are the best choice for monitoring any aquatic body (Hellawell, 1977). Aquatic biota copiously has been studied in Northern River and streams by various researchers (e.g., Malik et al., 2020; Rana et al., 2017; Singh et al., 2010; Kumar et al., 1998; Balodi and Koshal, 2015). Anthropogenic (a direct inlet of waste into the river, dam constructions, waste disposal etc.) and natural factors (flash floods, droughts etc.) are responsible for habitat degradation for aquatic fauna. A few researchers worked on benthic communities viz. on macroinvertebrates conservation of two Afrotropical streams (Arimoro et al., 2020), macrobenthos communities of Ghezel Ozan river in Iran (Aazami et al., 2019), on biomonitoring index of pollution assessment by using macroinvertebrates in Tropical African regions (Elias et al., 2014), on Osumi, Devolli, Shkumbini rivers in Albania (Duka et al., 2017) and on the biotic index of macroinvertebrates of Lepenci river in Kosovo (Pajtim et al., 2019). Some studies accomplished by Indian scientists are on macroinvertebrates and water quality assessment of Mahanadi river (Ganguly et al., 2018), monitoring of benthic macroinvertebrates of Dodi Tal, Uttarakhand (Singh and Sharma, 2020) and longitudinal and temporal study of snowmelt stream of Jhelum river of Kashmir (Sabha et al., 2020), Kamboj and Kamboj, (2020) studied river mining affected areas of river Ganga at Haridwar. The aim of the present study was to evaluate the relationship status between physicochemical water quality characteristics and macrobenthos (macroinvertebrates) of river Alaknanda in a stretch from Chamoli to Devprayag in Garhwal Himalayan region of Uttarakhand.

MATERIALS AND METHODS

Study area
Alaknanda river is originating in the state of Uttarakhand, India, from the confluence of Satopanth and Bhagirathi kharak glaciers at an elevation of 3880 m. It is one of the mainstream of the Ganges. The stretch was divided into four sampling zones. Study sites details are given in Table 1 and the complete stretch is represented in Fig. 1.

Methodology
The sampling was carried out on a monthly basis from September 2016- August 2018. Water samples were collected in sterilized polyethylene bottles in the early morning and afternoon hours (6:00 am to 02:00 pm). The physicochemical parameters like water velocity (m/s), sediment structure (%), water temperature (°C), pH, dissolved oxygen (DO) (mg/L) were performed on-site and the parameters like total dissolved solids (TDS) (mg/L), calcium (Ca) (mg/L) and magnesium (Mg) (mg/L)
are shown in Table 3.

In the present study, macroinvertebrates were found belonging to 5 different Orders - Coleoptera, Diptera, Ephemeroptera, Hemiptera and Odonata at all zones during September 2016-Aug 2018. The observed values of physicochemical parameters analyzed at all sampling zones are given in Table 2. The total number of identified macroinvertebrates species (33 ind/m²) are shown in Table 3.

Table 1. Geological characteristics of sampling sites of river Alaknanda

| Sampling Zones | Sites    | Geo-Coordinates            | Stretch (km) |
|----------------|----------|----------------------------|--------------|
| Zone-A         | Chamoli  | 30°17’37.48”N,79°33’37.24”E| 23           |
|                | Nandprayag | 30°19’54”N,79°18’55”E     |              |
| Zone-B         | Karnprayag | 30°15’30.85”N,79°13’05.98”E| 53           |
|                | Rudraprayag | 30°17’15.05”N,78°35’84.2”E |              |
| Zone-C         | Dharidevi | 30°15’26.1”N,78°52’41”E   | 32           |
|                | Srinagar  | 30°17’04.03”N,79°58’52.42”E|              |
| Zone-D         | Chauras  | 30°13’43.2”N,78°47’16”E   | 47           |
|                | Devprayag | 30°08’21.5”N,78°35’49.2”E |              |

Substratum features of river

The substratum structure of a river is the principal component to provide suitable habitat for macrobenthic communities. The substrate boulders were recorded highest 7±8 (%) at zone-A and the lowest value 4±3 (%) was reported at zone-B. Cobbles were measured maximum 28±4 (%) at zone-A and minimum 7±3 (%) value was noted at zone-D. Pebbles were recorded highest 35±5 (%) at zone-A and the lowest value 8±2 (%) was recorded at zone-C. Gravels were measured maximum 27±6 (%) at zone-B, minimum value 6±1 (%) was recorded in winter at zone-D. In sampling locations, sand was measured 25±5 (%) at zone-C.

Physicochemical characteristics of river water

Water temperature was recorded in the range of 14.94±3.63 (°C) to 16.4±4.01 (°C), lowest to highest at zone-A to zone-C, respectively. River water velocity was maximum 1.02±0.21 (m/s) at zone-C and the minimum water velocity 0.92±0.78 (m/s) was found at zone-D. The pH was recorded maximum 7.98±0.22 at zone-A, indicating the alkaline nature of river water suitable for biotic life. Electric conductivity ranged from 134.91±37.82 (mS/cm) to 178.43±32.52 (mS/cm) at zone-C to zone-A, total dissolved solids ranged from 70.94±14.98 (mgl⁻¹) at Zone A to 114.19±20.81 (mgl⁻¹) at Zone C. Dissolved oxygen varied from 9.30±0.55 (mgl⁻¹) to 9.60±0.55 (mgl⁻¹) at zone-B. Calcium concentration was reported in the range of 20.07±2.89 (mgl⁻¹) at zone-C to 23.17±2.82 (mgl⁻¹) at zone-A. Magnesium ranged from 4.11±1.58 (mgl⁻¹) at zone-C to 5.44±1.78 (mgl⁻¹) at zone-B (Table 2).

Macroinvertebrate diversity of river Alaknanda

In river Alaknanda, five different orders like Coleoptera (6 ind./m²), Diptera (5 ind./m³), Ephemeroptera (8 ind./m³), Hemiptera (4 ind./m³) and Odonata (4 ind./m³) were found at all sites during the study period. The

RESULTS AND DISCUSSION

In the present study, macroinvertebrates were found belonging to 5 different Orders - Coleoptera, Diptera, Ephemeroptera, Hemiptera and Odonata at all zones during September 2016-Aug 2018. The observed values of physicochemical parameters analyzed at all sampling zones are given in Table 2. The total number of identified macroinvertebrates species (33 ind/m²) are shown in Table 3.
Mean values are of 24 observations.

Mean values are of 24 observations.

Table 2. Physicochemical characteristics of the sampling zones of river Alaknanda during 2016-2018

| S. No. | Parameters | BIS/WHO criteria limit | Sampling Zones |
|--------|------------|-------------------------|----------------|
|        |            | Zone-A | Zone-B | Zone-C | Zone-D |
| 1.     | Boulder (%) - | 27±8  | 4±3   | 5±3   | 11±4  |
| 2.     | Gravel (%)  - | 28±4  | 18±1  | 15±4  | 7±3   |
| 3.     | Pebbles (%) - | 35±5  | 17±7  | 8±2   | 11±3  |
| 4.     | WT (°C)     - | 15±4  | 27±6  | 18±3  | 6±1   |
| 5.     | Sand (%)    - | 8±2   | 10±3  | 25±5  | 6±2   |
| 6.     | pH          6.5-8.5 | 7.98±0.22 | 7.98±0.14 | 7.92±0.15 | 7.97±0.17 |
| 7.     | EC (mS/cm)  <1000 μS/cm | 7.98±0.17 | 9.60±1.10 | 1.02±0.21 | 0.92±0.78 |
| 8.     | TDS (mg/L)  <500 mg/L | 114.19±20.81 | 22.74±1.99 | 70.94±14.98 | 100.98±19.94 |
| 9.     | Ca (mg/L)   ≤5 mg/L | 9.60±0.55 | 9.60±0.55 | 9.30±0.55 | 9.32±0.51 |
| 10.    | Mg (mg/L)   ≤30 mg/L | 23.17±2.82 | 22.74±2.35 | 20.07±2.89 | 22.29±1.99 |

WT water temperature, EC electrical conductivity, TDS total dissolved solids, D.O. dissolved oxygen, Ca calcium, Mg magnesium.

Mean values are of 24 observations.

**Relationship between macroinvertebrates and environmental variables**

Water quality and substrate structure are very important for the benthic fauna community to sustain life in a water body. According to Allan and Castillo (2007), the river water level and flow are responsible for transferring nutrients in an ecosystem process. Benthic macroinvertebrates are disturbed by various anthropogenic activities. A few researchers have worked on the relationship status between abiotic and macroinvertebrates of a headwater stream in urban and rural watersheds of Maryland (Smith and Lamp, 2008); (Koshal et al., 2017); (Burger et al., 2019); (Labuce et al., 2020) and (Ishaq and Khan, 2013). Silveira et al. (2006) noted riffles as the favourable substrate to macrobenthos in Macae Brazilian river. Belagali (2007) reported Coleoptera and Ephemeroptera species as pollution indicators in Mysore city lakes. A total number of 30 macrobenthos species have been reported by Jindal et al. (2020) in the Binwa Western Himalaya hill stream. Padmanabha. In present study, a total number of 27 macrobenthos communities belonging to 5 orders were recorded in the study zone of Alaknanda river. The two orders- Coleoptera and Ephemeroptera showed dominance in the river. Some previous studies showed the decline of water quality due to anthropogenic activities such as the discharge of sewage water (Aswal et al., 2016) and other activities such as tourism (Semwal and Mishra, 2019). However, in selected zones of the present study, the lowest number of macrobenthos was noted at zone-C of the river. It may be due to the more water temperature (17.34±4.16 °C) and the maximum sand percentage (25±5%) that interfered with the number of the benthic community. At this zone of the river, an increasing rate of water temperature was also observed due to the electricity generation of the Srinagar hydro-power dam that enhanced the water flow temperature in river water. The vast amount of water and its flow enhanced sedimentation as a major sandy habitat at this place. Though all physicochemical parameters of river water were under desirable limits of BIS/WHO, the species of Ephemeroptera were found in the dominant
number at zone-C with some pollution indicator species (Cloeon sp., Emphemera sp. and Bateis sp.). The slight river water pollution was due to direct inlet of waste and human interference such as clothes washing, bathing, and construction activities on river bank stretches.

### Biodiversity indices status of river Alaknanda

Variation in different biodiversity indices of macroinvertebrates in different regions based on the availability of essential resources for the biota in their habitat is given in Table 4. The values of the Dominance index were found to be highest 0.0382 at zone-D and lowest 0.0370 at zone-C. The values of Shannon index were observed as highest 3.3890 at zone-C and lowest 3.3700 recorded at zone-D. Kumari and Maiti (2020) also found Shannon’s value in the range of 2.46-3.15, and Simpson’s value of 0.86-0.95 was for macroinvertebrates in Jamshedpur city microalgal freshwater bodies. Matin et al. (2018) and Hossain et al. (2013) observed Shannon index values ranging from a minimum of 2.24 to a maximum of 2.97. In the present study, the evenness value was observed highest to be 0.8979 at zone-C, and the lowest value of 0.8809 was found at zone-D. The values of Brillouin index were lowest as 3.2490 at zone-D, and the highest 3.3000 was at zone-

| S. No. | Species (Ind/m²) | Zone A Avg±S.D. | Zone B Avg±S.D. | Zone C Avg±S.D. | Zone D Avg±S.D. |
|--------|------------------|-----------------|-----------------|-----------------|-----------------|
| 1.     | Agabinus sp.     | 29±19           | 19±15.29        | 17±14           | 24±21           |
| 2.     | Amphizoa sp.     | 33±25           | 25±23           | 19±18           | 27±29           |
| 3.     | Hydaticus sp.    | 29±17           | 28±27           | 17±16           | 23±28           |
| 4.     | Dineutus sp.     | 38±30           | 34±33           | 13±10           | 28±26           |
| 5.     | Limnus sp.       | 18±14           | 23±20           | 9±7             | 12±10           |
| 6.     | Gyninidae sp.    | 14±10           | 10±5            | 4±2             | 6±3             |

### Diptera

| S. No. | Species (Ind/m²) | Zone A Avg±S.D. | Zone B Avg±S.D. | Zone C Avg±S.D. | Zone D Avg±S.D. |
|--------|------------------|-----------------|-----------------|-----------------|-----------------|
| 1.     | Antoacha sp.     | 43±25           | 47±35           | 23±21           | 28±22           |
| 2.     | Chironomus sp.   | 27±16           | 23±11           | 11±7            | 16±14           |
| 3.     | Culex sp.        | 18±14           | 14±13           | 8±6             | 10±7            |
| 4.     | Simulium sp.     | 32±28           | 36±30           | 18±17           | 24±20           |
| 5.     | Phychoda sp.     | 24±19           | 29±27           | 14±12           | 21±16           |

### Ephemeroptera

| S. No. | Species (Ind/m²) | Zone A Avg±S.D. | Zone B Avg±S.D. | Zone C Avg±S.D. | Zone D Avg±S.D. |
|--------|------------------|-----------------|-----------------|-----------------|-----------------|
| 1.     | Baetis sp.       | 66±73           | 73±47           | 44±41           | 44±40           |
| 2.     | Cloeon sp.       | 50±45           | 55±62           | 23±19           | 27±32           |
| 3.     | Emphemera sp.    | 51±62           | 51±48           | 28±30           | 34±29           |
| 4.     | Ephemerella sp.  | 42±50           | 51±50           | 23±21           | 29±27           |
| 5.     | Siphlonurus sp.  | 30±27           | 35±29           | 17±27           | 23±20           |
| 6.     | Hydroptila sp.   | 39±41           | 24±18           | 17±14           | 30±28           |
| 7.     | Heptagenia sp.   | 31±29           | 22±20           | 9±7             | 13±8            |
| 8.     | Leptophlebia sp. | 14±8            | 19±15           | 21±19           | 7±4             |

### Hemiptera

| S. No. | Species (Ind/m²) | Zone A Avg±S.D. | Zone B Avg±S.D. | Zone C Avg±S.D. | Zone D Avg±S.D. |
|--------|------------------|-----------------|-----------------|-----------------|-----------------|
| 1.     | Gerris sp.       | 33±25           | 37±33           | 25±22           | 21±19           |
| 2.     | Corexia sp.      | 12±7            | 15±13           | 7±6             | 9±4             |
| 3.     | Hesperocorixa sp.| 21±15           | 19±11           | 9±5             | 13±9            |
| 4.     | Aphelocheridae sp.| 12±5         | 18±9            | 19±22           | 8±5             |

### Odonata

| S. No. | Species (Ind/m²) | Zone A Avg±S.D. | Zone B Avg±S.D. | Zone C Avg±S.D. | Zone D Avg±S.D. |
|--------|------------------|-----------------|-----------------|-----------------|-----------------|
| 1.     | Agrion sp.       | 16±10           | 22±12           | 11±9            | 9±3             |
| 2.     | Hegenius sp.     | 30±22           | 26±25           | 18±17           | 17±13           |
| 3.     | Ischnura sp.     | 19±27           | 23±22           | 9±5             | 12±15           |
| 4.     | Gomphidae sp.    | 14±9            | 19±17           | 25±22           | 7±5             |

Table 3. Mean values of macrobenthos in different zones of river Alaknanda during 2016-2018
The largest value of 1.3880 Menhinick index was noted at zone-C, and the smallest 1.0940 was observed at zone-B. Margalef index was highest 5.0500 at zone-C, and the smallest values were recorded as 4.6970 at zone-B. Fisher alpha index values were 6.7490 at zone-A, 6.7110 at zone-B, 7.6460 at zone-C and 7.5190 at zone-D. Higher 0.0802 Berger-Parker index was reported at zone-B, and the lowest 0.0736 was found at zone-D during two years of study. The biodiversity indices values showed good to medium diversity at all sampling sites. The anthropogenic activities like the construction of steps leading down to the river at zone-A, B and D, electricity generation by hydropower plant at zone-C; and road widening and tourism activities at all the zones interrupted the substrate structure of the aquatic habitat resulting in the variation of biodiversity with a biota loss at zone-C of the river Alaknanda.

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### Conflict of interest

The authors declare that they have no conflict of interest.

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