# STUDY ON DISTRIBUTION PATTERN OF BENTHIC DIVERSITY IN RELATION TO WATER QUALITY OF RIVER GANGA AND ITS TRIBUTARIES

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**ABSTRACT**

Macro-benthic invertebrates are important indicator of water quality as well as ecological disturbance. The community that lived in the bottom of water i.e. in streams, rivers, ponds etc are known as "benthos". During the present investigative studies of the River Ganga and its tributaries, slight variation in the distribution of macro-benthic invertebrate fauna was observed in the upstream as well as downstream sections. Analytical study of River Ganga and its tributaries revealed the presence of 9 taxa predominantly belonging to following groups, Ephemeroptera (4 species), Hemiptera (3 species), Diptera (5 species), Coleoptera (4 species), Plecoptera (3 species), Trichoptera (3 species), Odonatan (2 species), Mollusca (1 species), Annelida (1species). Amongst these 9 groups, Ephemeroptera was dominated both in qualitative and quantitative dominance over the other eight groups. Ephemeropterans, Plecopterans, and Trichopterans which are commonly known as pollution sensitive species were found to be numerically abundant in the upstream sections and downstream sections. On the other hand pollution tolerant species of order Coleoptera, Odonata, Diptera, and class Oligochaeta were also present but in lesser number in the downstream sections. Numerical abundance of *Emphemera sp.* and *Emhemerella sp.* throughout the experimental period reflected that there are lesser anthropogenic stresses on the River and its tributaries. The present also study revealed that the combined impact of water quality parameters such as water temperature, TDS, the velocity of water, turbidity and DO influenced the diversity of macro-benthos population dwelling Ganga river and its tributaries.

**Keywords:** Macro-benthos, Water quality, Shannon diversity, Ganga River.

## INTRODUCTION

Water is the first and basic ingredient of life and is present in three different forms like solid, gas and liquid on the earth also a basic need of every animals and human beings. Therefore, fresh water is very precious and natural gift for all living organisms because it can be used in many purposes in our daily life such as in agriculture, industrial purposes, and for drinking etc. The Bhagirathi River originated from the Gaumukh (Gangotri glacier) in western Himalaya. Alakananda River is sister stream originated from the Saptonath-Kharak group of glaciers 8km far from Badrinath. Both streams meet together at Devprayag then it is called the river Ganga (the holy river of India). Ganga River has many tributaries like Dhauli Ganga, Birahi Ganga, Mandakini, Pindar, Mandakini, Song, Henwal and Nayar etc. Lot of people worship Ganga river as it's a symbol of hindu tradition (Kumar, 2001). So, the water of river Ganga becomes a vital resource to all Indian. Water quality parameters provided correct information about the river and the information about the concentration of different solutes at a given time and place in the river. In the aquatic ecosystem benthic invertebrates are important and indicator of both the water quality and ecological disturbance. The term "benthos" is derived from a Greek word which means depth in the water body or bottom of water. It was introduce by the eminent/reputed German naturalist and artist Ernst Haeckel (1834-1919), who also proposed the term ecology. Benthos play an important role in the water body, feed upon phytoplankton as well as zooplankton & then act as a food source for larger organisms such as fish, and finally, it links Lower tropic level (primary production) with higher tropic levels. Fresh water macro-benthos is animals without backbone and is larger than ½ millimeter. These organisms live on rock, logs, sediment, debris and aquatic plants. They can be present in hot springs, small ponds & large lakes and some are even found in the soil beneath puddles. Macro-benthos plays an important role in the food chain, especially for fish. But, few invertebrates feed on algae and some bacteria that are the lower end of the food chain; some species of benthic fauna feed upon the leaves and other organic matter that enter the water and finally help in maintaining the natural flow of energy and nutrients. Benthic groups are especially suited for long term comparative analysis because lot of the component species are sessile or have low motility, these are relatively long live and integrated the effect of environmental change for a long time (e.g. dredge material, organic enrichment, aggregate extraction and climate change;). In lentil fresh water, the macro invertebrates act as a key ecosystem processes like as food chain dynamics, nutrient cycling, productivity and decomposition (Covich *et al*., 1999). There distribution and sufficiency is directly related to different environmental factors such as food utility and quantity , sediment type ,substrate and water quality (Wilhm, and Mcclintock , 1978; Bechara, 1996; Jonasson, 1996; Realm *et al*., 2000). They also show enough endemic variation with lake depth between across habitats and across rivers and lakes, (Petridis and Sinis, 1993; 1995, Digiovanni *et al*., 1996; Pamplin and Rocha, 2007). Substratum particle size and complexity in the water body may increase species richness. Trichoptera larvae show species-specific preference to different substratum sizes (Higler, 1975), In a California stream, (Hart, 1978) tested the affect of the rocks on lotic species diversity and abundance with different size and shaped substratum. He got significantly higher richness of species on irregular shape v/s smooth cubes or spheres. The effects substratum size, current velocity, silt deposition and trapped detritus on fauna distributions was evaluated by (Rabeni and Minshall, 1977). Macro invertebrates are very sensitive for any environment and highly influence to environmental change. A benthic organism directly depends upon the physicochemical parameters of the water and also nature of the sediment size, shape of substratum, biological complexes like as food, predation and other factors. that's why they are the indicator of the stream ecology. Macro invertebrate are good biological method for assessment of fresh water bodies receive domestic and industrial wastewater i.e. is the use of benthic fauna (Odiet, 1999). Previous studies on Ganga River for macro invertebrates were done by many scientists time to time (Sinha and Sharma, 2001; Khanna, 1993; Khanna and Bhutiani, 2003, Sharma et al, 2018).

## MATERIAL AND METHODS

### Study area

The study area was confined to the long of the riverine system of Ganga River and its tributaries in Rishikesh (Uttarakhand). In Present study, Six sampling sites have been selected for analysis the physic-chemical parameters and Macro-benthos determination.

**Table: 1 Geo-Coordinate of selected sampling sites.**

| Sampling Site | Name | Geo-coordinates | | Elevation |
|---|---|---|---|---|
| | | Latitude | Longitude | |
| Site 1 | Nayar and Ganga Confluence Point | $30^0$07'01.33" | $78^0$22 '34.72" | 1183 ft |
| Site 2 | Henwal and Ganga Confluence Point | $30^0$08'03.48" | $78^0$23' 27.03" | 1232 ft |
| Site 3 | Ganga (at Phoolchatti) | $30^0$07'07.58" | $78^0$22'00.04" | 1233 ft |
| Site 4 | Nayar River | $30^0$06'30.92" | $78^0$22'51.89" | 1270 ft |
| Site 5 | Ganga (at Shivpuri) | $30^0$07'38.47" | $78^0$23'29.51" | 1360 ft |
| Site 6 | Henwal River | $30^0$08'12.69" | $78^0$23'17.06" | 1306 ft |

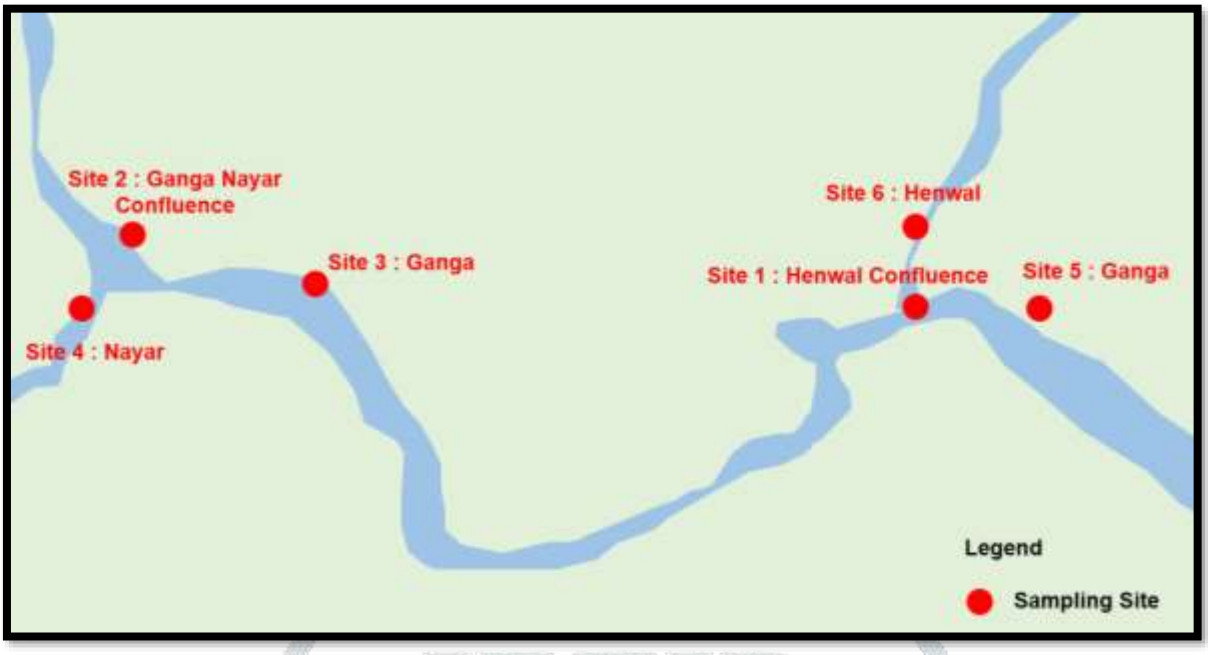


**Fig. 1: Sketch map of selected sampling sites on Ganga river and its tributaries.**

**Physiographic variables**

The percentage cover of different sized substrate within each Surber quadrate was estimated visually and substrate was classified with the help of Wentworth scale (Boulders (>256mm), Cobbles (64-256mm), Pebbles (16-64mm), Gravels (2-16mm), and Sand (<2mm).

**Water quality parameters**

Water has dynamic medium and its quality varied specially and temporally. For order to characters any water body, studies on the major components like physico-chemical and biological characteristics, should be carried out. For physico-chemical parameters, monthly water sample were collected in all sampling sites and analyzed following standard methods (APHA, 2012 and Trivedy et al. 1984). Temperature of air and water was recorded with the help of a digital thermometer (-50…+250$^0$C). Hydrogen ion concentration (pH) of the water was determined by the pH digital meter (Hanna), while the turbidity was measured by the turbidity meter (model- 5Dim), depth and velocity was measured by digital water velocity indicator, Light Intensity was measured by using digital Lux meter (Meco 930P). Relative Humidity was estimated by using digital hydrometer (HTC$^{TM}$ 288-CTH). UV Light was estimated with the help of digital UV Light meter (LT LUTRON UV-340A), alkalinity and hardness were calculated by titration methods.

**Macro-benthic fauna:** Relatively large sized organisms (usually above 6 mm) present at the substratum or bottom of the streams & rivers and belonging to several categories like as insects, sponges, molasses, worms etc. are referred to as macro benthos. They mainly settle at the bottom but may travel occasionally upwards. They may also find on the rocks, organic debris and other substrate at the bottom. Several indices have also been proposed using quantitative and qualitative changes in these populations (Edmonson, 1974)

**Procedure:** the samples are first sieved and then washed from sediment for this and transferred the sample along with same water to a coarse sieve with a mesh size of 0.5 to 0.6 mm and a fine one with a mesh width of less than 0.2 mm, one over the another. Quadrangular wooden, box at the bottom of which sieves of brass of various width are inserted has also been used for sieving macro-benthos sieving yield residue a mixture of animals and sediment. The organisms are picked from there by using forceps and pipettes. They can also be hand- picked, if bigger after keeping the slurry in white background. For quantitative sampling, handle each sample separately avoiding any loss. Macro-benthos was preserved in 10% formalin used 70% ethyl alcohol solution.

**Calculation:**

Use Eckman Dredge Sieve size = U.S. No. 60 cm.

Macro benthos (Individual/ $m^2$) = A/0.216

Where,

A = Number of macro benthos

0.216 = $m^3$ (60 cm Sieve size)

**Diversity Indices**

For the data of species, diversity indices were calculated using the Shannon-Wiener Index (1963). Shannon Weaver diversity index (H') was calculated using the following formula:

$$(H)=\sum_{i=1}\left(\frac{n_i}{N}\right)\text{Log }2\left(\frac{n_i}{N}\right)$$

Where,

H'= Shannon Diversity Index,

$n_i$= Total no of individuals of the species

N= Total no of individuals of all species

**Results and Discussions**

The aim of present research work is to represent the evaluation of different physical, chemical and biological parameters of the Ganga and its tributaries at Rishikesh. Some variations are observed in the physical, chemical and biological parameters as well as in the quality of water, which can influence living organisms of the water ecosystem. These variations indicate the water quality change. Temperature is most important factor of the water body and play important role for water ecosystem. It is only one of the parameter that direct and indirect effect and intense influence of biota of the water body. It influences the chemical and bio-chemical characteristics of water. In the present study, maximum (23.0°C) temperature was recorded at site 4 during March and minimum (13.10°C) at site 2 during December. A similar trend was found according to (Sharma et al., 2018) and (Malik et al., 2018) while working on phytoplankton status in Bharirathi river Tehri and observed that water temperature is the determining factor in the seasonal distribution of the organisms in the water body. The observed pattern of temperature fluctuations in the Ganga River is very similar. A similar trend was found by (Chakraborty at al., 1959) in Yamuna. The pH is a negative logarithm of $H^+$ concentration of a solution. It is measure of the concentration of alkalinity and acidity of the solution or water. pH effects the dissolved oxygen level, photosynthesis of aquatic plants and metabolic rates of aquatic organisms. It is important the growth of flora and fauna of water body and increase decomposition rate of organic matter. It is play an important role for chemical and biochemical reaction in an aquatic body take place at a particular pH. The maximum (8.8) pH was observed at site 4 during January and minimum (5.8) at site 6 during December (Table 2). In natural water, the pH also changes and fluctuate cause of variation in photosynthetic activities which increase the value of pH to consumption of $CO_2$ in the process. Similar trend was found by (Pahwa and Mehrotra, 1996) in Ganga near Allahabad and similar observation was found by (Zafar, 1964). The electrical conductivity is measure of the current an aqueous solution by dissociation of ions and cation into the positive and negative charges. It evaluates the estimate degree of salts contents and total dissolved solids in the water. The maximum (192.2µS/cm) conductivity was observed at site 2 during December and minimum (51.2 µS/cm) at site 1 during January. Joshi and Sharma (2011) also found similar result in Bhaigirathi and Yamuna river. Khanna *et al.* (2003) also found similar trends in Ganga River at Bulandshahar. The total dissolved solids are solids contents which presents in the water and it indicates the salinity behavior of water. The maximum (300.0 mg/l) TDS was observed at site 2 during December and minimum (60.6 mg/l) at site 3 during February. Similar trend was found by (Khanna, 1993) in the river Ganga at Haridwar. Similar trend has been found by (Abbasi *et al.*, 1996). Dissolved oxygen is another important parameter of the water. it is good for utilization of microorganisms in the water body. It maintains the life form and variety of the organisms and use for respiration of the plants and animals in water ecosystem. DO is affected by the waste discharge through industrial and sewage. The maximum (9.6 mg/l) DO was observed at site 1 during January and minimum (7.8 mg/l) at site 2 during December. Khanna, 2003) also reported same trend in the Ganga river system at foothills, of Garhwal, Himalaya. (Kumar et al., 2010) was also found similar trend in Beas River. Biochemical Oxygen Demand represents the pollution condition of the water body. It indicates the entry of organic waste and pollution load in the water system. The maximum (3.5mg/l) BOD was observed at site 1 during January and minimum (1.0mg/l) at site 6 February (Table 4). Similar trend was found by (Singh, 2014) at Rasoolabad Ghat, district of Allahabad in Ganga River. The value of BOD was found increasing due the value of nitrates, phosphates, and macrophytes in the month of November, December and January.A similar trend was found in river Ganga by (Khanna, 2003) in river Ganga at Haridwar. Depth is important parameter in the riverine system; it directly influences the aquatic biota. As we know that the light does not reaches in such condition where the depth increases. Similarly, light intensity is very important parameter for aquatic biodiversity i.e. macro benthos, fish species etc. The maximum (0.7 m) depth was observed at site 3 during December and minimum (0.3 m) at site 1 during March. Velocity is also an important parameter in any riverine ecosystem. Aquatic biodiversity directly depends upon the flow movement of the water. Many species like fast flowing water while other species show stagnant water habitat condition for their feeding and breeding. The maximum (1.4m/sec) velocity was observed at site 6 and minimum (0.7m/sec) at site 4 during March. Similar trend was found by (Nautiyal and Mishra, 2013) in the Himalayan river. A similar trend was also observed by (Khanna, 1993) in Suswa River. Substratum is another parameter for some species of water body like as benthos. The maximum (80%) substratum was observed at site 1 and minimum (20%) at site 5. (Reice, 1980) has been observed the relation between benthos and substratum. Similar trend was found by (Rabeni and Minshall, 1977). Air temperatures is important parameter and show the hot or cold in the air .it affects the growth and reproduction of the flora and fauna. The maximum (39.9ºC) air temperature was observed at site 3 during March and minimum (18.1ºC) at site 4 during December. Light intensity comes at the earth in the form of wavelength which affects the all living organisms of the earth. It increases the temperature of the land and water body and influence the flora and fauna. The maximum (68400.0 lux) light intensity was observed at site 1 during February and minimum (53900.0 lux) at site 1 during January (Table 3). Relative humidity is the amount of water vapors present in the air. It maintains the temperature of the earth. The maximum (50.0%) relative humidity was observed at site 1 and 6 during December and minimum (10.0%) at site 3 during March. The maximum (990.0µW/cm$^2$) light intensity was observed at site 6 during February and minimum (8.0µW/cm$^2$) at site 3 during December. The benthic fauna is indicator of biological conditions in the water body. It is like a key species in the river for fish food and maintains the ecological food balance in the water ecosystem. It lives at the bottom of river and decompose different leaf species etc. the maximum (404 ind/m) number of species found in the December and minimum (186 ind/m) in the month of March (Table 8). Similar trend was found by the (Bonsdorff and Osterman, 1985). The greatest abundance and species number was found in the summer and lowest in the months of winter due to affecting of the temperature. Shannon Weiner indices of macro-benthos (Fig. 6) dwelling Ganga river and its tributaries was found to be maximum (2.90) in the month of December at site 6 and was found minimum (1.24) in the month of March at site 1 (Table 9).

**Table 2: Monthly variation in meteorological parameters at selected sampling sites.**

| Site | Month | Air temp ($^0$C) | Light intensity(lux) | Relative humidity (%) | UV Light(μW/cm$^2$) |
|---|---|---|---|---|---|
| Site 1 | December | 20.9 | 32200 | 50 | 85 |
| | January | 25.1 | 53900 | 46 | 214 |
| | February | 22.4 | 68400 | 43 | 113 |
| | March | 39.3 | 60400 | 10 | 283 |
| | **Average** | **27** | **53725** | **37.2** | **174** |
| Site 2 | December | 19.3 | 79700 | 51 | 27 |
| | January | 29 | 27000 | 39 | 51 |
| | February | 30.9 | 59100 | 10.5 | 300 |
| | March | 39.1 | 54900 | 13 | 189 |
| | **Average** | **29.6** | **55175** | **28.7** | **142** |
| Site 3 | December | 17.8 | 16200 | 59 | 8 |
| | January | 31.4 | 41300 | 30 | 201 |
| | February | 23.8 | 13950 | 41 | 41 |
| | March | 39.9 | 63030 | 10 | 308 |
| | **Average** | **28.2** | **33620** | **35** | **140** |
| Site 4 | December | 18.1 | 47800 | 59 | 10 |
| | January | 25.4 | 55900 | 27 | 179 |
| | February | 26.4 | 19720 | 34 | 60 |
| | March | 35.1 | 56760 | 18.3 | 244 |
| | **Average** | **26.2** | **45045** | **34.6** | **123.2** |
| Site 5 | December | 27.2 | 41200 | 46 | 157 |
| | January | 32.1 | 57100 | 30 | 304 |
| | February | 33.2 | 26100 | 20 | 85 |
| | March | 37.9 | 62430 | 16.3 | 392 |
| | **Average** | **32.6** | **46708** | **28.1** | **235** |
| Site 6 | December | 22.8 | 14300 | 50 | 53 |
| | January | 28.8 | 56300 | 32 | 268 |
| | February | 27 | 60700 | 20 | 990 |
| | March | 38.2 | 63060 | 23 | 385 |
| | **Average** | **29.2** | **48590** | **31.25** | **424** |

**Table 3: Monthly variation in morphological parameters at selected sampling sites.**

| Site | Month | Depth (m) | Velocity (m/sec.) | Substratum |
|---|---|---|---|---|
| Site 1 | December | 0.6 | 1.1 | Boulders – 80%, Cobbles- 12%, Pebbles-5%, Silt-3% |
| | January | 0.5 | 1 | Boulders – 80%, Cobbles- 12%, Pebbles-5%, Silt-3% |
| | February | 0.5 | 0.9 | Boulders – 80%, Cobbles- 12%, Pebbles- 5%, Silt-3% |
| | March | 0.3 | 0.8 | Boulders – 80%, Cobbles- 12%, Pebbles- 5%, Silt-3% |
| Site 2 | December | 0.6 | 1.0 | Boulders -70%, Cobbles- 22%, Pebbles- 6%, Silt-2% |
| | January | 0.5 | 1 | Boulders -70%, Cobbles- 22%, Pebbles- 6%, Silt-2% |
| | February | 0.5 | 0.9 | Boulders -70%, Cobbles- 22%, Pebbles- 6%, Silt-2% |
| | March | 0.4 | 0.8 | Boulders -70%, Cobbles- 22%, Pebbles- 6%, Silt-2% |
| Site 3 | December | 0.7 | 1.3 | Boulders –40%, Cobbles- 20%, Pebbles-5%, Sand-3%, Silt-32% |
| | January | 0.5 | 1 | Boulders – 40%, Cobbles- 20%, Pebbles-5%, Sand-3%, Silt-32% |
| | February | 0.5 | 0.9 | Boulders – 40%, Cobbles- 20%, Pebbles-5%, Sand-3%, Silt-32% |
| | March | 0.4 | 0.8 | Boulders – 40%, Cobbles- 20%, Pebbles-5%, Sand-3%, Silt-32% |

| | | | | |
|---|---|---|---|---|
| Site 4 | December | 0.6 | 1.0 | Boulders – 50%, Cobbles- 20%, Pebbles- 23%, Sand-2%, Silt-5% |
| | January | 0.5 | 1 | Boulders – 50%, Cobbles- 20%, Pebbles- 23%, Sand-2%, Silt-5% |
| | February | 0.5 | 0.9 | Boulders – 50%, Cobbles- 20%, Pebbles- 23%, Sand-2%, Silt-5% |
| | March | 0.5 | 0.8 | Boulders – 50%, Cobbles- 20%, Pebbles- 23%, Sand-2%, Silt-5% |
| Site 5 | December | 0.6 | 1.1 | Boulders – 20%, Cobbles- 15%, Pebbles- 20%, Sand-5, Silt-40% |
| | January | 0.5 | 0.9 | Boulders – 20%, Cobbles- 15%, Pebbles- 20%, Sand-5, Silt-40% |
| | February | 0.5 | 0.8 | Boulders – 20%, Cobbles- 15%, Pebbles- 20%, Sand-5, Silt-40% |
| | March | 0.6 | 1 | Boulders – 20%, Cobbles- 15%, Pebbles- 20%, Sand-5, Silt-40% |
| Site 6 | December | 0.7 | 1.4 | Boulders – 45%, Cobbles- 30%, Pebbles- 20%, Sand-1%, Silt-4% |
| | January | 0.5 | 1 | Boulders – 45%, Cobbles- 30%, Pebbles- 20%, Sand-1%, Silt-4% |
| | February | 0.6 | 0.9 | Boulders – 45%, Cobbles- 30%, Pebbles- 20%, Sand-1%, Silt-4% |
| | March | 0.5 | 0.8 | Boulders – 45%, Cobbles- 30%, Pebbles- 20%, Sand-1%, Silt-4% |

**Table 4: Monthly variation in physico-chemical parameters of Ganga river and its tributaries.**

| Site | Month | Water temp ($^0$C) | pH | Electrical Conductivity (µS/cm) | TDS (mg/L) | DO (mg/L) | BOD (mg/L) |
|---|---|---|---|---|---|---|---|
| Site 1 | December | 15.3 | 7.3 | 63.4 | 100.0 | 9.6 | 2.4 |
| | January | 16.4 | 7.2 | 51.2 | 80.3 | 9.0 | 3.5 |
| | February | 17.2 | 8.0 | 108.8 | 170.2 | 8.5 | 1.2 |
| | March | 18.5 | 6.7 | 64.5 | 102.2 | 8.8 | 2.1 |
| | **Average** | 16.8 | 7.3 | 71.9 | 113.1 | 8.9 | 2.3 |
| Site 2 | December | 13.1 | 6.5 | 192.2 | 300.0 | 9.0 | 2.5 |
| | January | 21.0 | 8.7 | 64.1 | 100.2 | 7.8 | 1.8 |
| | February | 16.0 | 7.2 | 89.6 | 140.8 | 9.4 | 1.4 |
| | March | 21.1 | 7.5 | 76.8 | 120.2 | 8.2 | 1.6 |
| | **Average** | 17.8 | 7.4 | 105.6 | 165.3 | 8.6 | 1.8 |
| Site 3 | December | 15.0 | 7.0 | 64.0 | 100.0 | 9.1 | 1.5 |
| | January | 17.2 | 7.5 | 44.8 | 70.5 | 9.0 | 1.3 |
| | February | 14.5 | 7.4 | 38.4 | 60.6 | 8.6 | 1.2 |
| | March | 17.5 | 6.7 | 76.8 | 120.0 | 9.2 | 1.3 |
| | **Average** | 16.0 | 7.1 | 56 | 87.7 | 8.9 | 1.3 |
| Site 4 | December | 16.0 | 6.2 | 128.1 | 200.0 | 8.6 | 2.9 |
| | January | 20.1 | 8.8 | 70.4 | 110.5 | 8.4 | 2.6 |
| | February | 19.5 | 7.4 | 72.1 | 110.1 | 8.0 | 2.9 |
| | March | 23.0 | 7.7 | 76.8 | 120.4 | 8.1 | 1.4 |
| | **Average** | 19.6 | 7.5 | 86.8 | 135.2 | 8.2 | 2.4 |
| Site 5 | December | 14.0 | 6.0 | 64.1 | 100.2 | 9.0 | 2.0 |
| | January | 17.2 | 8.1 | 68.3 | 100.0 | 9.5 | 2.7 |
| | February | 16.2 | 7.2 | 76.8 | 120.1 | 9.1 | 2.0 |
| | March | 17.1 | 6.8 | 51.4 | 80.6 | 9.4 | 2.5 |
| | **Average** | 16.1 | 7.0 | 65.3 | 100.2 | 9.2 | 2.3 |
| Site 6 | December | 17.0 | 5.8 | 128.2 | 200.0 | 8.0 | 1.1 |
| | January | 19.1 | 8.0 | 125.0 | 180.2 | 8.6 | 1.1 |
| | February | 18.0 | 7.0 | 134.4 | 165.2 | 8.2 | 1.0 |
| | March | 22.1 | 7.3 | 149.3 | 233.3 | 8.4 | 1.2 |
| | **Average** | 19.05 | 7.025 | 134.2 | 194.6 | 8.3 | 1.1 |

**Table 5: Macro-benthos species richness of selected sites in Ganga Basin and its tributaries during December.**

| Taxon | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 |
|---|---|---|---|---|---|---|
| ***Ephemeroptera*** | | | | | | |
| *Bateis sp.* | 1 | 3 | - | 2 | - | 5 |
| *Emphemera sp.* | 6 | 8 | 3 | 12 | 5 | 8 |
| *Emhemerella sp.* | 8 | 5 | 5 | 7 | 3 | 18 |
| *Siphlonurus sp.* | 4 | 5 | 5 | 12 | 5 | 10 |
| **Total** | **19** | **21** | **13** | **33** | **13** | **41** |
| ***Hemiptera*** | | | | | | |
| *Gerris sp.* | - | - | 2 | 15 | 2 | 12 |
| *Corexia sp.* | - | - | 2 | 10 | 2 | 10 |
| *Hesperocorixasp* | - | - | 3 | 4 | 2 | 5 |
| **Total** | **0** | **0** | **7** | **29** | **6** | **27** |
| **Diptera** | | | | | | |
| *Cironomus sp.* | 1 | 1 | 2 | 5 | 1 | 3 |
| *Culex sp.* | 2 | 2 | 3 | 5 | 4 | 2 |
| *Simulium sp.* | - | - | 2 | 2 | 3 | 4 |
| *Phychoda sp.* | - | - | 1 | 3 | 1 | 4 |
| *Tabanus sp.* | - | - | 2 | 4 | 2 | 5 |
| **Total** | **3** | **3** | **10** | **19** | **11** | **18** |
| **Coleoptera** | | | | | | |
| *Agabinus sp.* | - | - | - | 2 | 1 | 2 |
| *Dineutussp* | - | - | - | 1 | - | 1 |
| *Limnius sp.* | - | - | 1 | - | 1 | 1 |
| *Psephenus sp.* | 2 | 2 | 1 | 5 | 3 | 9 |
| **Total** | **2** | **2** | **2** | **8** | **5** | **13** |
| ***Placoptera*** | | | | | | |
| *Isoperla sp.* | - | - | 2 | 4 | 3 | 3 |
| *Perla sp.* | - | - | - | 2 | 2 | 2 |
| *Teeniopteryx sp.* | - | - | 1 | 2 | 3 | 3 |
| ***Total*** | **0** | **0** | **3** | **8** | **8** | **8** |
| ***Tricoptera*** | | | | | | |
| *Glossosoma sp.* | - | - | 1 | 10 | 3 | 13 |
| *Hydroptela sp.* | - | - | - | 2 | - | 1 |
| *Hydropsyche sp.* | - | - | 1 | 4 | 1 | 5 |
| **Total** | **0** | **0** | **2** | **16** | **4** | **19** |
| **Odonata** | | | | | | |
| *Agrion sp.* | 2 | 2 | 3 | 5 | 2 | 6 |
| *Ischnura sp.* | - | - | 1 | 1 | 1 | 2 |
| **Total** | **2** | **2** | **4** | **6** | **3** | **8** |
| **Mollusca** | | | | | | |
| *Pleurocera sp.* | - | - | - | - | - | - |
| **Total** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Annelida** | | | | | | |
| *Hirudinaria sp.* | - | - | 4 | - | 2 | - |
| **Total** | | | **4** | | **2** | |

**Table 6: Macro-benthos species richness on selected sites in Ganga Basin and its tributaries during January.**

| Taxon | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 |
|---|---|---|---|---|---|---|
| ***Ephemeroptera*** | | | | | | |
| *Bateis sp.* | 1 | 2 | - | 2 | - | 3 |
| *Emphemera sp.* | - | - | 1 | 1 | 1 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Emhemerella sp.* | 6 | 8 | 2 | 15 | 3 | 18 |
| *Siphlonurus sp.* | 5 | 6 | 2 | 10 | 2 | 14 |
| **Total** | **12** | **16** | **5** | **28** | **6** | **37** |
| ***Hemiptera*** | | | | | | |
| *Gerris sp.* | - | - | - | 5 | - | 6 |
| *Corexia sp.* | - | - | 3 | 2 | 1 | 6 |
| *Hesperocorixasp* | - | - | 1 | 3 | - | 1 |
| **Total** | 0 | **0** | **4** | **10** | **1** | **13** |
| **Diptera** | | | | | | |
| *Cironomus sp.* | 2 | 2 | 1 | 3 | 1 | 3 |
| *Culex sp.* | 1 | 1 | 2 | 1 | 3 | 1 |
| *Simulium sp.* | - | - | 2 | 1 | - | 3 |
| *Phychoda sp.* | - | - | 1 | - | - | - |
| *Tabanus sp.* | - | - | 2 | - | - | 1 |
| **Total** | **3** | **3** | **8** | **5** | **4** | **8** |
| **Coleoptera** | | | | | | |
| *Agabinus sp.* | - | - | - | - | - | - |
| *Dineutussp* | - | - | - | - | - | - |
| *Limnius sp.* | - | - | - | - | - | - |
| *Psephenus sp.* | 2 | 3 | 8 | 1 | 2 | 7 |
| **Total** | **2** | **3** | **8** | **1** | **2** | **7** |
| ***Placoptera*** | | | | | | |
| *Isoperla sp.* | - | - | 1 | - | - | 2 |
| *Perla sp.* | - | - | - | - | - | - |
| *Teeniopteryx sp.* | - | - | - | - | 2 | - |
| ***Total*** | | **0** | **1** | **0** | **2** | **2** |
| ***Tricoptera*** | | | | | | |
| *Glossosoma sp.* | 4 | 3 | - | 12 | 3 | 15 |
| *Hydroptela sp.* | - | - | - | - | 2 | 1 |
| *Hydropsyche sp.* | 1 | 2 | - | 4 | 2 | 6 |
| **Total** | **5** | **5** | **0** | **16** | **7** | **22** |
| **Odonata** | | | | | | |
| *Agrion sp.* | 2 | 1 | - | 2 | 1 | 2 |
| *Ischnura sp.* | 1 | 1 | - | 1 | 2 | 1 |
| **Total** | **3** | **3** | **3** | **3** | **3** | **3** |
| **Mollusca** | | | | | | |
| *Pleurocera sp.* | - | - | - | - | - | - |
| **Total** | | | | | | |
| **Annelida** | | | | | | |
| *Hirudinaria sp.* | - | - | 1 | - | 2 | - |
| **Total** | | | **1** | | **2** | |

**Table 7: Macro-benthos species richness on selected sites in Ganga Basin and its tributaries during February.**

| **Taxon** | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 |
|---|---|---|---|---|---|---|
| ***Ephemeroptera*** | | | | | | |
| *Bateis sp.* | - | - | 1 | 1 | - | 2 |
| *Emphemera sp.* | - | - | - | - | - | 1 |
| *Emhemerella sp.* | 3 | 3 | 2 | 12 | 3 | 15 |
| *Siphlonurus sp.* | 1 | 2 | 2 | 10 | 1 | 14 |
| **Total** | **4** | **5** | **5** | **23** | **4** | **32** |
| ***Hemiptera*** | | | | | | |
| *Gerris sp.* | - | - | - | 5 | - | 8 |
| *Corexia sp.* | - | - | 1 | 2 | - | 1 |
| *Hesperocorixasp* | - | - | - | 2 | - | |
| **Total** | **0** | **0** | **1** | **9** | **0** | **9** |
| **Diptera** | | | | | | |
| *Cironomus sp.* | - | - | 1 | - | - | 1 |
| *Culex sp.* | 1 | 1 | 1 | 1 | 1 | 2 |
| *Simulium sp.* | - | - | 1 | - | - | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Phychoda sp.* | - | - | 1 | - | - | - |
| *Tabanus sp.* | - | - | 2 | - | - | 2 |
| **Total** | **1** | **1** | **6** | **1** | **1** | **7** |
| **Coleoptera** | | | | | | |
| *Agabinus sp.* | - | - | - | - | - | - |
| *Dineutussp* | - | - | - | - | - | - |
| *Limnius sp.* | - | - | - | - | - | - |
| *Psephenus sp.* | 3 | 2 | - | 5 | - | 8 |
| ***Total*** | **3** | **2** | **0** | **5** | **0** | **8** |
| ***Placoptera*** | | | | | | |
| *Isoperla sp.* | - | - | - | 2 | - | 2 |
| *Perla sp.* | - | - | - | - | 1 | 1 |
| *Teeniopteryx sp.* | - | - | - | 1 | 2 | 2 |
| ***Total*** | **0** | **0** | **0** | **3** | **3** | **5** |
| ***Tricoptera*** | | | | | | |
| *Glossosoma sp.* | 1 | 1 | - | 4 | 1 | 6 |
| *Hydroptela sp.* | - | - | - | - | - | - |
| *Hydropsyche sp.* | - | - | - | - | 1 | - |
| **Total** | **1** | **1** | **0** | **4** | **2** | **6** |
| **Odonata** | | | | | | |
| *Agrion sp.* | - | - | 1 | 1 | 3 | 2 |
| *Ischnura sp.* | - | - | 1 | 2 | 1 | 2 |
| **Total** | **0** | **0** | **2** | **3** | **4** | **4** |
| **Mollusca** | | | | | | |
| *Pleurocera sp.* | - | - | - | - | - | 1 |
| **Total** | **0** | **0** | **0** | **0** | **0** | **1** |
| **Annelida** | | | | | | |
| *Hirudinaria sp.* | - | - | - | - | - | - |
| **Total** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Taxon** | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 |
| ***Ephemeroptera*** | | | | | | |
| *Bateis sp.* | - | - | - | 1 | - | 2 |
| *Emphemera sp.* | - | - | - | - | - | - |
| *Emhemerella sp.* | 4 | 3 | 2 | 12 | 3 | 15 |
| *Siphlonurus sp.* | 2 | 2 | 2 | 8 | - | 12 |
| **Total** | **6** | **5** | **4** | **21** | **3** | **29** |
| ***Hemiptera*** | | | | | | |
| *Gerris sp.* | - | - | - | 6 | - | 6 |
| *Corexia sp.* | - | - | - | 1 | - | 3 |

**Table 8: Macro-benthos species richness on selected sites in Ganga Basin and its tributaries during March.**

| | | | | | | |
|---|---|---|---|---|---|---|
| *Hesperocorixasp* | - | - | 1 | 2 | - | 1 |
| **Total** | **0** | **0** | **1** | **9** | **0** | **10** |
| **Diptera** | | | | | | |
| *Cironomus sp.* | - | - | 1 | 1 | 1 | 2 |
| *Culex sp.* | - | - | 1 | - | - | 3 |
| *Simulium sp.* | - | - | 1 | - | | 2 |
| *Phychoda sp.* | - | - | - | - | - | - |
| *Tabanus sp.* | - | - | 1 | - | - | 2 |
| **Total** | **0** | **0** | **4** | **1** | **1** | **9** |
| **Coleoptera** | | | | | | |
| *Agabinus sp.* | - | - | 1 | 2 | - | 4 |
| *Dineutussp* | - | - | 1 | - | - | 6 |
| *Limnius sp.* | - | - | - | - | - | 1 |
| *Psephenus sp.* | 2 | 2 | | 5 | - | 3 |
| **Total** | **2** | **2** | **2** | **7** | **0** | **14** |
| ***Placoptera*** | | | | | | |
| *Isoperla sp.* | - | - | - | 2 | 1 | 4 |
| *Perla sp.* | - | - | - | - | - | - |
| *Teeniopteryx sp.* | - | - | 1 | - | 1 | 2 |
| ***Total*** | **0** | **0** | **1** | **2** | **2** | **6** |
| ***Tricoptera*** | | | | | | |
| *Glossosoma sp.* | - | - | 1 | 4 | 3 | 5 |
| *Hydroptela sp.* | - | - | - | 1 | 1 | 1 |
| *Hydropsyche sp.* | 2 | 1 | - | 3 | - | 4 |
| **Total** | **2** | **1** | **1** | **8** | **4** | **10** |
| **Odonata** | | | | | | |
| *Agrion sp.* | 2 | 1 | 1 | 2 | 3 | 4 |
| *Ischnura sp.* | 1 | - | 1 | 1 | 2 | 1 |
| **Total** | **3** | **1** | **2** | **3** | **5** | **5** |
| **Mollusca** | | | | | | |
| *Pleurocera sp.* | - | - | - | - | - | - |
| **Total** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Annelida** | | | | | | |
| *Hirudinaria sp.* | - | - | - | - | - | - |
| **Total** | **0** | **0** | **0** | **0** | **0** | **0** |

**Table 9: Monthly variation in Shannon-Wiener index in selected sampling sites at Ganga basin and its tributaries**.

| Name of Site | December | January | February | March |
|---|---|---|---|---|
| **Site 1** | 1.831 | 1.990 | 1.464 | 1.206 |
| **Site 2** | 1.897 | 2.052 | 1.523 | 1.522 |
| **Site 3** | 2.848 | 2.225 | 2.342 | 2.523 |
| **Site 4** | 2.881 | 2.273 | 2.204 | 2.370 |
| **Site 5** | 2.843 | 2.491 | 2.069 | 1.956 |
| **Site 6** | 2.904 | 2.462 | 2.434 | 2.744 |

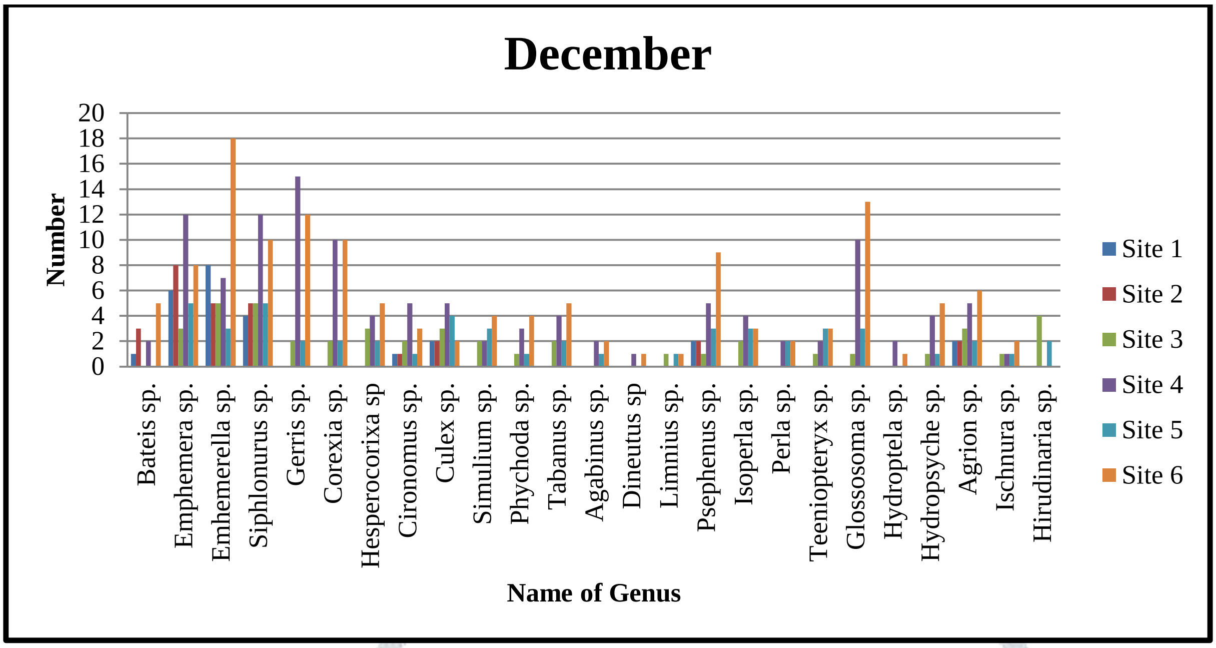


**Fig. 2: Macro-benthos species richness on selected sites in Ganga Basin and its tributaries during December.**

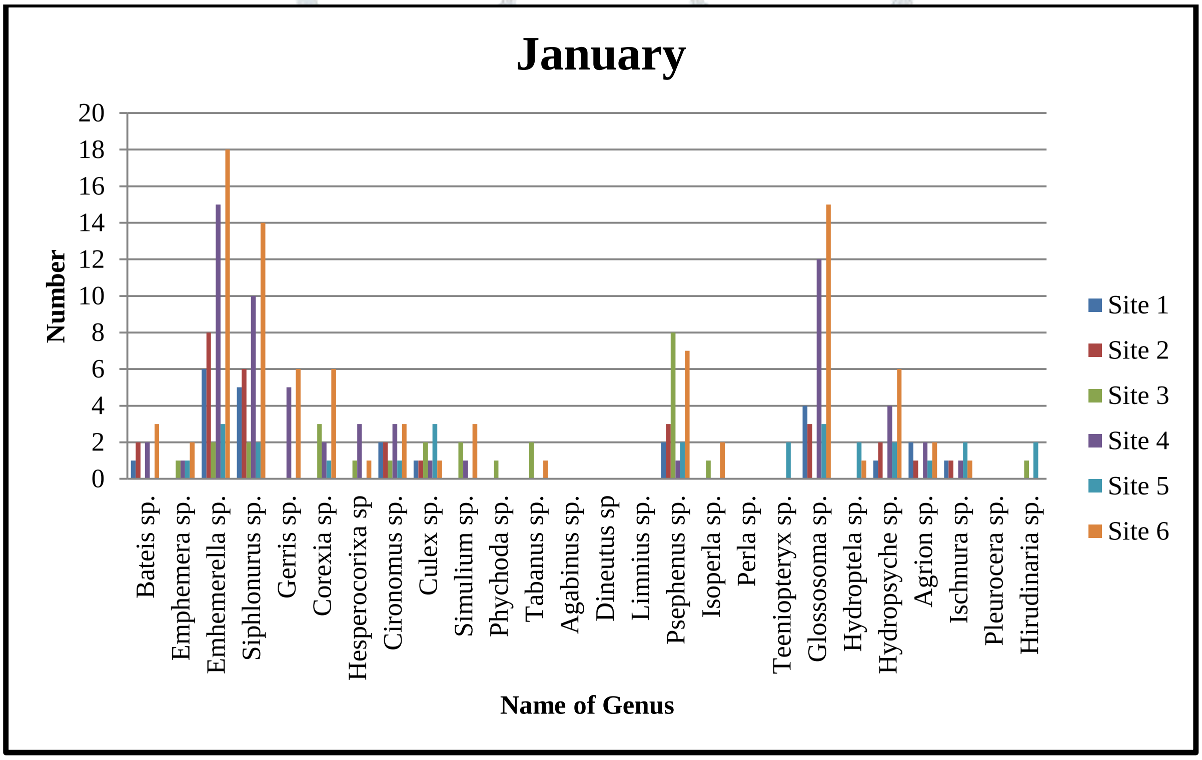


**Fig. 3: Macro-benthos species richness on selected sites in Ganga Basin and its tributaries during January.**

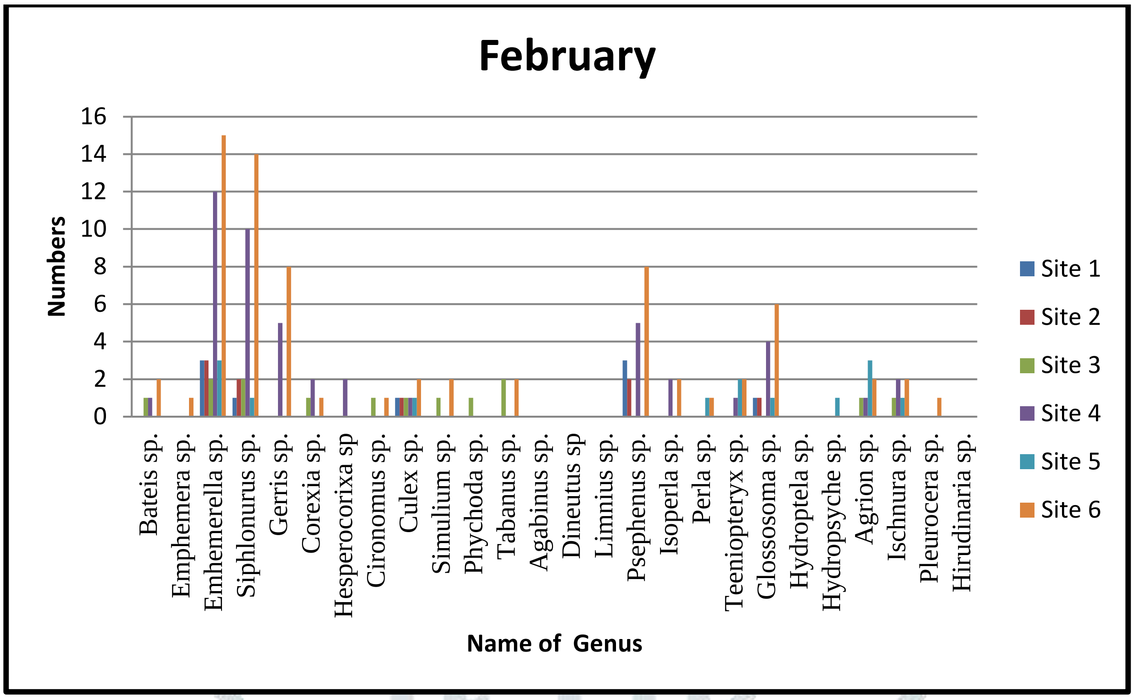


**Fig. 4: Macro-benthos species richness on selected sites in Ganga Basin and its tributaries during February.**

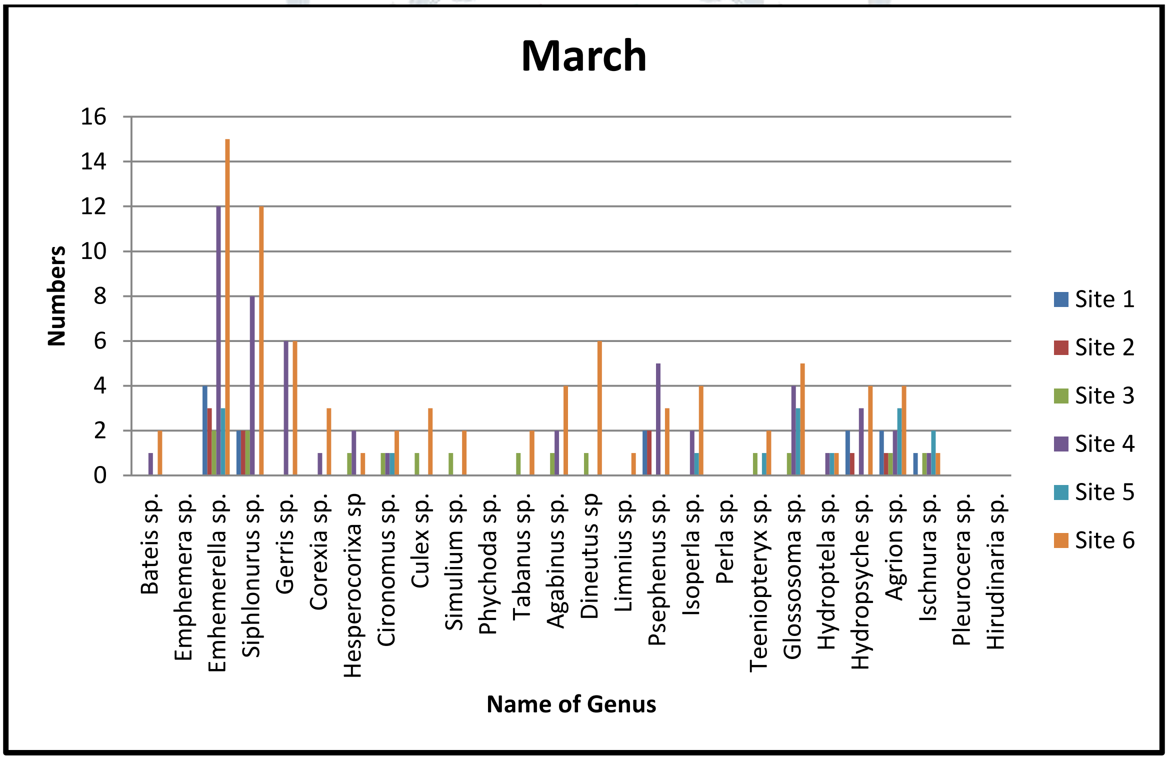


**Fig. 5: Macro-benthos species richness on selected sites in Ganga basin and its tributaries during March**

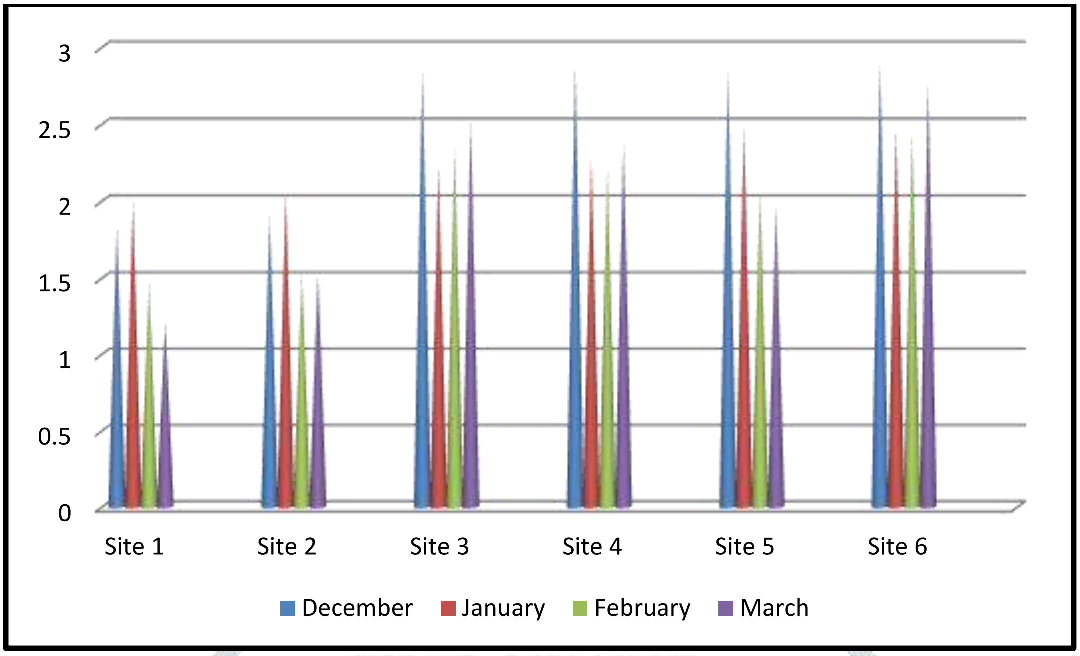


**Fig. 6: Monthly variation in Shannon-Wiener index in selected sampling sites at Ganga basin and its tributaries.**

## CONCLUSION:

The present study concluded that Nayar and Henwal are the tributary of Ganga river and are of good habitat for aquatic biota i.e. for fish species etc. The water quality of Nayar and Henwal River are good and can be used for irrigation and domestic purpose. Both rivers are Perennial River and rich in aquatic biodiversity like fishes. Both river water posses threat due to anthropogenic and construction activities in its catchment basin. A creative awareness program should be planned among the people in the neighborhood for conservation of river water.

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