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Evaluation of altitudinal distribution and population dynamics of introduced Brown trout (*Salmo trutta*) and native Snow trout (*Schizothorax richardsonii*) in river Asiganga, Uttarakhand (India)

Madhu Thapliyal[1], Madhu Bartwal[2], Ashish Thapliyal [3] ✉

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Abstract

Mountains of Himalaya, with unique topology and geographical regions, are hotspots of biodiversity. Their flora and fauna have been investigated for abundance in species composition and interactions. One of the most important driving forces of ecosystem differentiation is altitudinal gradients that results in changes in species composition. Sometimes, an introduced species can also have a major impact on endemic species if the introduced species can survive in entire altitudinal gradient zone. Our study focuses on this aspect and defines the pattern of altitudinal variation and distribution of *Salmo trutta* (Brown trout) and native *Schizothorax sp*. (Snow trout) in river Asiganga (a tributary of Ganges) that originates from Dodital (4400 m). We analyzed population dynamics of both species along altitudinal gradients (2200m to 1100m approximately). The physicochemical parameters of water showed significant variation along the altitudinal gradient. Our study suggests that the population groups of Brown trout are establishing in the lower altitudinal regions of the river Asiganga, and even into the river Ganges, due to their ability to survive in wider range of temperature and availability of food. Usually it is believed that species inhabiting higher elevations are superior competitors at lower temperature while species inhabiting lower altitude are better competitors at warmer temperature. Our study suggests that although altitudinal variations are powerful for species distribution but prey-predator effect and availability of preferred food is also pro-lasting and can have a wider role in distribution of predator fish species.

Keywords: altitudinal gradient, biodiversity, taxonomical groups, ecosystem differentiation

Introduction

Garhwal Himalaya in India has a vast network of fresh water rivers and streams that harbor rich diversity of fish species. Two major rivers, The Ganges and The Yamuna, of India originate from Garhwal Himalaya. Most of these fresh water systems have their water heads at higher elevations and these rivers/streams cross diverse altitude zones before merging into either of the two major rivers, The Ganges or The Yamuna. Altitudinal zonation has been well studied and it has been reported that altitudinal zonation of fish species occur in response to various factors, especially temperature, operating differentially across altitudes. Every fish species has a specific thermal physiology and therefore its distribution is reflected by the spatial arrangement as per required temperature range(s) within a river network. This varied pattern of temperature regimes changes the distribution pattern of fish species. One species replacing other, along the altitudinal gradient, is observed commonly in Mountain River and streams throughout the world (Bozek and Hubert, 1992; Magoulick and Wilzbach, 1998; Taniguci and Nakano, 2000; McHugh and Budy, 2005). This phenomenon, termed as altitudinal species zonation, can also occur locally due to biotic and abiotic factor interaction. In almost all the studies done so far, it is hypothesized that species inhabiting higher elevations are superior competitors at lower temperature while species inhabiting lower altitude are better competitors at warmer temperature. Each species might be capable of surviving at all temperatures in the absence of competition (Taniguchi and Nakano, 2000). One of the tributaries of Ganges, river Asiganga is an interesting river with respect to the different ecological niches and habits available in this river within a span of 30 km. River Asiganga originates from Dodital (4400 m – altitude,

Author's Address
[1]Department of Zoology, Pt. L.M.S. Government autonomous (P.G.) College, Rishikesh Uttarakhand
[2]Department of Zoology, Doon (P.G.) College of Agriculture, Science & Technology, Selaqui, Dehradun, Uttarakhand
[3]Govt. Department of Biotechnology, Graphic Era University, Dehradun, Uttarakhand, India
E-mail: ashish.thapliyal@gmail.com

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$30^0 51'01''$ N and $78^0 30'52''$ E) and merges into Ganges near Gangori (Altitude 1100 m). This provides a steep gradient of altitude and temperature variation within a short span. Indiscriminate introductions of exotic trout fishes have been carried out by different agencies in different fresh water bodies of Garhwal Himalaya. One such introduction of brown trout (*Salmo trutta*) was also carried out in Dodital and river Asiganga in district Uttarkashi of Uttarakhand India.

In Uttarkashi district, since the introduction of brown trout, it is disturbing to identify brown trout in catches almost entire length of the river (starting from the point of introduction) and even beyond the confluence region where river Asiganga merges into the Ganges. This widespread distribution of brown trout along the altitude gradient is varying from approximately 1100 m to above 4400 m altitude. This spread is not very evident because of the fact that, to date, there has been no long-term study in entire Garhwal Himalaya on the population abundance and dynamics of introduced exotic trout species. Our study is an attempt to document the extent of spread of exotic brown trout in river Asiganga. The study also focuses on determining and documenting the possibility that either this exotic predator is establishing its population at various temperature zones or it is just an occasional fish that wonders away from the habitat they usually occupy. We are also attempting to understand if, besides survival in various temperature zones, other factor like easy available food is also helping brown trout in establishing their population

Material and Methods

Sampling Sites:

River Asiganga originates at Dodital (4400 meters) and merges into Ganges near Village Gangori (1100 m). Fish were sampled from River Asiganga, a tributary of Ganges, from July, 2009 to June, 2012. Permanent sampling segments were established in the study rivers such as Site1 (Sangamchatti; height: 1345m), Site 2 (Rawara; height: 1505m) and Site 3 (Gangori; height: 1160m) and a control site for brown trout (Control Brown Trout site - CBT). Brown trout were caught by hired fisherman at each sites of river Asiganga. The fisherman used cast net for capturing the fishes which differ in the sinkers and thus in the weights. All the fishes sampled were released without harm.

Physicochemical parameters

Physicochemical parameters were measured following methods of APHA (1995) and Trividi and Goel (1986). Some of the physico-chemical parameters were determined on the site and the rest were determined in the laboratory depending upon the requirement. The selected parameters were described as below:

Water temperature: Water temperature was recorded with the help of mercury thermometer by dipping it into water.

pH: pH was measured on the sampling sites by the portable pH meter (Hanna pocket pH meter-H196-107 Systronic-361 pH meter).

Free Carbon Dioxide: Method of Trividi and Goyal – 1986 was used for CO_2 estimation. Free CO_2 was determined by titrating the sample using a strong alkali (pH 8.3). The analysis was done on the sampling site. Drops of neutralized phenolphthalein indicator were added to 100 ml of water sample taken in an Erlenmeyer's flask and titrated with 0.05N sodium hydroxide (NaOH) until a pink colour appears. The volume of titrant was noted down and free CO_2 was calculated using following equation:

$$Free\ CO_2\ (mg/L) = (ml \times N)\ of\ NaOH \times 1000 \times 44 / ml\ sample$$

Total Alkalinity: Alkalinity is the expression of the total quantity of base (usually in equilibrium with carbonate or bicarbonate) and was determined by titration with a strong acid (Hutchinson, 1957).

Dissolved Oxygen (DO): DO was estimated at the study site by the Winkler's Iodometric method. The estimation of oxygen in water depends on the fact that sodium hydroxide together with manganese sulphate gives a white precipitate of manganese hydroxide.

$$MnSO_4 + 2\,NaOH ------\rightarrow Mn(OH)_2 + Na_2SO_4$$

Water sample was taken in a 300 ml BOD bottle. 1.0 ml of both manganese sulphate (MnSo4) and alkaline iodide (KOH+KI) were added to the sample and mixed gently. Addition of 2.0 ml of conc. Sulphuric acid (H_2SO_4) liberates iodine equivalent to DO. 200 ml of the aliquot was titrated with the standardized sodium thiosulphate $Na_2S_2O_3$ (0.025N), aqueous starch was used as indicator. The volume of titrant used was recorded and the result was expressed as milligram per litre (mg/L). The formula used to calculate DO was as follows:

$$DO\left(mg/L\right) = \left(ml \times N\right) of\ titrant \times 8 \times 1000 / V_2\left(V_1 - V\right)/V_1$$

Where, V_1 = volume of sample bottle after placing the stopper, V_2 = Volume of the part of the contents titrated and V = Volume of $MnSO_4$ and KI added.

Turbidity - Nephelometeic method using systronics - digital Nephlo-turbidity meter 132 was used to determine turbidity.

Fish population estimates:

Data on fish populations was obtained from sampling sites established during the original survey. These sites was chosen to capture the existing range of fish communities (e.g., dominated by native fishes vs. exotic fishes) as well as the range of habitat types and quality. Fish were sampled using a combination of hired fisherman and other efforts (e.g., three pass depletion technique), and population estimates were completed based on modified depletion technique (Zippin, 1958, Thapliyal 2012). For fish population estimates, a specifically marked area of 800 meters to 1 km was quardened off with nets and then the sampling was conducted. All the sample collections and measurements were done from these specifically marked sites. Identification of fish species was completed by Day Fauna (Book) and Badola and Singh (1975), and Badola (2012). Fishes were released without harming.

Benthos

Benthos was collected by placing a quadrate of 1m X 1m at three different locations in same site and samples were collected. The collected sample was preserved in 5% formalin solution. Quantitative estimation was based on numerical counting i.e. units per meter square (Ind.m^{-2}). Qualitative analysis was made with the help of Ward and Whipple (1959) and Needham and Needham (1962).

Data analysis

For an in depth analysis of data recorded on various quantitative characters and estimation of certain genetic parameters the following statistical procedure were followed. Origin 8.1 and SPSS software were used for statistical analysis.

Species richness

Shannon-Wiener species diversity index (Shannon and Wiener, 1963): The monthly counts obtained through regular sampling were used to compute the Shannon-wiener species diversity index ($\overline{H}$). Seasonal values of $\overline{H}$ were computed for each genera to obtain total diversity.

$$\overline{H} = \sum p_i \log_e \sum p_i$$

Where,

$p_i = n_i/N$;

n_i = number of individuals of one species,
N = total number of organisms.

Richness index: Monthly variation in species richness was computed on the basis of data available on the number of species (genera) and individuals both (Margalef, 1957; Odum, 1971).

$$d' = \frac{S-1}{\log_e N}$$

Where, d' = Margalef's index, S = number of species, N = total number of individuals in community.

Evenness index: The Monthly value of evenness index was calculated in the following manner.

$$e = \frac{\overline{H}}{\log_e S}$$

Where, $\overline{H}$ is the Shannon diversity index and S is the number of species. In all the indices natural log ($\log_e$) was used.

t-distribution analysis: If x_1, x_2 ……x_n is the random sample drawn from a normal population with mean (μ) and variance (σ^2) then the distribution of the variable $\frac{(\overline{x} - \upsilon)}{\sqrt{s^2/n}}$ where n is small which is sample size is called t-distribution with (n-1) df **(Hoshmand, 1988)**. The t-distribution, like the normal distribution, is symmetrical in shape, and has a mean equal to zero. Where $\bar{x}$ = sample mean

$$s^2 = \frac{1}{(n-1)}\sum(x-\bar{x})^2$$

$$\frac{(\bar{x}-\upsilon)}{\sqrt{s^2/n}} \Rightarrow t_{(n-1))} \leftarrow df$$

Results and Discussion

Major fish species found in various altitudinal zones of river Asiganga were *Salmo trutta* (brown trout), *Schizothorax (*snow trout), *Pseudecheneis*, *Nemacheilus* and *Tor chilinoides* (Fig. 1).

a. Brown trout (*Salmo trutta*)

b. *Schizhothorax* sp.

c. *Pseudecheneis sulcatus*

***d. Nemacheilus* sp.**

e. Tor chilinoides

Figure 1. Fish species recorded from river Asiganga in the year (2009-10, 2010-11 and 2011-12)

The number of fish on monthly basis representing the population of Brown trout and other fish species in river Asiganga at site CBT 1 (Control Brown Trout 1), site 1 (Sangamchatti), site 2 (Rawara) and site 3 (Gangori) are presented in Fig. 2. Site CBT 1 was chosen for representing control site for brown trout as only *Salmo trutta* were present while sampling at this site (4±0.13). No *Schizothorax* sp., *Noemacheilus* sp. and *Pseudecheneis sulcatus* Mc. (McClelland) were recorded during all the three year (2009-2012) at this CBT 1 site.At site 1 the maximum number of fish recorded were *Salmo trutta* (12±0) followed by *Schizothorax* sp. (4±0), *Nemacheilus* sp. (1±0) and *Pseudecheneis sulcatus* Mc. (1±0) during all three year (2009-2012). Also, in site 2 maximum number of fish recorded for *Schizothorax* sp. (12±1) followed by *Salmo trutta* (8.64±0), *Nemacheilus* sp. (2±0) and *Pseudecheneis sulcatus* Mc. (1±0) during three years of study (2009-2012). But in site 3 the trend was drastically changed. Maximum number of fish was recorded for *Schizothorax* sp. (15±1) followed by *Salmo trutta* (5±0), *Pseudecheneis sulcatus* Mc. (1±0), *Nemacheilus* sp. (1±0) and *Tor Chilinoides* (1±0) during all the three years of study. The number of *Salmo trutta* and *Schizothorax* sp. may vary but other fish species were also present in lower number. *Tor Chilinoides* was present only at site 3 i.e., Gangori (Altitude: 1160m).One of important pointers from our sampling data was that *Salmo trutta* was sampled from all the four sites and all sizes were (weighing from <150g to >550g) were found in each location (Fig. 3). Percentage of different fish species at four sites of river Asiganga on pooled basis (over the years 2009-10, 2010-11 and 2011-12) are represented in Table 1. The CBT 1 site had highest percentage for *Salmo trutta* (100%). In site 1, *Salmo trutta* (69.97%) was a major group followed by *Schizothorax* sp. (25.40%), *Noemacheilus* sp. (2.56%), *Pseudecheneis sulcatus* Mc. (2.07%). At site 2 *Schizothorax* sp. (50.11%) was most abundant followed by *Salmo trutta* (36.25%), *Pseudecheneis sulcatus* Mc. (7.93%) and *Noemacheilus* sp. (5.71%). At site 3, highest percentage was that of *Schizothorax* sp. (67.48%) followed by Brown trout (20.29%), *Pseudecheneis sulcatus* Mc. (5.87%), *Noemacheilus* sp. (3.79%) and *Tor Chilinoides* (3.86%).

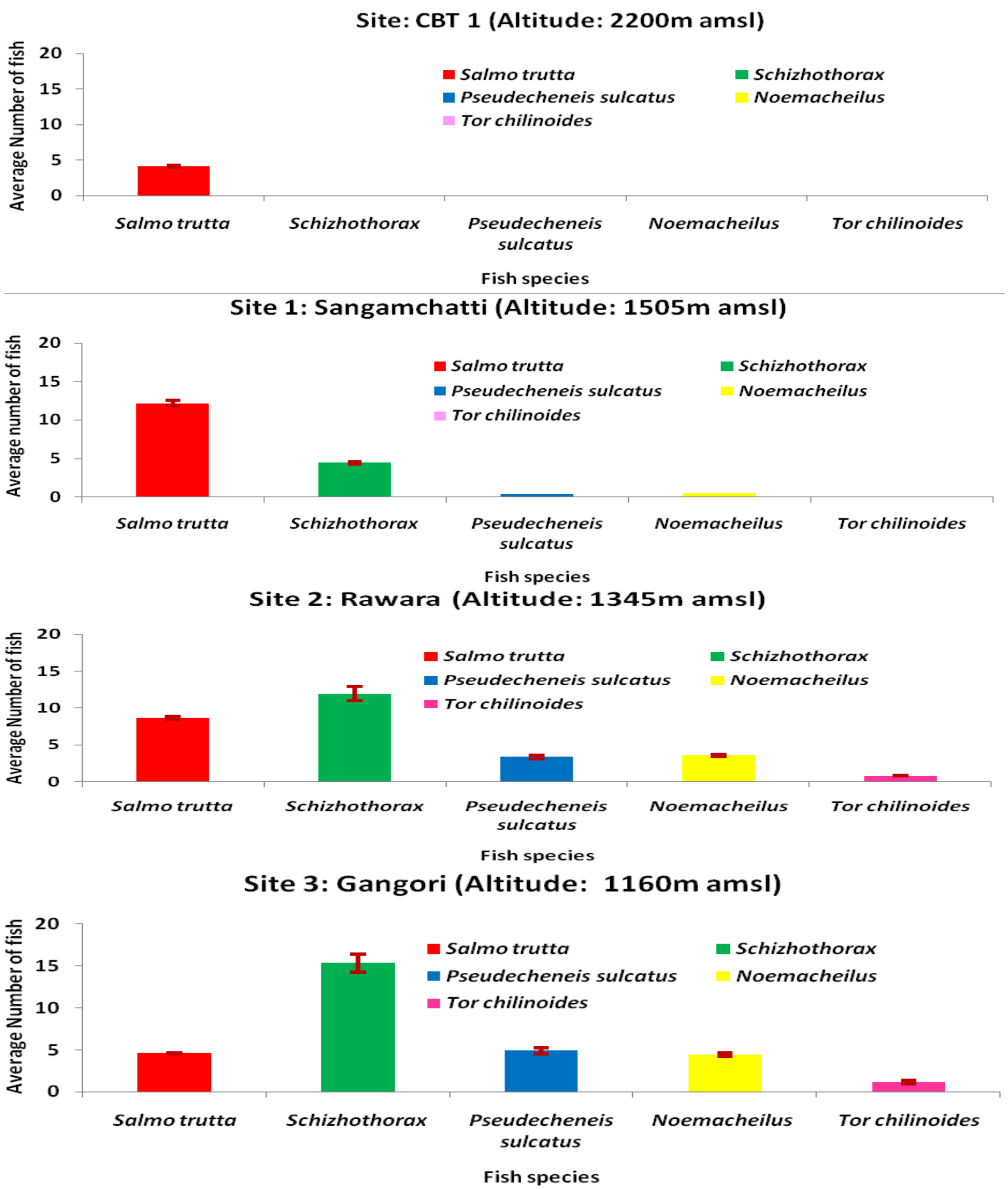


Figure 2. Altitudinal variation of fish species in river Asiganga (2009-10, 2010-11 and 2011-12). *Salmo trutta* was presnet in all four sites. CBT 1 site was dominated by *Salmo trutta.* At Site 1, *Salmo trutta* was the dominant fish species. *Schizhothorax* sp. was found to be dominated in site 2 and site 3, respectively at lower altitudes. *Tor Chilinoides* was rarely found only at site 3 and absent in the other two sites.

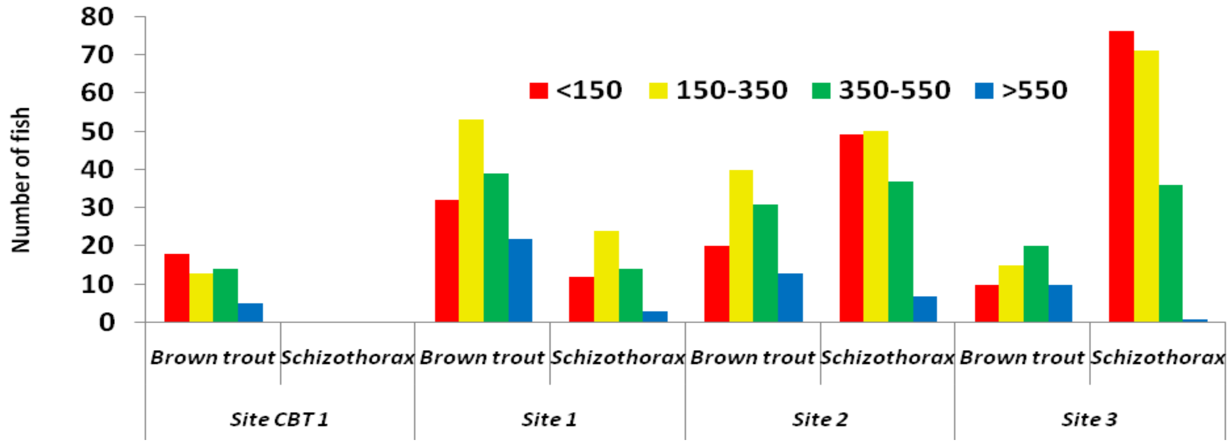


Figure 3. Graph representing the number of fish on class interval pattern as per weight of fishes in gram. Brown trout and *Schizothorax* sp. Brown trout represented by different sizes and weight categories are found at all the sites. This suggests that finding brown trout at lower altitudes is not a random occurrence but these are distinct groups will all sizes and age groups

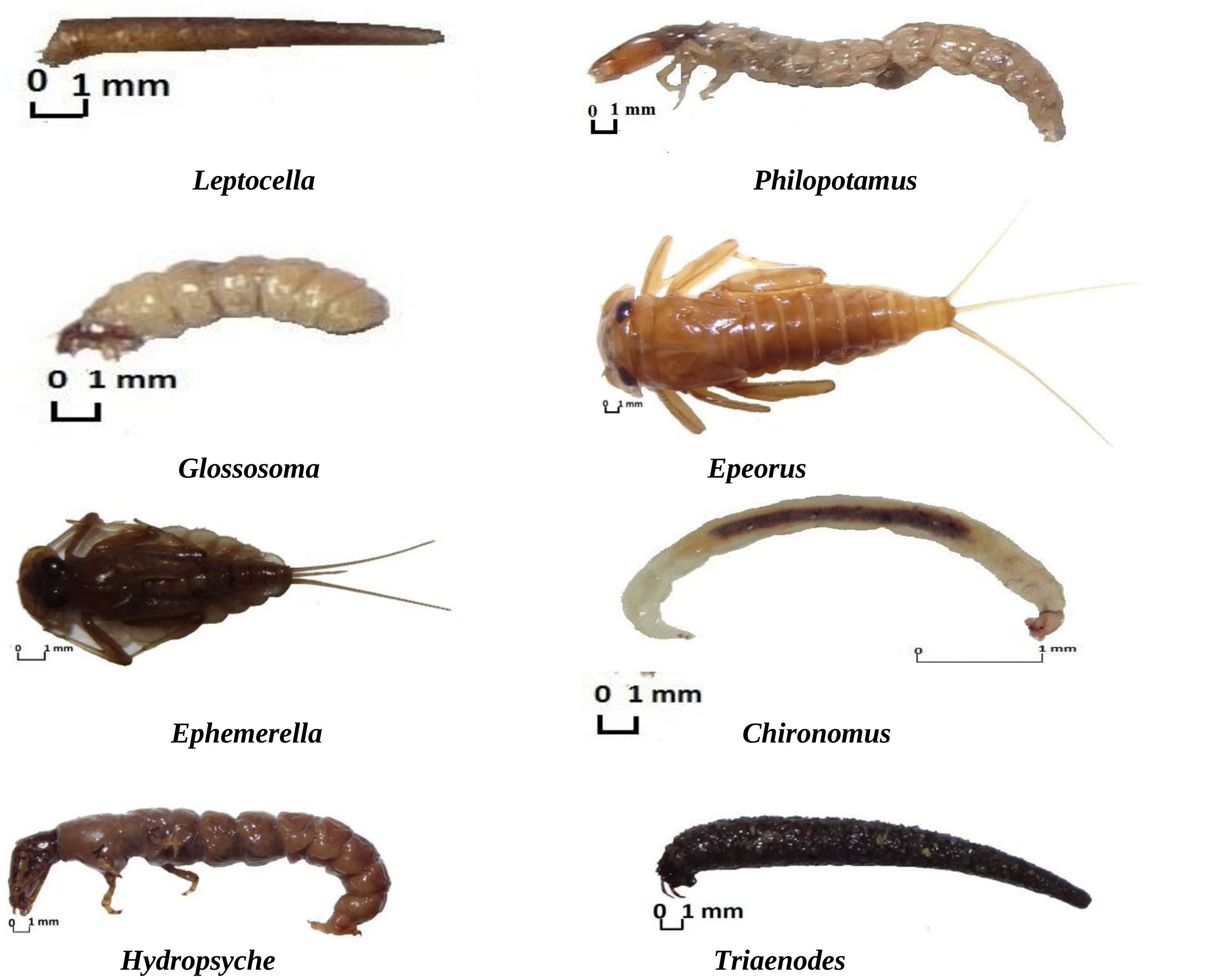


Figure 4. Macrobenthos recorded from river Asiganga in the year (2009-10, 2010-11 and 2011-12)

Table 1. Percentage of different fish species at four sites in river Asiganga from year 2009-10 to 2011-12.

Fish species	Site CBT 1 (%)	Site 1 (%)	Site 2 (%)	Site 3 (%)
Salmo trutta	100	69.97	36.25	20.29
***Schizhothorax* sp.**	--	25.40	50.11	67.48
Pseudecheneis sulcatus	--	2.07	7.93	5.87
***Noemacheilus* sp.**	--	2.56	5.71	3.79
Tor chilinoides	--	--	-	2.57

Table 2. Average number of fish (*Salmo trutta* and *Schizothorax* sp.) on yearly basis representing the class interval pattern (on weight basis).

Class Interval (weight in gram)	Site CBT 1		Site 1		Site 2		Site 3	
	Salmo trutta	***Schizothorax* sp.**	***Salmo trutta***	***Schizothorax* sp.**	***Salmo trutta***	***Schizothorax* sp.**	***Salmo trutta***	***Schizothorax* sp.**
<150	18	0	32	12	20	49	10	76
150-350	13	0	53	24	40	50	15	71
350-550	14	0	39	14	31	37	20	36
>550	5	0	22	3	13	7	10	1
Total	**50**	**0**	**146**	**53**	**103**	**143**	**55**	**184**

Table 3. Macrobenthos recorded from river Asiganga in the year 2009-10, 2010-11 and 2012-13.

Phylum	Class	Order	Family	Genus
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	*Ephemerella*
			Heptageniidae	*Epeorus*
			Baetiade	*Baetis*
		Trichoptera		*Triaenodes*
			Leptoceridae	*Leptocella*
			Limnephilldae	*Limnephilus*
			Hydropsychidae	*Hydropsyche*
			Philopotamidae	*Philopotamus*
			Glossomatidae	*Glossosoma*
				Agapetus
		Diptera	Simuliidae	*Simulium*
			Chironomidae	*Chironomus*

The average number of *Salmo trutta* (Brown trout, BT) and *Schizothorax* sp. (Snow Trout, ST) were represented as a class interval pattern as per weight (in gram) category in Table 2. Highest average number of BT were found at site 1 (146) followed by site 2 (103), site 3 (55) and site CBT 1 (50). Similarly, the ST was represented in the anti parallel manner. Highest average number were found in site 3 (184) followed by site 2 (143) and site 1 (53). Moreover, in class interval (CI) weight distribution pattern, 53 number of BT were recorded weight between (150-350)g followed by 39 BT for 350-550g, 32 BT for <150g and 22 Brown trout for >550g at site 1. Also, for ST highest number (76) of fish found in <150g weight category along with 71 number of fish in (150-350) g at site 3 followed by 37 fishes under 350-550g and 7 fishes under >550g weight category at site 2.

The benthic macro-invertebrates appear to be intimately related with the changing environment by causing and effective pathways. The alterations produced in the physical and chemical status of the riverine ecosystem become recognizable through elasticity of the community structure of the organisms expressible numerically as an index (Wilhm and Dorris, 1966). Thus, benthic macro-invertebrates make ideal subject for such studies and hence have often been used for biological assessment of water quality. The major objectives of the present investigation were fixed to measure the abundance and distribution of different macro benthos in the river and establish Shannon-Wiener Index for the benthic organisms to determine the species diversity of the river Asiganga. A total of twelve (12) genera of benthos viz. *Ephemerella*, *Epeorus*, *Baetis*, *Triaenode*, *Leptocella*, *Limnephilus*, *Hydropsyche*, *Philopotamus*, *Glossosoma*, *Agapetus*, *Simulium* and *Chironomus* were collected and identified from the river Asiganga (Table 3 and Fig. 4) from October to June of all the three years from 2009-10 to 2011-12. It included ten families, 3 orders and 1 class. The highest number of benthos genera belonged to order Trichoptera followed by Ephemeroptera and Diptera. Therefore, Shannon-Weaver (S-W) Diversity Index (*H*), Richness Index (d') and Evenness Index (e) of benthos of river Asiganga during 2009-10, 2010-11 and 2011-12 were presented in Table 4. Also, the S-W Diversity Index (H'), Richness Index (d') and Evenness Index (e) of benthos of river Asiganga for three years (2009-10, 2010-11 and 2011-12) were represented in Table 5.

Shannon-wiener diversity index ($\overline{H}$)

The Shannon-wiener diversity index showed a range of diversity varied from 1.309 to 2.811 for site 1; 0.811 to 2.519 for site 2 and 0.577 to 2.549 for site 3, respectively. In pooled analysis over the years diversity index ranged from 1.345 to 2.433 for site 1; 0.878 to 2.146 for site 2 and 1.007 to 2.304 for site 3, respectively (Table 4 and 5).

Richness Index (d')

The benthos species richness was ranged from 0.758 to 2.265 for site 1; 0.434 to 2.175 for site 2 and 0.254 to 2.308 for site 3, respectively. Richness Index for pooled analysis over the years varied from 0.966 to 1.607 for site 1; 0.565 to 1.722 for site 2 and 0.541 to 1.959 for site 3, respectively (Table 4 and 5).

Evenness Index (e)

The evenness index of benthos varied from 0.812 to 0.981 at site 1, while it ranged from 0.469 to 0.970 for site 2 and ranged from 0.478 to 0.971 for site 3, respectively. In pooled analysis over the years Evenness Index ranged from 0.875 to 0.959 for site 1; 0.584 to 0.960 for site 2 and 0.591 to 0.869 for site 3, respectively (Table 4 and 5). The physico-chemical characters are the important parameters in determining the health and ecology of freshwater river and streams. The aquatic biodiversity depends upon the abiotic factors such as temperature, pH etc. Therefore, assessments of these parameters help in knowing the habitat and food habit of aquatic species dominating in the river/stream fauna i.e. fish species.The results regarding mean performances of different physico-chemical parameters *viz*. water temperature [surface temperature (^{0}C) and depth temperature (^{0}C)], DO (mg/l), free CO_2 (mg/l), alkalinity (mg/l), pH, turbidity NTU (mg/l) at each site and for each month along with general mean, standard error of mean and range are presented in Table 6 for all three years (2009-2010, 2010-2011 and 2011-2012), respectively. Moreover, the t-test was conducted to understand the variation among physico-chemical parameters taken at three sites i.e., site 1, site 2 and site 3, respectively (Table 7). t-test showed significant variation between site 1 and site 3 for all the characters studied except for pH.Altitudinal variation of fish species in rivers and streams is well known. Altitudinal zonation of fish species occur in response to factors operating differentially across altitudes. Over all the variation in seasonal distribution and relative abundance of fish fauna is directly related to change in physico-chemical nature of stream, variation in altitude and longitude (Bisht, 2009). In the present study period (2009-2012) four major fish species were found at all the three sites but one fish species *Tor chilidnoides* were present only at site 3 i.e., Gangori. Three species (*Shizhothorax* sp.,

Table 4. Diversity Index ($\overline{H}$), Richness Index (d’) and Evenness Index (e) of benthos in river Asiganga during the year 2009-10, 2010-11 and 2011-12

	Site 1			Site 2			Site 3		
	$\overline{H}$	d'	e	$\overline{H}$	d'	e	$\overline{H}$	d'	e
2009-10									
JUL	-	-	-	-	-	-	-	-	-
AUG	-	-	-	-	-	-	-	-	-
SEP	-	-	-	-	-	-	-	-	-
OCT	1.522	1.243	0.960	0.811	0.721	0.811	1.459	1.116	0.921
NOV	1.359	1.251	0.929	2.122	1.737	0.914	1.892	1.329	0.732
DEC	1.459	1.116	0.921	1.522	1.243	0.960	1.320	0.932	0.660
JAN	1.837	1.365	0.918	2.108	1.412	0.908	1.827	1.478	0.651
FEB	1.943	0.921	0.972	1.469	0.434	0.469	2.345	1.430	0.907
MAR	2.145	1.200	0.881	1.325	0.805	0.836	0.758	0.525	0.478
APR	1.555	0.805	0.981	1.669	1.170	0.835	0.971	0.369	0.971
MAY	2.102	1.259	0.905	1.837	1.365	0.918	0.577	0.254	0.577
JUN	1.859	1.251	0.929	1.486	0.869	0.917	1.501	1.073	0.935
2010-11									
JUL	-	-	-	-	-	-	-	-	-
AUG	-	-	-	-	-	-	-	-	-
SEP	-	-	-	-	-	-	-	-	-
OCT	1.561	0.962	0.980	0.863	0.514	0.863	1.352	0.910	0.853
NOV	1.379	1.028	0.870	2.197	1.820	0.946	1.900	1.385	0.735
DEC	1.531	0.910	0.966	1.706	1.001	0.853	2.116	1.501	0.819
JAN	1.863	0.914	0.863	2.013	1.470	0.779	2.537	2.308	0.800
FEB	1.873	1.059	0.936	1.592	0.879	0.592	2.248	1.355	0.870
MAR	2.694	2.006	0.850	2.509	2.135	0.839	1.861	1.511	0.663
APR	1.557	0.758	0.982	1.555	1.108	0.777	0.592	0.514	0.592
MAY	2.144	1.125	0.923	1.459	0.692	0.921	2.095	1.941	0.924
JUN	1.868	1.251	0.934	1.555	0.805	0.981	1.562	1.485	0.859
2011-12									
JUL	-	-	-	-	-	-	-	-	-
AUG	-	-	-	-	-	-	-	-	-
SEP	-	-	-	-	-	-	-	-	-
OCT	1.379	1.028	0.870	0.970	0.434	0.970	2.412	1.949	1.379
NOV	1.309	0.834	0.826	2.118	1.610	0.912	1.478	1.338	1.309
DEC	2.092	1.477	0.901	1.825	1.019	0.912	1.958	1.485	2.092
JAN	2.811	2.265	0.937	1.959	1.485	0.758	2.549	2.090	2.811
FEB	2.491	1.418	0.964	1.097	0.558	0.692	2.137	1.207	2.491
MAR	2.461	1.616	0.877	1.461	1.511	0.521	1.893	1.653	2.461
APR	2.121	1.335	0.914	1.383	0.932	0.692	1.457	0.739	2.121
MAY	1.625	0.957	0.812	1.459	0.692	0.921	2.527	1.888	1.625
JUN	1.309	0.834	0.826	1.555	0.805	0.981	1.423	1.618	1.309

Table 5. Average Diversity Index ($\overline{H}$), Richness Index (d') and Evenness Index (e) of benthos in river Asiganga on pooled basis (2009-10, 2010-11 and 2011-12).

	2009-10, 2010-11 and 2011-12								
	Site 1			**Site 2**			**Site 3**		
	$\overline{H}$	**d'**	**e**	$\overline{H}$	**d'**	**e**	$\overline{H}$	**d'**	**e**
JUL	-	-	-	-	-	-	-	-	-
AUG	-	-	-	-	-	-	-	-	-
SEP	-	-	-	-	-	-	-	-	-
OCT	1.497	1.078	0.929	0.878	0.565	0.584	1.741	1.325	0. 591
NOV	1.345	1.038	0.875	1.765	0.896	0.924	1.757	1.371	0.685
DEC	1.798	1.168	0.939	1.684	1.088	0.908	1.788	1.336	0.745
JAN	2.171	1.515	0.906	2.027	1.722	0.815	2.304	1.959	0.759
FEB	2.102	1.133	0.957	1.386	1.634	0.960	2.243	1.331	0.868
MAR	2.433	1.607	0.881	2.146	1.494	0.732	1.524	1.230	0. 869
APR	1.784	0.966	0.959	1.536	1.070	0.768	1.007	0.541	0.827
MAY	1.957	1.114	0.880	1.590	0.916	0.920	1.733	1.361	0.800
JUN	1.679	1.112	0.896	1.532	0.831	0.881	1.495	1.392	0.868

Table 6. Monthly recorded physico-chemical parameters (Mean ± SEM) of river Asiganga at sites (Site 1, Site 2 and Site 3) in the year (2009-10, 2010-11 and 2011-12)

Mean	**Air Temperature (^{0}C)**			**Water Temperature (^{0}C)**			**Dissolved Oxygen (mg/l)**			**Free CO_2 (mg/l)**		
	Site 1	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
Jul	17.6±0.33	19±0.58	23.0±0.33	16.6±0.33	18.0±0.58	20.0±0.58	7.0±0.88	6.6±0.88	5.7±0.33	3.2±0.09	3.6±0.08	4.3± 0.08
Aug	17.0±0.33	18.3±0.33	22.6±0.88	15.6±0.33	17.0±0.58	19.0±0.58	7.2±0.99	6.6±0.21	5.3±0.23	2.3±0.12	3.4±0.12	3.5±0.12
Sep	15.0±0.67	17.6±0.88	19.0±0.33	14.3±0.33	15.6±0.67	17.3±0.33	9.0±0.58	8.9±0.17	8±0.99	2.1±0.06	2.5±0.09	2.8±0.09
Oct	13.0±0.58	18.6±0.88	21.0±0.58	10±1.16	12.3±1.21	15.0±1.16	9.4±0.31	9.0±0.38	7.7±0.54	2.3±0.07	2.5±0.03	3.1±0.28
Nov	9.3.0±0.88	13.0±0.58	17.6±0.88	8±0.58	11.3±0.33	13.6±0.88	9.4±0.11	8.3±0.27	7.5±0.18	2.5±0.18	2.9±0.09	3.5±0.07
Dec	6.6±1.21	9.6±1.21	12.0±0.57	5.3±0.88	8.3±0.88	10.6±0.33	10.8±0.07	9.7±0.07	9.5±0.19	1.2±0.12	1.8±0.09	2.3±0.12
Jan	5.7±0.37	7.8±0.73	10.8±0.73	4.3±0.35	7.0±0.58	9.2±1.27	9.7±0.57	9.3±0.34	8.2±0.41	1.2±0.15	2.4±0.12	3.4±0.06
Feb	10.6±0.75	11±0.64	12.8±0.69	8.6±0.63	9.4±0.69	10.4±0.32	10.4±0.36	8.8±0.48	8.1±0.29	1.2±0.12	1.7±0.06	2.6±0.15
Mar	11.2±0.64	14.5±0.29	15.0±0.58	9.8±0.83	12.2±0.93	12.6±1.45	8.2±0.23	7.5±0.37	7.2±0.69	2.2±0.06	2.6±0.09	3.0±0.09
Apr	14.5±1.51	17.6±1.31	18.6±0.33	10.1±0.44	12.1±1.17	14.6±1.2	8.6±0.32	8.4±0.12	7.6±0.32	3.0±0.06	3.2±0.09	3.5±0.09
May	15.6±0.88	17.6±0.67	20.3±0.88	14.3±0.67	16.3±0.33	19.0±0.58	8.0±0.12	7.5±0.33	7.0±0.08	2.4±0.26	2.6±0.13	3.3±0.18
Jun	15.3±0.88	17.3±0.33	20.6±0.67	14.3±0.88	16±0.58	18.3±0.67	7.3±0.33	6.8±0.19	6.3±0.13	2.7±0.15	3.4±0.21	3.9±0.58
Rang e	5.7±0.37- 17.6±0.33	7.8±0.73- 19±0.58	10.8±0.73 23.0±0.33	4.3±0.35- 16.6±0.33	7.0±0.58- 18.0±0.58	9.2±1.27- 20.0±0.58	7.0±0.88- 10.8±0.07	6.6±0.21- 9.7±0.07	5.3±0.23- 9.5±0.19	1.2±0.12- 3.2±0.09	1.7±0.06 - 3.6±0.08	2.6±0.15- 4.3±0.08

Mean	Alkalinity (mg/l)			pH			Turbidity (NTU)		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Jul	13.5±0.97	18.2±2.61	21.2±2.35	7.0±0.03	7.1±0.06	7.2±0.12	2.7±0.06	3.0±0.33	4.7±0.33
Aug	13.7±0.55	15.4±0.95	18.4±0.19	7.1±0.06	7.1±0.17	7.1±0.02	7.5±0.39	8.3±0.13	9.5±0.09
Sep	13.6±0.99	15.8±0.17	16.3±0.38	7.4±0.13	7.5±0.06	7.5±0.03	7.3±0.12	8.1±0.37	9.5±0.61
Oct	15.5±0.5	17.9±0.48	21.4±0.45	7.4±0.21	7.5±0.12	7.5±0.03	1.0±0.09	2.0±0.12	1.8±0.31
Nov	9.3±0.56	13.5±0.85	18.7±0.43	7.4±0.09	7.7±0.03	7.6±0.07	1.6±0.12	2.0±0.12	4.1±1.62
Dec	6.2±0.23	9.2±0.95	13.1±0.19	7.8±0.03	7.6±0.03	7.6±0.01	0.4±0.09	0.9±0.12	1.5±0.06
Jan	9.9±0.32	12.6±0.49	15.7±0.95	7.6±0.19	7.5±0.09	7.5±0.03	1.5±0.22	2.4±0.06	3.4±0.20
Feb	13.5±0.32	15.9±0.74	17.6±0.64	7.6±0.09	7.6±0.03	7.4±0.01	1.3±0.33	1.7±0.19	2.2±0.15
Mar	9.4±0.43	16.6±0.88	17.8±0.58	7.3±0.15	7.4±0.13	7.4±0.01	2.1±0.26	2.4±0.19	3.1±0.13
Apr	12.6±0.15	19.7±0.58	23.9±0.46	7.6±0.37	7.5±0.35	7.4±0.34	2.2±0.41	2.9±0.52	3.3±0.57
May	12.0±0.69	22.0±0.87	22.7±1.09	7.4±0.03	7.4±0.09	7.1±0.08	2.6±0.28	3.6±0.22	3.6±0.31
Jun	23.3±0.62	23.4±1.04	26.7±0.79	7.4±0.15	7.3±0.06	7.6±0.05	2.6±0.37	3.3±0.03	4.5±0.17
Range	6.2±0.23- 23.3±0.62	9.2±0.95- 23.4±1.04	13.1±0.19 26.7±0.79	7.0±0.03 7.8±0.03	7.1±0.06 7.7±0.03	7.1±0.02 7.6±0.07	0.4±0.097 .5±0.39	0.9±0.12 8.3±0.13	1.5±0.06 -9.5 ±0.6

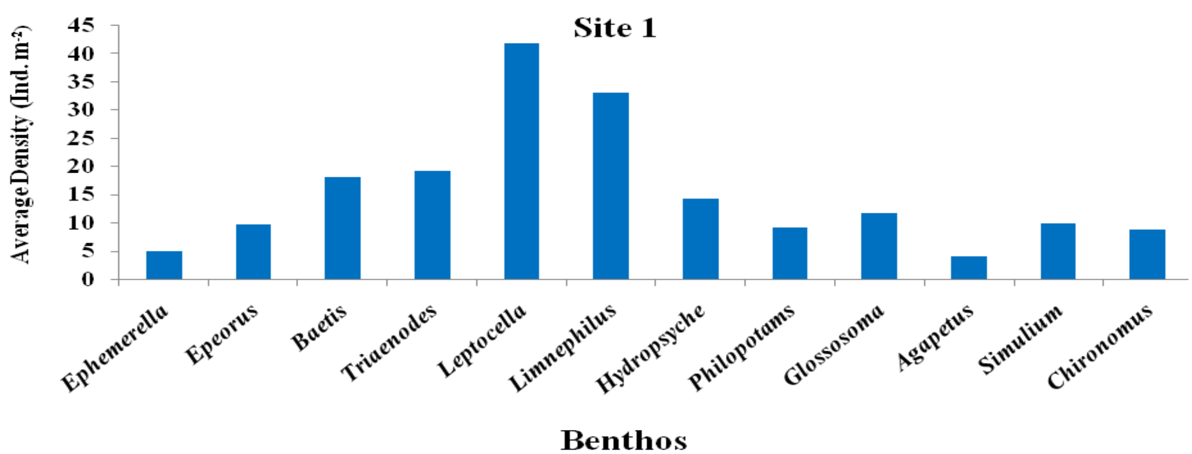
Table 7. t-test among different physico-chemical parameters representing the variability between sites (Site 1 vs Site 2, Site 2 vs Site 3, and Site 1 vs Site 3).

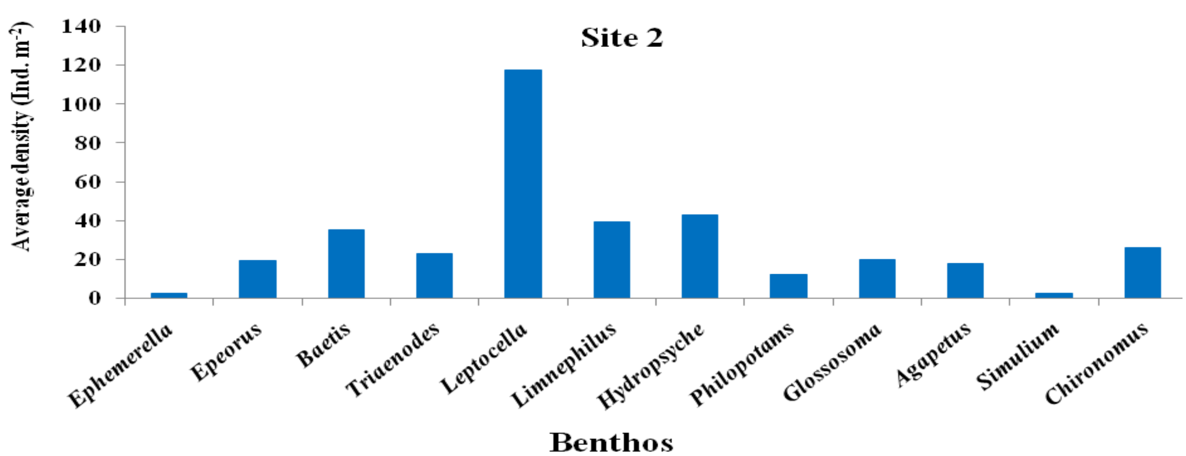
Months	Air Temperature			Water Temperature			Dissolved Oxygen			Free CO_2			Alkalinity			pH			Turbidity		
	Site 1 vs Site 2	Site 2 vs Site 3	Site 1 vs Site 3	Site 1 vs Site 2	Site 2 vs Site 3	Site 1 vs Site 3	Site 1 vs Site 2	Site 2 vs Site 3	Site 1 vs Site 3	Site 1 vs Site 2	Site 2 vs Site 3	Site 1 vs Site 3	Site 1 vs Site 2	Site 2 Vs Site 3	Site 1 vs Site 3	Site 1 vs Site 2	Site 2 vs Site 3	Site 1 vs Site 3	Site 1 vs Site 2	Site 2 vs Site 3	Site 1 vs Site 3
Jul	2.00	6.51**	12.02***	2.00	2.45	5.00**	3.48*	9.19***	13.79***	3.50*	5.61**	8.75***	1.70	0.85	3.02*	1.99	0.25	1.34	0.81	3.61*	5.81**
Aug	2.12	4.60*	5.66**	2.00	2.45	5.00**	2.59	3.41*	6.57**	6.74**	0.61	7.35**	1.49	3.16*	8.15**	0.38	0.01	0.29	1.80	7.60**	4.94**
Sep	1.91	1.83	4.91**	1.79	2.24	6.36**	1.10	5.00**	9.53***	4.43*	2.41	7.27	2.19	1.34	2.62	0.23	0.51	0.49	2.03	2.00	3.57
Oct	2.34	2.24	9.80***	1.40	1.60	3.06*	0.74	1.97	2.70	3.13*	2.18	2.97*	3.48*	5.30**	8.8***	0.28	0.27	0.49	8.41**	0.61	2.53
Nov	3.48*	4.43*	6.68**	5.00**	2.48	5.38**	3.67*	2.36	9.04***	1.86	5.73**	5.30**	4.09*	5.48**	13.26***	2.83*	0.89	1.81	2.36	1.32	1.56
Dec	1.76	1.75	4.00*	2.41	2.48	5.66**	11.66***	1.27	6.48**	4.02*	3.21*	6.40**	3.04*	4.07*	23.14***	3.54*	1.99	4.24	3.53*	4.25*	9.81***
Jan	3.21*	2.92*	6.80**	4.00*	1.62	3.78*	0.55	2.07	2.09	6.19**	7.25**	13.65***	4.71**	2.86*	5.81**	0.49	0.35	0.71	3.65*	5.06**	6.32**
Feb	0.44	1.84	2.14	0.85	1.35	2.59	2.56	1.31	4.93**	3.25*	5.97**	7.25**	2.94*	1.78	5.77**	0.36	1.39	1.57	2.46	1.98	6.24**
Mar	4.70**	0.67	4.35*	1.94	0.23	1.69	1.60	0.38	1.37	4.11*	3.21*	7.91**	7.29**	1.13	11.51***	0.66	0.20	0.55	0.98	2.92*	3.34*
Apr	1.58	0.73	2.71	1.60	1.49	3.52*	1.37	1.18	2.06	2.21	2.41	5.06**	11.89***	5.70**	23.39***	0.26	0.07	0.33	1.02	0.52	1.54
May	1.81	2.42	3.74*	2.68	4.00*	5.29**	3.61*	5.30**	6.42**	0.57	3.32*	2.86*	9.01***	0.47	8.22**	0.32	2.01	3.18*	2.71	0.08	2.23
Jun	2.12	4.47*	4.82**	1.58	2.65	3.62*	1.47	1.94	2.92*	2.50	2.31	7.25**	0.08	2.58	3.46*	0.61	0.94	0.61	1.90	6.62**	4.60*

***, **, *** = Significance at 5%, 1% and 0.1% probability levels, respectively**.

Psudecheneis sulcatus and *Nemacheilus* sp.) increases towards downriver but brown trout decreases from upriver to downriver gradient (Fig. 1). Main cause is due to slight increase in average temperature towards lower portion of the river. This pattern of distribution of native and non native fish species can be summarized in three parts. Brown trout showed its cold water dominance at high altitude. At site CBT 1 (Altitude: 2200m) other species were not found because there are very few connecting small catchment streams. Any connecting catchment stream also has a very steep gradient and the water temperature doesn't support other hilly stream fishes. Hence, only Brown trout survives at this site and above this altitude. In other sites below CBT 1 site, the connecting streams have hill stream fish species. These species (*Schizothorax* sp., *Pseudecheneis sulcatus* Mc., *Nemacheilus* sp. and *Tor Chilinoides*) were recorded to be coexisting with Brown trout in river Asiganga. Silsbee and Larson (1982) reported that the streams at higher elevation, especially the low-gradient sections, are colder in summer as described in stream of Rock Creek. Similarly, Bistoni *et al.* (2002) explained that the number of fish species increases along the downriver gradient and showed that changes in the fish assemblage composition of the eastern region of the province of Cordoba of Argentina. Every fish species has a specific thermal physiology and therefore its distribution is reflected by the spatial arrangement as per required temperature within a river network. The varied distribution pattern, one species replacing other along the altitudinal gradient is observed commonly in Mountain Rivers and streams throughout the world (Bozek and Hubert, 1992; Magoulick and Wilzbach, 1998; Taniguci and Nakano, 2000; McHugh and Budy, 2005). This phenomenon termed as altitudinal species zonation can also occur locally due to biotic and abiotic factor interaction. In one of the extensively studied species–Salmon, temperature mediated competition plays a vital role in its distribution pattern along altitude gradient of a fresh water system (Fausch *et al*. 1994; Franco and Budy, 2005; Mchugh and Budy, 2005). Second, the average number of *Salmo trutta* (Brown trout) in the main river was much greater, which provides greater potential for adult Brown trout to invade the tributaries lower down (Fig. 3). Our data suggests that Brown trout present in all the sampling site representing highest number (146 at site 1 followed by 103 at site 2, 55 at site 3 and 50 at site CBT 1) at upper sites of river Asiganga (Table 2). Besides their numbers entire spectrum of fish population from size 0-10g to over 350g were sampled in each site. This suggests that finding of Brown trout at all the sites are not just coincidence and that the fish just did not reaches there by chance (either due to wash off or just wandering off). Entire spectrum of population was present at each site so it is being suggested that they are properly establishing at their population at these locations. Breeding of Brown trout at these locations needs to be verified. Higher fish diversity was always observed at downstream sites but Brown trout population densities decreases downstream (Lobon-corvia *et al*. 1986; Maisse and Bagliniere, 1990; Rodrigues, 1995). It may be due to the increase in temperature toward the downstream. It is also hypothesized that species inhabiting higher elevations are superior competitors at lower temperature while species inhabiting lower altitude are better competitors at warmer temperature. Each species might be capable of surviving at all temperatures in the absence of competition (Taniguchi and Nakano, 2000). Brown trout is a native of cold stream and was the only species present at all sampling site, representing more than 50% of the total catch at upstream site. These results are in agreement with the previous finding and suggested that Brown trout is widespread in the basin of River Lima, Portugal (Valente, 1990, 1993; Goncalves, 1996). Trout population in the Michigan's Au Sable River, USA (United State of America) varied considerably over the study period at some sites; supported greater trout densities than other site (Zorn and Nuhter, 2007). In the present study the number of Brown trout on weight basis varied considerably with in tributaries sampled for population estimates analysis (Table 2). Highest number of BT was 53 recorded at Site 1 in 150-350g weight category and lowest number (10) was observed at Site 2 in <150g and >550g weight category, respectively. The Brown trout in this manner establishes its population all along the river Asiganga gradient. Whereas, highest number of *Schizothorax* sp. (76) were observed in <150g weight category and the lowest number (1) were recorded in >550g weight category at Site 3 (down river) (Table 2). In the other studied tributaries and upstream of River Vade, mean estimated trout occurred in higher number in upstream stretches of River Vade and Estoraos, Portugal (Maia and Valente, 1999). In case of Brook Trout (*Salvelinas fontinalis*) is the native *Salmonid* species of stream in southern

Appalachian mountain, USA. It presently distributed from Head water to lower reaches of largest stream (Larson *et al*. 1995). It seems that Brown trout was slowly encroaching upon the *Schizothorax* sp. waters down the river. This study documented differences in the distributions of native *Schizothorax* sp. and non native Brown trout in different sections of river Asiganga. It has been documented that non native rainbow trout were present in Rock Creek river, USA from 1979 to 1993 and that the brook trout-rainbow trout associations was found related to differences in habitat in those stream sections (Moyle and Vondracek, 1985). Moreover, in Rock Creek river very much different observed by others (Larson and Moore, 1985; Larson *et al*. 1986) from those in other park streams.The data sets suggested the following facts: 1) At site CBT 1 only Brown trout population exist, 2) At site 1 (Sangamchatti) and site 2 (Rawara), Brown trout and *Schizothorax* sp. were present with Brown trout as dominating species and 3) At lowest site (site 3: Gangori) *Schizothorax* sp. was dominated species but entire population of Brown trout also exist. The focus of such studies has changed according to time with factors forming the patterns of species diversity and influence of human impact. Approaches include comparing and modeling species diversity patterns worldwide in relation to human-induced environmental factors, such as land use and climate change (Sala *et al*. 2000). Today, the main parameters of climate e.g., temperature and precipitation are changing rapidly (IPCC, 2007), with drastic consequences for ecosystems, such as species extinction, species shift, changes in species composition and phenologically driven mismatch (Walther *et al*. 2002; Parmesan, 2006). It is pertinent to understand the influence of temperature mediate distribution of species because of the evident threat to endemic native fish population. The taxonomic groups analyzed the methods used and the goals in altitudinal gradient studies vary greatly, as do the results of our studies. Many species groups have been studied: endemic species, exotic species, native species and benthic macro invertebrates. The altitudinal variation is a norm at higher elevation where river always flows from upper to lower part of mountain or hilly terrain. The species could be occurred more at higher elevation and other species at lower down the slope. But in our study, an entire population of Brown trout was found and individuals of all the sizes were sampled at all the sites. The possible reason is that these individuals might be washout due to excessive rainfall and flood. But all sizes of Brown trout at all location suggest occurrence of population as a whole and not the single individuals. Our results also suggest and concluded that Brown trout might be shifting and invading down the river locations as climatic variation and food availability are already present in abundance down the river gradient. Thus, Brown trout might be attempting to colonizes and invade river and is probably exerting dominance over the native fish species i.e., *Schizothorax* sp. Our results also suggested that physico-chemical factors such as temperature and dissolved oxygen were found in suitable range for colonization of Brown trout and spreads effectively over the total range and even lower altitude of river. This conclusion also supported the observation made by Harvey and Stewart (1991) that stated the largest individuals of several fish species were the first to colonize newly created pool in small stream in eastern Tennesse. Our study suggests that Brown trout is slowly expanding to other places from point of introduction and this should be of conservation concern from the point of view of native *Schizothorax* sp. found in the lower region of river Asiganga. Small invertebrates are functionally important in many terrestrial and aquatic ecosystems (Wilson, 1992; Freckman *et al*. 1997; Palmer, 1997; Postel and Carpenter 1997). In freshwater sediments, benthic invertebrates are diverse and abundant, but they are often patchily distributed and relatively difficult to sample, especially when they live in deep subsurface sediments (Covich, 1999). In the present study diversity of macrobenthos was assessed in river Asiganga. The larvae of water insects are the main component of Brown trout food. Also, most of them belong to the class insecta and most preferable were substrate surface or active drifting preys such as Simulids, and classify as order Ephemeroptera (*Ephemerella*, *Baetis*), Trichoptera and Diptera. Further the classifications of macro benthos (genus wise) on average density were represented in Figure 5. Throughout the three year from 2009-10 to 2011-12 highest density of order Trichoptera were found in all months; mostly in January, February and March. Similar kind of trend was observed for Ephemeroptera and Diptera. Also at site 3, total density of benthos were found highest followed by site 2 and smaller density at site 1. It could be concluded that both Ephemeropterans and Trichopterans were present in abundance. Kazlauskas (1963) mentioned Ephemeropterans (both larvae and imago) as predominant food for Brown trout in the eastern part of Lithuania, with Trichopterans as an additional food source. The physico-chemical characteristics of water are important determinant of the aquatic life system. Their characteristics are greatly influenced by climatic condition, vegetation and general composition of water. The present study was carried out from July -2009 to June-2012 at Asiganga river; one of the tributary of Bhagirathi river. However, change in temperature (surface and depth) and alkalinity are present between site1-site 3. The main factor is altitude along the downward gradient of river. Also, the anthropogenic pressure at Gangori (site 3) is quite high due to rampant encroachment at stream banks in the form of shops, hotels, construction, road enlargement, tourism etc. Simultaneously from site 1 to site 3 much small influxes in the form of pollutes, garbage, salts and precipitates of inorganic matters joined the river downward. It causes change in ionic balance of the river particularly at Gangori. The runoff material from these instruments causes degradation of water quality at Gangori. Ultimately it affects the physico-chemical parameters of the river. The physico-chemical parameters are discussed here as below: Water temperature is one of the most important physical parameters, which controls the physiological activities and distribution of biota. For example in our results; site 1 has range from 4.3^0C to 16.6^0C, site 2 has range from 7^0C to 18^0C and for site 3 range from 9.2^0C to 20^0C.





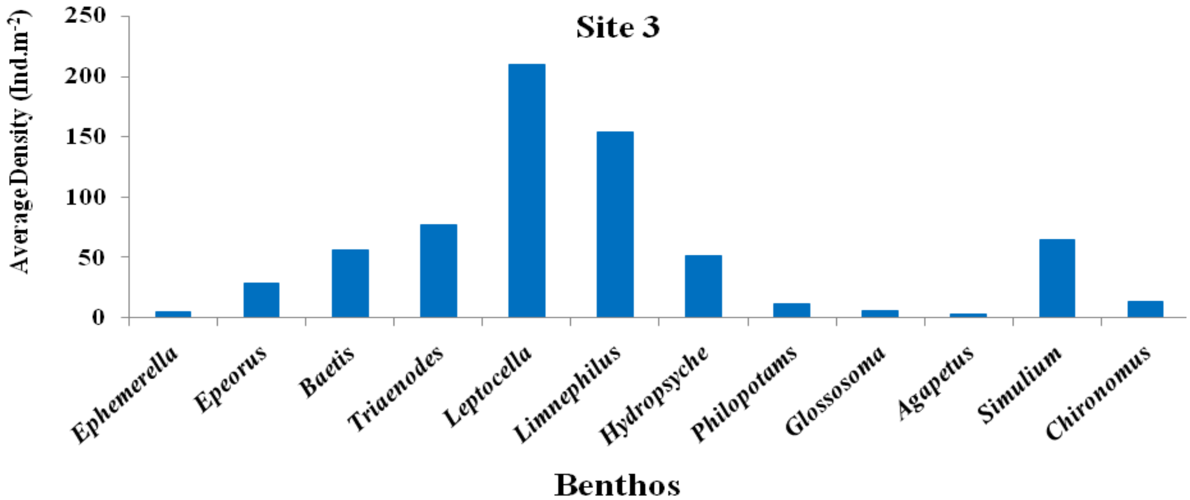


Figure 5. Genus wise average density of macrobenthos. Site 1: Maximum: *Leptocella* (41.975); Minimum: *Agapetus* (3.987); Site 2: Maximum: *Leptocella* (117.646); Minimum: *Ephemerella* and *Agapetus* (2.307) and Site 3: Maximum: *Leptocella* (209.918); Minimum: *Agapetus* (3.075).

Cadwallader (1996) reported that Brown trout can survive in downstream and optimum temperature range varies from 4^0C to 19^0C. Brown trout could be survived at downstream (high temperature i.e., 20^0C) due to its tolerance power and adaptability to local conditions of the habitat. Similar findings were observed by Jhingran and Sehgal (1978) for fingerlings and higher trout fishes as tolerance range of temperature was from 10°C to 21°C.
Thus, keeping in view the global hotspot nature of the study area, a clear redefining of policy would be required. The agencies involved in introduction of exotic species in several rivers of Uttarakhand (India) should take extreme precaution on the long term impact of these introduction and the threat native species.

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