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Impact of Tehri Dam Construction on Biotic and Abiotic Components of River Bhilangana, Central Himalaya, India

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Abstract

Currently, most of the large rivers worldwide have been fragmented due to the construction of hydroelectric dams. River damming has significant impact, not only in inducing the physical obstruction between upstream and downstream, but also a great threat to native biota. To understand the basic changes in biotic and abiotic parameters upstream and downstream of the dam, we investigated the case of river Bhilangana. The river Bhilangana is a snow-fed river, located in the Central Himalaya, which got fragmented in 2004 due to Tehri dam construction. In the present study, we investigated the biotic and abiotic parameters of the river from its three different habitats viz: S-1 (upstream to reservoir site), S-2 (impounded site) and S-3 (downstream to the dam). The analyzed data has revealed significant variations among the studied sites. The water temperature, transparency, pH, nitrate, phosphate increased in impounded site (S-2) while turbidity, water velocity, DO, free CO_2 and alkalinity observe decreased in the impounded site (S-2) in comparison to the natural, free-flowing site (S-1) and downstream site (S-3). The diversity and density of Chlorophyceae members significantly increased in the impounded site (S-2) in contrast to the free-flowing site (S-1) and downstream tail water site (S-3). Great variations in fish assemblages among the fragmented habitats have also been recorded. Only four (04) fish species were recorded from the impounded site (S-2) in comparison to Sixteen (16) species from the downstream site (S-3) and twenty-one (21) fish species from natural free-flowing upstream to reservoir site (S-1).

Keywords: River fragmentation, Ichthyo-faunal diversity, Phytoplankton, Gene pool, Physicochemical Parameters

1. Introduction

Dams and the water reservoirs they create have historically been viewed as a benefit to society. Hydroelectric power projects have provided comparatively cheap electric power for humankind, which is a clean and renewable source of energy when compared with fossil fuel facilities that emit carbon dioxide, nitrous oxide, sulfurous oxides, and other air pollutants (ICOLD, 2000). However, on the other hand, further construction of dams in delivering these services is currently strongly criticized. The extent of dam construction and resulting river fragmentation in the world today are so large that these hydrological alterations have global–scale environmental effects despite the large number of benefits claimed by the development seekers. The discontinuity created by dams in the natural structure and function of a river leads to changes in physical, chemical, and biological conditions both upstream and downstream of the dam (Ward and Stanford, 1995). This affects species composition, trophic community structure and risks to native species (Hoeinghaus *et al.*, 2008). Besides, the hydrologic modification also facilitates invasions by non-native species (Johnson *et al.*, 2008), which are again primary threats to native biodiversity. Alterations to species composition or community structure, due to river fragmentation, may disrupt the trophic levels and thus ecosystem functioning. The habitat fragmentation due to dam construction also leads to decreases in genetic diversity and therefore puts species at greater risk of extinction (Larsen *et al.*, 2005). For these reasons, dams are one of the greatest global threats to freshwater biodiversity. So, the present study aims to investigate the impacts of fragmentation on biotic and abiotic components of river Bhilangana.

2. Materials and Methods

The present study was carried out on river Bhilangana, snow-fed river originating from Khatling glacier (3634 m asl) located in the Central Himalaya, Uttrakhand, India, whose 25 km stretch from Ghansali (870 m asl) to Tehri (750 m asl] got impounded due to Tehri dam construction. Based on the objectives of the study and topographical feature; three sampling sites have been selected viz: – S-1 (at the free-flowing river habitat), S-2 (at mid of reservoir) and S-3 (at downstream to the dam) as shown in Fig.1. Abiotic components were analyzed according to standard methods prescribed in Trivedy and Goel (1986) and APHA (2005). Phytoplanktons were collected by using plankton net of standard bolting silk cloth of standard grade (No. 25). Water samples fixed by neutral Lugol solution were settled for 24 h. The upper layer was then siphoned with a small-diameter silicone tube to a final volume of 30 mL. After mixing, 0.1 mL was dropped into the counting chamber and counted at a magnification of ×400 with a light microscope manufactured by OLYMPUS CX21 (Eker *et al.*, 1999). After checking the whole chamber, the species were then identified to the genus level with the help of standard keys of Needham and Needham (1962). The fish samples were collected with the help of local fishermen and identified up to species level in the laboratory-based on their morphometric and meristic characters. Standard keys, literature and works

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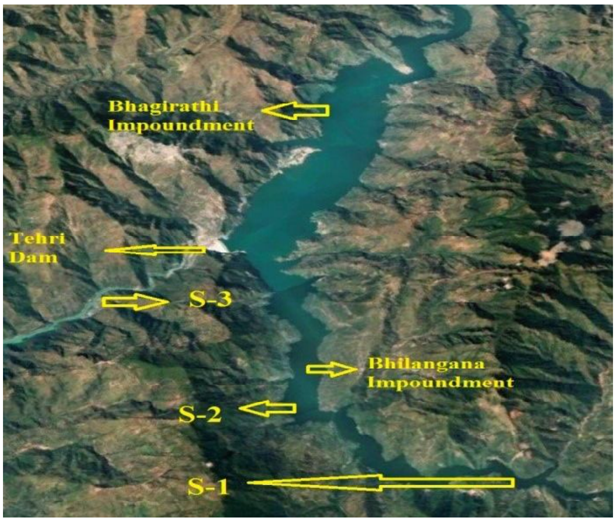

Fig. 1. Location of sampling sites S-1, S-2 and S-3 in study area

of Tilak, (1987), Badola (2009) and Jayaram (2010) were consulted for identification.

3. Results and Discussion

3.1. Impacts on Physiochemical Parameter

3.1.1. Surface Water Temperature

Water temperature is one of the most important abiotic factors affecting the bio-productivity of the aquatic body, solubility of gases, nutrient cycling and water mixing. In the present study, it was observed that annual average of surface water temperature in the impounded site, S-2 (Annual average 21.06±4.96 °C) had been increased ~4.5-5.5 ^{0}C compared to the upstream site, S-1 (Annual average 15.24±4.30 °C) and downstream site, S-3 (Annual average 14.79±2.95°C) as shown in Table 3. It is due to the large surface area of the reservoir, surface heating, thermal stratification and lesser mixing of the water in impounded sites. Similar trends in water temperature with reference to rivers and their reservoir were also noticed by Atobatele *et al.* (2008). The water temperature at S-3 observed moderately low (Annual average 14.79±2.95°C) compared to upstream site S-1(Table.3). This is possibly due to its release from the hypolimnion layer of the reservoir. Similar to our present findings, Liu and Yu, (1992) also recorded low water temperature from downstream of Danjiangkou dam on the Hanjiang River, China.

3.1.2. Transparency

The high transparency of the water body is an indicator of productivity and aquatic ecosystem health. During the present study, the water transparency has been recorded higher in the reservoir site, S-2 (Annual average 85.36±47.72 cm) followed by downstream site, S-3 (Annual average 82.52±44.82cm) and least in lotic site S-1 (Annual average 70.48±45.69 cm) as shown in Table.3. This increased transparency at reservoir site, S-2 can be linked with the reduced water velocity, which leads to settling of silt. Therefore water becomes more transparent, and at the downstream site, S-3 is because most of the suspended sediment particles were trapped within the reservoir. Thus water released downstream was comparatively being clearer, with a lower concentration of suspended sediment. This is further supported by the

Table 1. Ichthyofaunal diversity from fragmented sites, S-1, S-2 and S-3

Family	Sampling Sites		
	S-1 (USR)	S-2 (R)	S-3(DSR)
Cyprinidae	13	4	10
Cobitidae	6	Nil	4
Sisoridae	2	Nil	2
Total	**21**	**4**	**16**

Table 2. Composition of Phytoplankton among the fragmented sites, S-1, S-2 and S-3

Family	Sampling Sites		
	S-1 (USR)	S-2 (R)	S-3(DSR)
Bacillariophyceae	67%	50%	62%
Chlorophyceae	24%	33%	26%
Myxophyceae	9%	17%	12%

USR- upstream to reservoir, R- reservoir and DSR- downstream to reservoir

highly significant negative correlation between water velocity and transparency at upstream site, S-1 ($r = -0.89837$, $P < 0.01$) and downstream site, S-3 (-0.89058, $P < 0.01$) as shown in Table. 4. Ligon *et al.* (1995) also reported that Dams traps the sediments; thus, the water release to downstream be considerably free from suspended matter.

3.1.3. Water Velocity

The velocity (m^{-sec}) is considered as an important character for any river system and plays a vital role in the regulation of the river ecology. Water velocities distribute nutrients, energy, and matter. It plays an important role in species dispersal and is important for fish reproduction (Singh, 2018). In the present investigation, it was observed that water velocity reduced to nil in the impounded site, S-2 and maximum at the downstream site, S-3 (Annual average 0.72 ±0.29 m^{-sec}) followed by the upstream site, S-1 (Annual average 0.86±0.18 m^{-sec}). Further, at upstream site S-1 significant seasonal variations were recorded with high water velocity in summer months and low during winter months because of the snow-fed nature of river Bhilangana. The seasonal variations were less prominent downstream as the downstream flow of water is under the control of dam authority. Furthermore, hourly fluctuations in water velocity were recorded downstream in synchronization to the operation of turbines.

3.1.4. Turbidity

Turbidity is a principal physical characteristic of water and is an expression of clarity of the water. In the present investigation, it was observed that the turbidity reduced in impounded site S-2 (Annual average 5.02±5.78 NTU) and downstream S-3 (22.92±38.67 NTU) comparison to lotic site S-1 (31.93±50.38 NTU) as shown in Table.3. This reduced value of turbidity in dam impacted sites, S-2 and S-3, is attributed to sedimentation of suspended solids. Kondolf (1997) also reported that Dams reduce the amount of sediments deposited downstream.

3.1.5. pH

The pH indicates the hydrogen ion concentration in water. The pH of natural waters is an important factor because the variation of pH is linked with the life process of biotic components. During the present comparative study among the fragmented habitats, higher pH recorded in impounded site S-2 (Annual average 8.25±0.32) followed by the upstream S-1 (Annual average 7.62±0.13) and least in S-3 (Annual average 7.40±0.24). This comparatively higher value of pH in the impounded water (S-2) was most likely related to increased phytoplankton population, sedimentation of organic matter and absence or little amount of CO_2. This was further supported by a highly significant negative correlation ($P < 0.01$) between pH and CO_2 from all the study sites (Table 4). The less alkaline pH values at upstream and downstream water then the impounded sites attributed to the less sedimentation, low density of phytoplankton and presence of free CO_2.

3.1.6. Dissolved Oxygen

It is one of the important environmental factors affecting aquatic life. Oxygen is removed from the natural waters by the respiration of the biota, decomposition of organic matter, presence of iron and rise in temperature. The present study revealed that moderate spatial variation in the DO among the upstream S-1 (Annual average 9.58±1.40 mg $^{-l}$), impounded Site S-2 (Annual average 9.61±0.94 mg $^{-l}$) and downstream site S-3 (Annual average 9.20±0.90 mg $^{-l}$). This full saturation of dissolved oxygen in all the sites might be due to low temperature, low turbidity, high photosynthetic activity and transparency. Jhingran (1982), Agarwal *et al.* (2018a) and Alex *et al.* (2019) had also reported similar results from their respective study areas.

3.1.7. Free CO_2

The free CO_2 is one of the essential abiotic components of the aquatic ecosystem. It plays an important role in photosynthesis. In natural waters, CO_2 enters through various sources, i.e. through air, respiration, photosynthesis, the shakeup of inflowing groundwater and decomposition of organic matter etc. In the present study, moderate spatial variation in free CO_2 was noticed among the fragmented habitats. The annual average value of free CO_2 reported slightly higher in the upstream site, S-1(1.73±0.92 mg^{-l}) followed by the downstream site, S-3 (1.43±0.80 mg^{-l}) and nil in the impounded site, S-2 in most months of the year except in winter months (November to March) Table.3. Absence of free CO_2 during summer months in the euphotic zone of the impounded sites (S-2) may be related to the raised temperature and increase in photosynthesis rate. On the other hand presence of free CO_2 in winter months is due to a decrease in photosynthesis, temperature and reduced discharge in the river, which results into increase in organic pollution. Pathak and Mudgal (2005) also reported the dissolution of carbon dioxide in water depends on the temperature.

3.1.8. Alkalinity

Alkalinity is the water's capacity to resist changes in pH that would tend to make the water more acidic. Alkalinity is important for fish and other aquatic life because it protects or buffers against rapid pH changes (Mitra and Zaman 2016). During the comparative study among the fragmented habitats, higher alkalinity recorded in lotic site S-1, (Annual average 44.17±11.97 mg^{-l}) and downstream site, S-3 (Annual Average 40.33±10.10 mg^{-l}) and least in lentic site S-2 (15.93±16.66 mg^{-l}). High value at the lotic site, S-1 and downstream site, S-3 seems related to the fast flow of water through soil and bedrock. Further, the impounded site has both type of alkalinity, i.e. Phenolphthalein and total alkalinity. It seems associated with the absence of free CO_2. This was also supported by a highly significant positive correlation ($P < 0.01$) between free CO_2 and alkalinity (Table.4). Other factors for low alkalinity in the reservoir site are reduced water velocity, high photosynthetic activity and raised temperature. Baoli *et al.* (2016) also reported similar impacts of the dam on downstream water quality

3.1.9. Nitrate

Nitrate is the highly oxidized state of the element found in water. It is brought into the aquatic body by the bacterial oxidation of atmospheric nitrogen and by the decomposition of organic matter in the watershed. In the present comparative study, moderate spatial variation in Nitrate concentration was noticed in different sites. It was observed that the nitrate concentration slightly higher in the reservoir site, S-2 (Annual average 0.31±0.09 mg^{-l}) and downstream site, S-3 (Annual average 0.31±0.07 mg^{-l}) comparison to upstream site S-1(Annual average 0.29±0.11 mg^{-l}). The bit high average nitrate concentration at reservoir site, S-2 and downstream site, S-3 is due to trapping and accumulation of organic wastes.

3.1.10. Phosphate

Phosphates are one of the major elements required by biota in an aquatic ecosystem and are an important nutrient in the eutrophication process along with nitrate (Vollen Weider, 1968). The value of phosphate have been observed slightly increased in reservoir site, S-2 (Annual average 0.09±0.04 mg^{-l}) compared to the lotic site, S-1(Annual average 0.07±0.02 mg^{-l}) and downstream site, S-3 (Annual average 0.08±0.02 mg^{-l}). The moderate high annual average value in the reservoir is attributed to the accumulation of organic waste and their decomposition.

3.2. Impacts on Phytoplankton

Comparative analysis of total phytoplankton among the fragmented habitats revealed that the quantity of phytoplankton population increased in impounded site S-2 (Fig.3). This high phytoplankton population in impounded site S-2 compared to S-1 and S-3 seems to be related with less turbidity, higher transparency, reduced water currents and increased nitrate and phosphate concentration. Further, comparative class wise composition analysis revealed that the Bacillariophyceae quantity reduced in reservoir site, S-2 and downstream site, S-3 compared to non impacted S-1 site. Contrary to this Chlorophyceae and Myxophyceae quantity increased in impounded site S-2 and downstream site S-3 compared to non-impacted site S-1 (Table.2). The decreased quantity of Bacillariophyceae in reservoir site S-2 and downstream site S-3 possibly due to their less adaptation in changed water chemistry, especially to increased water temperature. The increased quantity of Chlorophyceae and Myxophyceae in reservoir site S-2 and downstream site S-3 because of their better adaptability in sluggish, transparent and warm water. Sugunan (1991), Okogwu and Ugwumba (2013) and Agarwal *et al.* (2018b) also reported that Bacillariophyceae is better adopted in lotic cold water and Chlorophyceae and Myxophyceae in worm and stagnant water.

Table 3. Annual average of physico-chemical Parameters from fragmented sites, S-1, S-2 and S-3

	Sampling Sites		
Parameters	**S-1 (USR)**	**S-2 (R)**	**S-3(DSR)**
Water Temp. (°C)	15.24±4.30	21.06±4.96	14.79±2.95
Transparency (Cm)	70.48±45.69	85.36±47.72	82.52±44.82
Turbidity (NTU)	31.93±50.38	5.02±5.78	22.92±38.67
Water Velocity (m-sec)	0.72±0.29	-	0.86±0.18
pH	7.62±0.13	8.25±0.32	7.40±0.24
D.O (mg-l)	9.58±1.40	9.61±0.94	9.20±0.90
Free CO2 (mg-l)	1.73±0.92	1.20±1.86	1.44±0.92
Alkalinity (mg-l)	44.17±11.97	15.93±16.66	40.33±10.10
Nitrates (mg^{-l})	0.29±0.11	0.31±0.09	0.31±0.07
Phosphate (mg^{-l})	0.07±0.02	0.09±0.04	0.08±0.02

Table 4. The Correlation coefficient (r) of among the physicochemical parameters.

	Correlation coefficient (r)		
Parameters	**S-1 (USR)**	**S-2 (R)**	**S-3(DSR)**
Water velocity v/s Transparency	-0.89837**	—-	-0.89058**
Water Temp. v/s Water Velocity	0.874938**	——	0.562581*
Free CO_2 v/s Alkalinity	0.718903**	0.888409**	0.683797**

* - Values significant at 5% (P < 0.05), **- Values significant at 1% (P < 0.01)
USR- upstream to reservoir, R- reservoir and DSR- downstream to reservoir

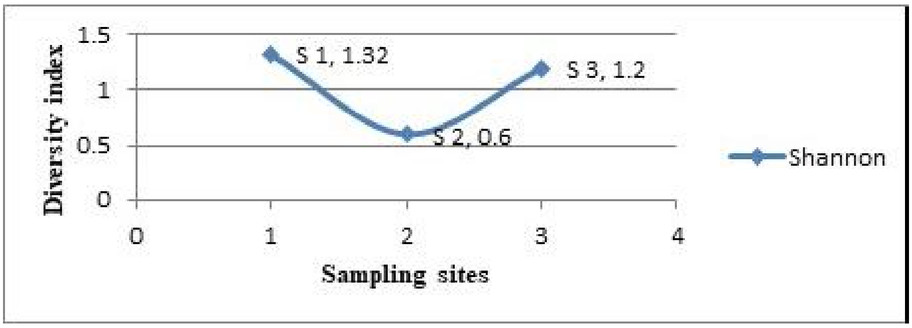

Fig. 2. Ichthyofaunal Shannon Diversity Index from three sampling sites

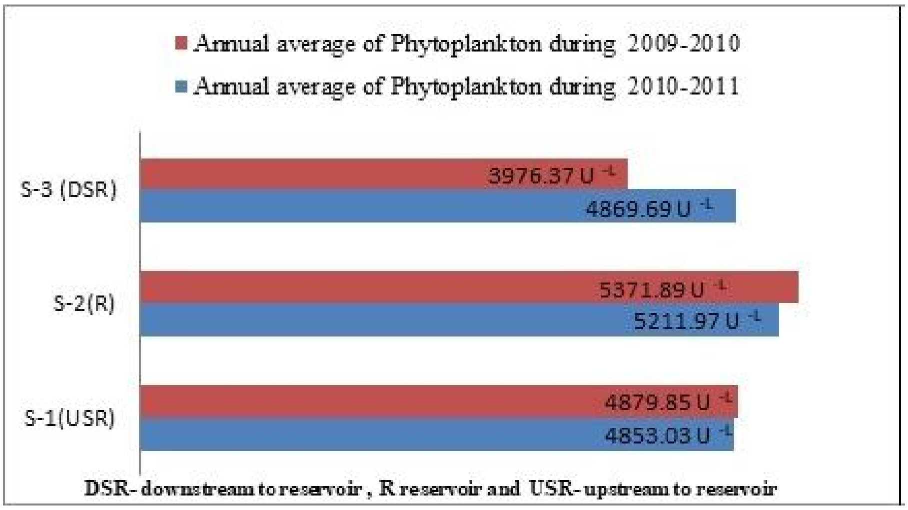

Fig. 3. Annual average Phytoplankton (units–l) from fragmented sites, S-1, S-2 and S-3

3.3. Impacts on Ichthyofaunal Diversity

The comparative study among the three different sites (S-1, S-2 and S-3) has revealed that the ichthyofaunal diversity and compositions severely changed after the installation of Tehri dam. Very low species richness (4 species) belonging to 1 family were recorded from the reservoir site (S-2). However comparatively high species richness (16 species) belonging to 2 order, three families and nine genera were recorded from downstream site (S-3) and 21fish species belonging to 2 orders, three families and 10 genera from S-1 site (Table.1 and Fig.2). In contrast to our study, Badola, (1979) reported 43 species and Singh *et al.* 1987 reported 37 species from intact river Bhilangana. This loss of freshwater biodiversity is possibly due to habitat fragmentation and other developmental activity. The fragmentation of river habitat has leads, great barriers to gene flow among them, which reduced gene pool and possibly led to genetic drift, higher risks of inbreeding, reduced fitness etc. Similar observations of various workers on the changes in species diversity associated with habitat fragmentation in reptiles and amphibians have been reported (Hitchings and Beebee, 1998; Noël *et al.*, 2007). Further, the decreased fish diversity in the S-2 site is possibly due to alterations in physico-chemical characteristics (Table.3). The factors responsible for the reduction in fish diversity in downstream water site S-3 are channelization, hydro peaking, disruption of seasonal flood cycles, Temperature, low Sediment loads, low nutrient and other water quality characteristics (Table 3). Lakra *et al.* (2010), Agarwal *et al.* (2011) and Singh (2015) have also reported the similar observations on reduction in fish species composition with the change of river habitat.

From the above observations and discussions, it is concluded that river fragmentation due to Tehri dam construction has greatly impacted the biotic and abiotic components of river Bhilangana.

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