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Original Article

Impact of hydropower project (RoR) on the ichthyofaunal diversity of river Birahiganga in Central Himalaya (India)

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Abstract
Study examined the present status of ichthyofaunal diversity of river Birahiganga in compliance to the construction of one hydropower project (HPP). The river is diverted through tunnel, leaving very less water in its fragmented course (~2.5 km). Sometime river gets almost dried in summer season. Altogether 20 fish species belonging to two orders, three families and eight genera were reported from fragmented and continuous flowing stretches of the river. Snow trout (*Schizothorax and Schizothoraichthys* spp.) have shown major share in total fish catch composition whereas the typical hill stream fishes (*Garra* and *Pseudecheneis* spp.) were the least contributor. Installation of HPP has effect on the fish population structure. Maximum species richness (20 sp.) was recorded from mainstream whereas 16 sp. were procured from the fragmented stretch. Relative abundance of most of the species was considerably high in the mainstream than the fragmented stretch, except *Glyptothorax pectinopterus* which has shown equal abundance at both the sites. Low water discharge in the fragmented stretch supports only small sized fishes. The degradation of habitat ecology and variation in physico-chemical features seems distressing the fish population structure. The threat status of fish fauna ascertain that out of 20 species, status of 6 species is under lower risk Near Threatened, 5 as Vulnerable and 4 as Endangered.

Keywords: Dams; river fragmentation; fish diversity, Central Himalaya; Birahiganga River.

1 | INTRODUCTION

On the global level aquatic biodiversity has declined abruptly and a large number of species are considered to be already extinguished or endangered (Moyle 1992; Fu *et al*. 2003). Most common causes of degradation of aquatic ecosystem are - flow regulation and river fragmentation caused by the construction of dams (Dale *et al.* 2005; Galib *et al.* 2016). Through provision of hydropower, water for drinking, canalisation for irrigation (Darwall and Vie 2005; De Silva *et al.* 2007) dams have supported human socio-economic development but in concert they had considerable impact on freshwater ecosystem. Dams and their associated impoundment results into the alteration in water flow regimes, water quality parameters, fragmenting habitats, modifying stream bed structure, loss of crucial spawning and nursery ground and blocking the migration routes which directly can pose a great threat to biodiversity (Larinier 2000). Most of these impacts are apparent on large impoundment schemes, but many of these impacts are equally relevant to small-scale run-of-river hydropower projects. The fragmentation of river ecology can occur during the periods of reduced flow in original river course associated with diversion through tunnels for run-of-river hydropower production. Essentially a reduction of water flow in the river course will seriously fragment the habitat, including important spawning and nursery grounds (Walters and Post 2008). Modifying the flow dynamics both in the fragmented river stretch and downstream to power project can potentially exacerbate the longitudinal movement of fish. Notable contribution on large impoundment of rivers specifying the upstream and downstream changes in fish assemblages (species composition and relative abundance) has been observed (Quinn and Kwak 2003; Quist *et al*. 2005; Han *et al*. 2008; Gao *et al*. 2010; Agarwal *et al*. 2011; Yang *et al*. 2012). The screening of literature revealed that a detailed account has been given on impact of small run-of-river hydropower projects in the form of final project report WFD 114 (SNIFFER 2011). At the local scenario studies hitherto conducted have not given much attention towards assessing the impacts of run-of-river HPP on fish population except Agarwal *et al*. (2014). Therefore, present stab is made to quantify the impact of river fragmentation by Birahiganga hydropower project on the fish species richness and relative abundance.

2 | METHODOLOGY

2.1 | Study area

Study area lies in Birahiganga Stream (Figure 1) located in district Chamoli, Uttarakhand, India. It is an important tributary of river Alaknanda joining on its left bank at Birahi (1056 m above sea level [asl]). It traverses a distance of 35 km. It is snow fed perennial stream and originates from Nanda glacier. The stream is joined by several small tributaries *viz.* Gudiyar, Dhadhali, Shyam, Biori, Rogilla and Pui rivulets. It is almost shallow and has high gradient in its upper course, which comparatively decrease in the lower stretch. Birahiganga hydropower project (7.30 MW) is commissioned on this stream (Figure 2). The project utilizes a rated head of 54.5 m at a design discharge of 17.435 cumecs for a generation capacity of 7.2 MW (3×2.4 MW). The project construction was started during 2011 and commissioned by the end of 2015. This power project fragmented ~2.5 km of river length, leaving very less water in its original course during summer season (May and June) affecting longitudinal river corridor. Two more HPPs also have been proposed on this river which will further fragment ~12 km of river length by its diversion through tunnel. Taking into consideration the continuous flowing stretch (CFS) and fragmented stretch (FS), two sampling sites (BG1 and BG2) were selected on this stream. Sampling site BG1 (30°25.95'N and 79°24.05'E) was selected in the fragmented stretch (Figure 3a) at Gardigaon (1080 m asl) after diversion of stream in to head race tunnel. Sampling site BG2 (30°24.37'N and 79°23.49'E) was selected d/s to HPP in the continuous flowing stretch (Figure 3b) at Birahi (1060 m asl).

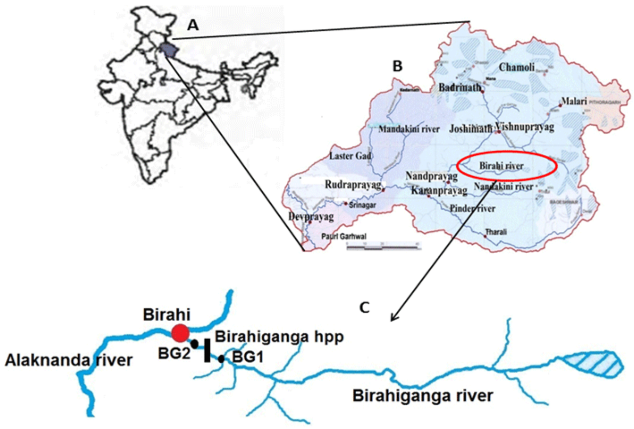

FIGURE 1 Geographical location of the Birahiganga River. A, India map; B, upper Ganga River system in Central Himalaya; and C, sampling sites selected along the Birahiganga River.

FIGURE 2 Overview of Birahiganga hydropower project installed on the Birahiganga River.

2.2 | Fish collection and Identification

Collection of fish samples was made in both fragmented and continuous flowing stretches of the river from March 2012 – February 2014. Experimental fishing was done bimonthly between morning hours to late afternoon and even sometimes also during night hours in both the sampling sites (in scheduled bimonthly sampling, 10–12 days trip was fixed and fishing was done during day as well as night hours). Fishing was done with the help of various fishing methods *viz.* cast net (1–2 m diameter, mesh size 1-1.8 cm), gill net (mesh size 1.2×1.2 cm, L×B, 12×1.0 m), *baur* (3–5 m long), *atwal*, hand picking, hammering and hooks. Detail of all these fishing methods is also available elsewhere (Singh and Agarwal 2014a). Collected fish samples were preserved in 10% formalin. Taxonomic studies were done on the basis of their morphometric, meristic and various descriptive characters following standards keys (Day 1878; Talwar and Jhingran 1991; Badola 2009; Jayaram 2010).

FIGURE 3 (a) Fragmented stretch (top) and (b) continuous flowing stretch (below) of Birahiganga River

2.3 | Data Analysis

The relative abundance (RA) of fish species across the study sites was worked out by the following formula.

$$RA = \frac{Number\ of\ samples\ of\ particular\ species}{Total\ number\ of\ samples} x\ 100$$

The fish species diversity indices at each site was calculated following Simpson (1949)

$$D = 1 - \sum \frac{ni(ni-1)}{N(N-1)}$$

Where, *ni* = the total number of individuals of a particular species; *N* = the total number of individuals of all species.

The Shannon and Wiener (1963) diversity index was also calculated for each sampling site.

$$H = \sum_{i=1}^{n} \left(\frac{ni}{N} \log 2 \left(\frac{ni}{N}\right)\right)$$

Where *H* = Shannon-Wiener diversity index, n_i = total numbers of individuals of species and *N* = total number individual of all species.

Threat status of fish fauna was ascertained from CAMP (1997).

3 | RESULTS

3.1 | Species diversity and abundance

Study conducted in both the stretches of river revealed the existence of altogether 20 fish species belonging to eight genera, three families and two orders (Table 1). Cypriniformes was the dominant order, and contributed 75% of fish species followed by Siluriformes order with only 25% of fish species. Among the families, Cyprinidae family contributed 50% species followed by Balitoridae and Sisoridae, each contributing 25% of fish species. In entire fish catch composition, snow trout (*Schizothorax and Schizothoraichthys* spp.) has shown major share (41.26%) whereas typical hill stream fish species (*Garra* and *Pseudecheneis* spp.) were the least contributor in fish catch.

TABLE 1 Relative abundance (RA) of fishes of Birahiganga River at fragmented stretch (BG1) and continuous flowing stretch (BG2)

Sl.	*Fish species*	*Threat status*	*RA* BG1	BG2
1	*Barilius bendelisis*	LRnt	1.66	2.77
2	*Barilius shacra*	LRnt	0.69	1.39
3	*Garra gotyla gotyla*	VU	1.11	2.22
4	*Garra lamta*	NA	0.0	1.39
5	*Schizothoraichthys progastus*	LRnt	0.0	5.26
6	*Schizothorax plagiostomus*	NA	5.54	9.70
7	*Schizothorax richardsonii*	VU	7.62	13.2
8	*Tor chilinoides*	NA	0.0	3.05
9	*Tor putitora*	EN	1.11	3.05
10	*Tor tor*	EN	0.0	0.97
11	*Noemacheilus bevani*	NA	1.94	2.08
12	*Noemacheilus gangeticus*	NA	1.80	2.35
13	*Noemacheilus montanus*	EN	1.66	2.77
14	*Noemacheilus rupicola*	LRnt	2.08	3.05
15	*Noemacheilus scaturigina*	VU	0.83	2.08
16	*Glyptothorax cavia*	EN	1.66	2.22
17	*Glyptothorax madraspatanum*	VU	1.25	1.66
18	*Glyptothorax pectinopterus*	LRnt	2.22	2.22
19	*Glyptothorax telchitta*	LRnt	0.42	1.25
20	*Pseudecheneis sulcatus*	VU	2.35	3.19
Species richness			**16**	**20**

3.2 | Diversity indices

For the quantitative estimation of biological variability in fish fauna between FS and CFS of river, diversity indices were calculated (Table 2). The Shannon-Weiner diversity value at BG1 was 3.60 showing relatively low richness than the BG2 having its value as 3.92. Simpson's index of dominance for BG1 and BG2 was calculated as 0.10 and 0.087 respectively which has also supported relatively high species richness at BG2 than the BG1. The value of Simpson's index of diversity (1 - D) ranged between 0.89 to 0.91 at BG1 and BG2 respectively.

3.3 | Variation in diversity and relative abundance between FS and CFS

Study conducted at both the sites (CFS and FS) revealed that species richness was slightly higher in the CFS than the FS. From the continuous flowing stretch (BG2), 20 species were reported while from fragmented stretch of river (BG1), only 16 species could be procured. The relative abundance of species has shown considerable variation between fragmented and continuous flowing stretches (Table 1). All the species have shown considerably high relative abundance in the CFS than the FS except *Glyptothorax pectinopterus* which has shown equal abundance at both the sites. Fragmented stretch having low water discharge supported only small sized fish species *viz.* lesser barils, loaches, few cat fishes and small sized snow trout at their early stages of life. Species *viz. Garra lamta*, *S. progastus*, *Tor chilinoides* and *Tor tor* were found completely absent from the fragmented stretch.

3.4 | Threat status

Threat status of fish fauna was ascertained by CAMP (1998) assessment. As per this assessment out of 20 species, status of 5 species could not be assessed due to Data Deficient, 6 species are under lower risk Near Threatened, 5 as Vulnerable and 4 species as Endangered.

TABLE 2 Species richness, Shannon -Weiner and Simpson diversity indices at fragmented stretch (BG1) and continuous flowing stretch (BG2) along river Birahiganga

Diversity indices	*Sampling sites*	
	BG1	*BG2*
Species richness	16	20
Shannon –Weiner Index (H')	3.60	3.92
Simpson's index of dominance (D)	0.10	0.087
Simpson's index of diversity (1 - D)	0.89	0.91

4 | DISCUSSION

Present record of 20 fish species from Birahiganga River in comparison to the earlier reports of 22 species (Badola 1979) and 29 species (Singh *et al*. 1987) revealed a decline in fish diversity in the reference river. The dominance of snow trout group over other genera as recorded in present study is in accordance with these earlier studies. In overall fish collection from both the river stretches (FS and CFS), most of the fish species have shown good abundance in continuous flowing stretch whereas their abundance was found seriously impacted and it was quite low in the fragmented stretch of ~2.5 km. Along with abundance, species richness was also found low (16 spp.) in FS than the CFS having 20 spp. Four species *viz. G. lamta*, *S. progastus*, *T. chilinoides* and *T. tor* were found completely absent from the fragmented stretch. Only small sized fishes were collected from the FS of river. This impact on fish population structure (richness and abundance) may be due to fragmentation of river by installation of Birahiganga hydro power project. However, this variation in species richness between FS and CFS was comparatively low which may be due to installation of only one small hpp fragmenting only 2.5 km of river length and the fish fauna may rehabilitate in upper river stretch. Contrary to this, large variation in species richness and abundance was recorded from river Nandakini due to the existence of two HPPs which intensify the impact (Agarwal *et al*. 2014). On the other hand, Agostinho *et al*. (2008) also reported that dams profoundly influence composition and structure of fish assemblages and these effects are augmented when dams are constructed in cascades.

The occurrence of fragmentary relative abundance and low species richness in the FS of river may not be attributed to a single factor but number of interrelated factors seems to be responsible. The diversion of river for HPPs put number of alterations in the fragmented stretch. Depending upon the magnitude of withdrawal, water volume gets reduced, resulting to increase in water temperature, decrease in dissolved oxygen (Richter *et al*. 1996) and variation in other physico-chemical features and habitat characteristics. Due to reduction in water volume and flow, most of the typical hill stream, fluvial specialist species found unsuitable to survive in that fragmented stretch of river and therefore may migrate to another places (Agarwal *et al*. 2011). In Georgia, Freeman and Marcinek (2006) reported that some species *viz.* minnows, suckers, darters and catfishes are very sensitive to the altered flow regime. Similarly, Hakala and Hartman (2004) also reported that population of native and intolerant species gets reduced due to reduction in water flows by withdrawal and during droughts.

Flow reductions and reduced water level in the FS of river tends to increase in water temperature and decrease in DO concentration. Both of these abiotic variables are very important factors which influence the distribution of fish fauna in any rivers (Petts 1984). The disappearance/ low relative abundance of *Garra* and *Schizothorax* spp. from fragmented stretch may be due to reduced water flow as these fish species are highly adapted to torrential hill streams (Singh and Agarwal 1991; Singh *et al*. 1993). Present study also revealed that substratum in FS of river is exposed and river becomes shallow due to reduction in water volume. Reduced water level and flow has resulted into complete disappearance of one or more habitat types (pool, riffle, rapid, run and cascade). These alterations in river habitat and substratum may be responsible for alteration in existing fauna in any river (Singh and Agarwal 2013, 2014b). Annual report published by SNIFFER (2011) also signified that the habitats and substratum characteristics can be lost or damaged in fragmented reaches such as those in run-of-river schemes. In conformity to present study, Angermeier (1987) also reported that diverse habitat and substratum features are preferred by fish and changes in flow volume and habitat features can adversely impact the structure, distribution and composition of fish communities.

The diversion of river through tunnel for a length of 2.5 km has disrupted the longitudinal connectivity in river. This longitudinal connectivity is considered to be one of the most important factors that influence the distribution of species Branco *et al*. (2012). This fragmentation in river continuity has affected the movement of migratory fishes up and down in the rivers. In riverine environments even a single barrier immediately isolates contiguous river segments (Jager *et al*. 2001). The longitudinal migrations play a key role in the ecology of riverine fishes and involve movements for spawning and feeding. The impeding of longitudinal connectivity is considered as special habitat destruction and may pose distinct threat to the long-term survival of fish species in the stream.

5 | CONCLUSION

Present study revealed that due to installation of one hydropower project on river Birahiganga, the river has been fragmented for a distance of ~2.5 km. The fish population also has been impacted in this particular river stretch however it may rehabilitate in upper continuous flowing river stretch. Study further divulges that fragmentation of fish population by installation of one small hydropower project on the reference river is comparatively low and this impact is not much more detrimental to the existing fish fauna. On the other hand, if two more hpps have been installed which are proposed on this river they will further fragment ~12 km of river stretch by its diversion through tunnel. Consequently, almost half of the river length will be destructed which will seriously fragment the fish population in this river. It is therefore concluded that hydropower projects may be installed on any river but their number and water volume diverted through tunnels should be limited keeping in mind the river ecology so that limited river length may get fragment and also avoiding the obliteration of longitudinal river corridor.

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CONTRIBUTION OF THE AUTHORS

GS primary data collection and draft manuscript preparation; **NKA** Research Supervisor, research design, secondary data collection, statistical analysis and finalization of manuscript.