IMPACT OF THE LOW HEAD DAM/BARRAGE ON FISHERIES – A CASE STUDY OF GIRI RIVER OF YAMUNA BASIN (INDIA)

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ABSTRACT

Shannon's diversity index H' = pi $\log_2$ pi was calculated for 16 fish species. The index was resolved into its components, species richness and relative abundance, to determine which components played a larger role in the determination of diversity pattern. Changes in diversity were correlated with species richness (r), habitat heterogeneity, and hydrological regimes in a longitudinal stretch of 35 km along the river Giri, a major tributary of the Yamuna River system, in Western Himalayas. Abundance differs with change in habitat structures, habitat preference of fish species and water regimes. The decrease in diversity in the lower stretch of about 3-4 km upstream of the barrage was found to be associated with habitat fragmentation and as well as d/s with loss of biotic integrity of aquatic ecosystem due to water scarcity. Species richness was found to be maximum at upper and middle reaches (elevation 650-800 m, msl) of the river, whereas it was low in lower reaches. Change in water chemistry was also noticed at Jatan barrage-low head dam due to impoundment of river water. It is inferred that the regulation of water has an impact on species richness and relative abundance, and on habitat heterogeneity which has decreased due to the change in environmental condition.

RÉSUMÉ: Impact des barrages de seuil sur les pêcheries – Etude de cas sur la rivière Giri du bassin de Yamuna, en Inde.

L'indice de diversité de Shannon H' = pi $\log_2$ pi a été calculé pour 16 espèces de poissons. L'indice a été résolu dans ses composantes, la richesse spécifique et l'abondance relative, afin de déterminer quelles composantes ont joué un rôle plus important dans la détermination du modèle de diversité. Les changements dans la diversité ont été corrélés avec la richesse spécifique(r), l'hétérogénéité de l'habitat et les régimes hydrologiques sur un secteur longitudinal de 35 km sur la rivière de Giri, un des tributaires majeurs du bassin hydrologique de Yamuna, dans le Ouest des Himalaya. L'abondance diffère selon les changements dans les structures des habitats, les préférences d'habitat des poissons et les régimes hydrologiques. La baisse en diversité dans le secteur inférieur à 3-4 km en amont du barrage a été associée avec la fragmentation de l'habitat et le rapport d/s a été associé avec la perte d'intégrité biotique de l'écosystème aquatique à cause du manque d'eau. La richesse spécifique a atteint la valeur maximale dans les secteurs supérieur et moyen de la rivière (altitude 650-800 m au-dessus du niveau de la mer) et elle est basse dans le secteur inférieur. De même un changement dans la chimie de l'eau a été détecté au barrage de seuil de Jatan, dû à la retenue d'eau de la rivière. On considère que la régularisation de la rivière porte atteinte à la richesse spécifique et à l'abondance relative ainsi qu'à la hétérogénéité de l'habitat, qui a baissé à cause des changements des conditions environnementales.

REZUMAT: Impactul stăvilarelor asupra resurselor piscicole – Studiu de caz pe râul Giri din bazinul Yamuna, India.

S-a calculat indicele de diversitate Shannon H' = pi $\log_2$ pi pentru 16 specii de pești. Indicele a fost calculat pe componente individuale, diversitatea specifică și abundența relativă, pentru a determina care sunt componentele determinante în tiparele de diversitate. Schimbările în biodiversitate au fost corelate cu diversitatea specifică (r), heterogenitatea habitatului și regimul hidrologic pe un sector longitudinal de 35 km în râul Giri, unul dintre afluenții majori din bazinul hidrografic al râului Yamuna din vestul lanțului himalayan. Abundența diferă în funcție de modificările în structura habitatelor, preferințele pentru anumite habitate ale diferitor specii de pești și dinamica regimului hidrologic. Diminuarea diversității în sectorul inferior la 3-4 km în amonte de baraj a fost asociată cu fragmentarea habitatului, iar raportul d/s a fost asociat cu pierderea integrității biotice a ecosistemului acvatic din pricina lipsei de apă. Diversitatea specifică a atins valori maxime în sectorul superior și mijlociu (altitudinea 650-800 m deasupra nivelului mării) și a fost scăzută în sectorul inferior. De asemenea, din pricina stagnării apei la stăvilarul din Jatan, s-a înregistrat și o modificare în chimismul apei. Se poate conchide că regularizarea cursului apei afectează diversitatea specifică și abundența relativă a peștilor, dar și heterogenitatea habitatului, care a scăzut din pricina modificării condițiilor de mediu.

INTRODUCTION

Rivers maintain ecological integrity through a river continuum process which is facing challenges worldwide due to instream barriers and other anthropological practices. The construction of dams and flow diversion are a matter of serious concern for ecologists (Covich, 1993; Dynesius and Nilson, 1994; Roserberg et al., 1995; Postel et al., 1996; Pringle and Scatena, 1998). Because their direct ecological effects include blocking the migration routes, the fragmentation of habitat with associated isolation of populations, the mortality of larva and juvenile at water intakes, alteration of natural hydrologic and geomorphic regimes. All these factors result in loss of biodiversity and alternation of natural food webs, disruption of riparian plant communities and shift in the water chemistry, whereas biological pattern is considered a vital foundation to sustain ecological integrity in aquatic ecosystems (Jonathan et al., 1999).

Due to an increasing demand of potable water and power supply, in the virgin area of Himalayas numerous river valley projects are executed. These projects either low head dams (barrages and weirs) or high head dams have had an impact on the habitat structure and endemic biodiversity. Such instream barriers have negative effects on the native ichthyofauna of streams by preventing the migration in the upstream areas, to spawning sites and wintering habitats (Irving and Modde, 2000). Similarly, these dams have had a negative impact on river fisheries in various systems throughout India. A sharp decline is noted in catches of *Hilsa ilisha* as a result of dams, barrage, weirs and Cauvery on the Hoogly, Godavari, Krishna and Cauvery rivers. A similar impact on *Tor putitora* and *T. tor* was inferred at Nangal and Talwara dams on river Sutlej and Byas. The impact has also restricted the migration of Indian major carps, in spite of fish ways (Sandhu and Toor, 1984). In recent studies it has been clearly inferred that mitigation measures with regards to providing fish ways for potamodramous as well as catadromous fishes, harms their migration (Pelicive and Agostinho, 2008).

These activities are factors of dying or shrinking rivers in India as well. This study assess the impact on biological diversity, habitat structures and water chemistry in river Giri, a major tributary of the Yamuna River system, west-central Himalayas. The study was focused on the evaluation of the fish diversity pattern and habitat structures and to highlight the stress posed from construction of a barrage – low head dam in Yamuna River basin (Figs. 1 and 2).

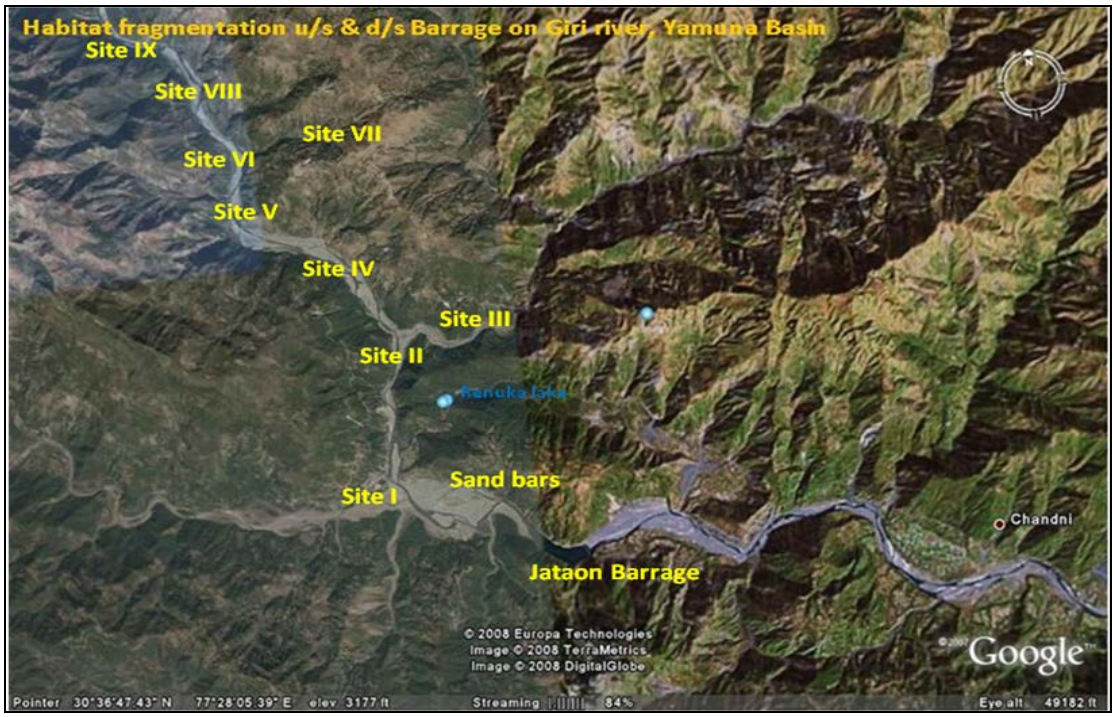

Figure 1: Study sites of Giri River, Yamuna Basin, western Himalayas.

Figure 2: Giri River course and its confluence with Yamuna Basin, western Himalayas.

MATERIAL AND METHODS

Physiography. The study sites are located in Sirmour District of Himachal Pradesh falls under sub-Himalayas lower region in Siwalik Hills. The river Giri flows from NE to SW direction and near the study sites it takes a "U" turn (NE-SW-SE) at Dadahu, Sirmaur. The catchment ranges from 440 m to 3,600 m msl. The slope varies from 15-50%. The hill ranges of Churdhar and Haripurdhar are present on the left bank in northwest side of river Giri, whereas Saindhar range on the right bank in the S-SW direction of selected study sites. Both the bank spurs have very steep precipitous slopes right from the river bank is to hilltops, interspersed with partly rocky portions, having practically less habitation along the spurs. These slopes along the river bank contain khair and Sheesham Forest, i.e. mixed deciduous forest. Geologically the area lies in the major krol belt of Himachal Pradesh. The lithostratigraphy of the Blani formatting of the Krol belt is – boulder beds at the base, carbovavous shale, grey limestone, varved angillite, minor gray and pale quartezite in the middle and over lain by – flesh coloured and purple dolomite limestone, interbedded with red shale in the upper part. The area along the stretch of Joggar River is comprised of conglomerate (at base), shale, slate and limestone. Joger ka khala consists of famous Blaini boulders of considerable size. They are found randomly enclosed in a finely bedded silty matrix of slates. The size varies from a few centimetres to over half a meter in length. The krol formation forming the core of the Sain Dhar declines along the right bank of Giri and in the basins of Jalal River, which is comprised of thick bedded massive limestone and purple green calcareous shale/slates. The alkaline nature of water (pH) is clearly indicative of limestone in the river (above 8.0). There is a number of geo-environmental factors such as slope aspect, slope morphology, land use/land cover, rock mass, drainage, geology, ridge/crest line, road, and relative relief, which are playing a significant role in basin stability. The land is formed by the fluvial action of the river Giri and its tributaries. The mean run-off efficiency of the catchment came out to be 32.2% and the suspended sediment load 9.6 t/ha/yr (1.9-17.4 t/ha/yr) as observed from 1981-1992 by Chaudhary and Sharma (1999). The detail of the physiography of downstream and upstream sites of the study area is illustrated in table 1.

Table 1: Study Sites selected on the river Giri, part of Yamuna Basin.

Study site	Location	Longitude (E)	Latitude (N)	El (feet)	Distance from Giripul, Dadahu (km)
I	Satibag – Giri confluence with Jalal	077°26'420"	30°35'809"	2045'	1.0 km d/s
II	Dadahu – Giri confluences with Joggar	077°27'907"	30°37'327"	2160'	1.8 km u/p
III	Dhanoie Bridge – Joggar ka Khala	077°27'908"	30°37'327"	3192'	7.0 km u/p
IV	Jaincha Manjhai – Giri River Sunnan kund	NR	NR	NR	8.0 km u/p
V	Sieun – Giri confluences with Palar	077°22'782"	30°41'413"	2264'	13.0 km u/p
VI	Sieun Kandva – Palar Khad	077°22'732"	30°41'413"	2260'	14.5 km
VII	Balta – Giri confluences with Nait	077°18'804"	30°45'465"	250'	19.0 km u/p
VIII	Nait/baga khad (Anukoti)	077°18'804"	30°45'465"	2501'	20.0 km u/p
IX	Khairi (Lana marg) – Giri River	077°17'872"	30°46'486"	2523'	24.0 km u/p
–	Jatan Barrage	077°26'420"	30°35'809"	2010'	5.0 km d/s

Study Area Description. The river Giri, a major tributary of river Yamuna, has an approximate stretch of 150 km to its confluence with Yamuna at Paonta Sahib. The river flows from NE toward the SW direction. It's a spring river and also receives water from melting of snow during winters. The catchment area falls in the subtropical climate zone. The annual rainfall is about 1,675 mm. The climate is subtropical interspersed between cold weather, hot weather and southwest monsoon. During the monsoon period from June to September the weather remains humid. The relative humidity varies from 33 to 30%. The survey was carried out during monsoon (August-September 2007) and post-monsoon (October-November 2007) seasons. Nine sampling sites locations from I to IX were selected along the river reach length upto 35 km in the influence zone. This covers the upstream area of Khairi Village and downstream to the Jateon barrage of the Giri River basin, in Sirmour district, Himachal Pradesh. The studied area lies between 30°33'5" N to 30°38'277" N and 77°23'48" E to 77°30' E. The study area lies between elevations of 600-820 m mean sea level. The details of the selected study sites/locations are given in table 1 and in figure 1. The study sites include a three km stretch of the river Jalal, seven km stretch of Joggar, three km Palar, two km Nait and 30 km along river Giri from Jateon barrage to upstream. Its right bank, the Jalal, which joins it at Dadahu below Sati Bagh is present at the south-eastern extremity of the Sain Dhar Hills. On its left bank the perennial and cold water streams are the Joggar, Palar and Nait, which rises on the Kawal in Haripurdhar and Churdhar Hill range, which first flow westward and eventually falls into the Giri.

Sample collection procedure

For assessment of aquatic faunal diversity the biological parameters, fishes, plankton and zoo benthos were studied. To assess the fish diversity different fishing gears like cast net, scoop net, hand net, hook and line method and pot method were used. Random sampling in selected areas in the river was carried out at morning (6:00-8:00) hours. They were also visually observed in different habitats. Representative specimens were preserved in 10% formalin solution and brought to the laboratory for their identification. The sampled fishes were identified using the taxonomic keys.

Plankton samples were also collected using a tericot ring net of 20 µm net. For enumeration of phytoplankton and zooplankton population, 100 l composite water samples were collected from the river surface up to 60 cm depth and were filtered through a 20 µm net to make one l of bulk sample. The bulk samples collected in this way were preserved in 5% formalin solution or Lugol's solution and were brought to the laboratory for analysis. Ten replicate water samples each of 15 ml were made out of the preserved one l bulk sample and were centrifuged at 1,500 rpm for 10 minutes. After centrifuging, the volume of aliquot concentrate was measured. One ml of aliquot concentrate was used for enumeration of phytoplankton population in each replicate. A plankton chamber of one ml capacity was used for counting of plankton under a light microscope.

The total number of planktons present in a litre of water sample was calculated using the following formula:

$$N = (n \times v \times 100)/V$$

Where N = Number of phytoplankton per litre

n = average number of plankton cells in one ml of aliquot concentrate

v = volume of plankton concentrate (aliquot)

V = volume of water from bulk sample centrifuged

Zoobenthos invertebrates or Benthic invertebrates are organisms that live on the bottom of a water body (or in the sediment) and have no backbone. Their size spans six to seven orders of magnitude and they range from microscopic (e.g. micro-invertebrates, < 10 microns) to a few tens of centimetres or more in length (e.g. macro-invertebrates, > 50 cm). Benthic invertebrates live either on the surface of bed forms (e.g. rock, coral or sediment – epi benthos) or within sedimentary deposits (infauna), and comprise several types of feeding groups e.g. deposit-feeders, filter-feeders, grazers and predators. The abundance, diversity, biomass and species composition of benthic invertebrates can be used as indicators of changing environmental conditions. Construction of dams can impact the benthic invertebrates by alteration of the physical characteristics of the river which includes substratum, current velocity, food availability, water temperature, dissolved oxygen concentration, and water chemistry. In the present study, an enumeration of benthic invertebrates was done in order to know their composition, density and diversity in different reaches of the river.

Benthic invertebrates were collected from the pebbles, cobbles and gravels surface upto 15 cm sediment depth by stirring an area of one square meter at different elevations and dislodging the substrate to catch the dislodged organisms in a net (0.5 mm mesh) held downstream. Three replicates were collected at each site. Samples were also collected with the help of iron sieves of different mesh size, scrapers and forceps and were preserved in 5% formalin solution. The species were then brought to the laboratory and sorted order-wise and were later on identified and enumerated. The identification was done under stereomicroscope to the lowest possible taxonomic levels.

Sampling period. The sampling period was divided into monsoon (wet) and post monsoon (dry) season. The sampling was carried out twice during the months from September to November 2007. The samples of aquatic fauna and water quality which emphasize on fish communities were also collected. The monitoring of aquatic ecosystem at all selected locations was carried out once in a season. The samples were collected separately for fishes, plankton and zoo benthos from all selected sites. It was followed by the detail fish catch studies for establishing baseline data aiming to investigate the possible impacts and find the means of mitigating strategies.

Water sample collection. Representative water samples from different sites of the Giri River basin were collected twice. Three samples from running water upstream and one sample downstream from impounded water at Jatan barrage were collected and analysed for physical and chemical characterization of water quality. In the present context the water quality analysis was carried out at various places covering sections of river Giri u/s and d/s sites of river basin and Jataun barrage to have a holistic view of water quality (Tab. 6).

Data Analysis

The limnological parameters were recorded mainly following the standard methods described by Welch (1948), CSIR (1974), Mackereth et al. (1978), and APHA (1992, 1995, 1998). Attempts were made to identify all the samples up to generic level. For qualitative studies of biota, the references of Usinger (1950), Ward and Whipple (1959), Edmondson (1959), Pennak (1953), Needham and Needham (1962), Macan (1979), Tonapi (1980), Trivedy and Goel (1984), Welch (1948) and Edington and Hildrew (1995) and APHA (1992, 1998) were consulted. Fishes were identified upto the ssp. level with the help of keys given in Days (1958), Jayaram (1981, 1999), Menon (1987, 1999), Talwar and Jhingran (1991). The IUCN red data list was used for identification of threatened, endangered and vulnerable species in the Giri River a major tributary of the Yamuna River.

Habitat Inventory. Habitat features were quantified using transects within each stream reach. Variables measured at each point of the transect were water depth, water velocity and wetted width. Five transects each of 80 m length were laid down at interval of about 20 m distance and habitat were measure at 90^o across the river/stream. In each stream reach, habitat such as pools, riffles, cascades and runs were identified in 500 m thalweg length. Length and width of each habitat were measured based upon criteria outlined by Armontrout (1990, 1999) and Arunachalam (1999). In stream covers were small boulder edge, big boulder edge, bedrock edge, canopy, root undercut and snags/logs. The substratum observed was heterogeneous and represented by gravels, pebbles, cobbles, boulders, rocks and silt (Armantrout, 1999). The study sites were classified after Rosgen (1996). The classification was derived from 450 rivers throughout the U.S., Canada and New Zealand. Quantification of the availability of microhabitats (e.g. depth, water column velocity, cover type and substratum type) was carried out using the instream flow Incremental Methodology (Bovee et al., 1998). It was carefully done without disturbing the fish by the observer. Habitat diversity for each site was calculated using species diversity index (Pusey et al., 1993). Shields et al. (1995) classified the water area as pool habitat with depth > 30 cm and velocity < 10 cm s^{-1} which consists of 5-20% of the water area at base flow. Stream habitat is separated into different habitat types based on their hydraulic characteristics. To define habitat types, methods described by Bisson et al. (1982) were used with slight modifications (Tab. 1).

Table 1: Stream habitat types as modified from Bisson et al. (1982).

Habitat type	Characteristics
Riffle	A shallow reach of gradient < 4% with moderate current velocity and moderate turbulence.
Rapid	A shallow reach of gradient > 4% with high current velocity and considerable turbulence.
Cascade	A series of small steps of alternating small waterfalls and small pools.
Glide	A moderately shallow reach with an even flow and no pronounced turbulence.
Pools	
Trench pool	A long, usually deep slot in a stable substrate (often bedrock).
Plunge pool	A basin scoured by a vertical drop over a channel obstruction.
Lateral scour pool	A scoured basin near the channel margin caused by flow being directed to one side of the stream by a partial channel obstruction.
Mid-channel scour pool	A scoured basin near the centre of the channel usually caused by a channel constriction or high gradient rapid.
Dammed pool	A pool impounded upstream from a complete channel blockage.
Alcove	A slack water along the channel separated from the main current by stream banks or large channel obstructions such that it remains quiet even at high flows.
Beaver Pond	A pool impounded by a beaver dam.
Backwater pool	An eddy or slack water along the channel margin separated from the main current by a gravel bar or small channel obstruction.

Statistical Analysis. The Shannon and Wiener (1963) information function (1963) was used to describe species diversity in natural communities. The index (H') is

$$\overline{H} = \sum_{i=1}^{S} \left(\frac{Ni}{N}\right) log_{10}\left(\frac{Ni}{N}\right)$$

where, Ni is the total number of individuals of species i (from 1 to S) and N is the total number of all species in a stand.

Or H' = – ∑ pi ln or $\log_2$ pi, Where pi (Ni/N) is the proportion of individuals in the species (i = 1, 2, S). Lloyd and Ghelardi (1964) have pointed out that this measure has two separate components, "species richness and equitability or evenness" of species abundances. Species richness is simply S, the number of species in the sample. Several expressions have been employed to measure the relative abundance component; here we will use the index J' = H'/H' max in which H'max is $\log_2$S. This index represents the ration of observed diversity to the maximum diversity possible for the same number of species. It has a maximum value of unity when all species are equally abundant are represented by only one individual; the more individual in the sample, the closer Jmin approach zero.

RESULTS

The results of habitat structures, biological diversity and water chemistry are described in tables 3-8 and figures 1-4. The biotic profiles of the aquatic ecosystem are characterized by periphyton and macrophytes at the primary trophic level, and zooplankton and aquatic benthic insects at a secondary trophic level and fishes at tertiary trophic level. These biotic components are food for the hill stream carps, perches, cat fishes, loaches etc. During the present investigation, a total of 16 taxa of fishes at the study sites were observed (Tab. 5). The percentage occurrence, species richness, seasonal variation and abundance of fishes at all selected sites are illustrated in tables 3-8. The water quality of river water and impounded river water is illustrated in table 6.

Table 3: Percentage (%) habitat distribution in the study area of Yamuna River basin.

Study sites*	Riffles	Pools*	Run	Rapids	Cascades
I	60.0	15.0	14.0	11.0	–
II	35.7	14.3	45.0	5.0	–
III	4.5	21.8	6.4	29.1	38.2
IV	35.0	21.0	37.0	7.0	–
V	20.0	7.0	38.0	35.0	–
VI	6.0	17.0	8.0	39.0	30.0
VII	25.0	12.0	18.0	45.0	–
VIII	15.0	21.0	11.0	23.0	30.0
IX	34.0	13.0	46.0	7.0	–

* Site – Jataon Barrage has pool habitat only.

Table 4: Fish species richness and Shannon diversity index in river Giri.

	Monsoon season				Post monsoon season			
Index	N	H'	Hmax	J'	N	H'	Hmax	J'
Site I	4	0.56	0.6	0.94	6	0.63	0.78	0.81
Site II	6	0.7	0.78	0.89	6	0.64	0.78	0.83
Site III	4	0.51	0.6	0.84	5	0.63	0.7	0.9
Site IV	8	0.75	0.9	0.83	14	0.87	1.15	0.76
Site V	7	0.64	0.85	0.75	10	0.67	1	0.67
Site VI	4	0.57	0.6	0.94	4	0.49	0.6	0.81
Site VII	5	0.59	0.7	0.85	5	0.54	0.7	0.77
Site VIII	3	0.47	0.48	0.98	4	0.49	0.6	0.81
Site IX	7	0.725	0.845	0.858	13	0.843	1.114	0.757

*Site – Jataon Barrage has pool habitat and manmade structure only.

Table 5: Habit and habitat preference of fishes in the Study Area.

Fish Species*	Dwelling habits and habitat			
	Pools	Runs	Riffles	Rapids
Tor putitora (Ham.)	+++	++	+++	++
Schizothorax richardsoii (Gray)	++	++	+++	++ PH
Labeo dero (Ham.)	++ PH	++	++	–
Barilius bendelesis (Ham.)	++	++	++	+
B. barila (Ham.)	+	++	++	–
B. vagra vagra (Ham.)	+	++	++	–
P. ticto ticto (Ham.)	++	–	–	–
P. sarana (Ham.)	++	–	–	–
Bagarius bagarius	+	++	++	++ PH
Glyptothorax ssp.	+	++	++	++ PH
Channa orientalis (Bloch)	+++ PH	+	+	–
C. marulius	+++ PH	+	+	–
C. punctatus	+++ PH	+	+	–
Schistura ssp.		+	++	–
Brachiodenio rerio	++ PH	–	–	–
Mastecembelus armatus	++ PH	–	–	–

PH-Preferable habitat, +present, ++abundance, +++dominant, – Not recorded.

Table 6: Water Quality of the study area during monsoon and Post monsoon (2007).

S. no.	Parameters	Monsoon Season (August 2007)		Post monsoon season (November 2007)	
		Giri River n = 3	Jateon Barrage n = 1	Giri River n = 3	Jateon barrage n = 1
Physical Parameters					
1.	pH	7.88-7.90	8.0	8.04-8.20	8.2
2.	Temperature, ºC	20.0-22.0	23.0	16.0-17.0	18.0
3.	Dissolved Oxygen, mg/l	8.0-8.5	7.6	7.4-7.6	7.0
4.	Conductivity, mg/l	260-275	390	350-410	396
Chemical Parameters					
5.	Alkalinity, mg/l	90-98	110	156-178	120
6.	Total Hardness, mg/l	64-70	168	172-196	180
7.	Ca Hardness, mg/l	58-60	90	116-136	95
8.	Mg, mg/l	6-10	78	56-60	85
9.	Nitrate, mg/l	0.7-0.8	2.36	0.75-0.85	2.50
12.	Phosphate, mg/l	BDL	0.12	0.03-0.31	0.15
13.	Fluoride, mg/l	BDL	BDL	BDL	BDL
14.	Chloride, mg/l	6-10	20	4-10	24
15.	Sulphate, mg/l	4-5	50	32-40	66
16.	Sodium, mg/l	5-6	14	8-13	16
17.	Potassium, mg/l	BDL	5	2	7

BDL – Below Detection Limit.

Table 7: Detail Physiography of the Giri River and falling streams in the Impact zone of Renuka Dam Project; R = Bedrock/impregnated rocks, B = boulders, L = large boulders, B = small boulders, s = sand, C = cobbles, G = gravels Habitat; Rf = riffles, P = pools; Rp = Rapids; Rn = run. Cs = Cascade.

Geomorphology*	Jateon	D/s-Satibag	Dadahu	Upstream Sites						
	Barrage	I	II	III	IV	V	VI	VII	VIII	IX
Elevation (feet)	2010’	2045’	2160’	3192’	NR	2264’	2260’	250’	2501’	2523’
Gradient % (slope)	–	< 2%	< 2%	> 4%	< 2%	< 2%	> 4%	< 2%	> 4%	< 2%
Avg. channel width-m	–	6.3	35	7	32	40	10.75	32	8.9	40
Avg. channel depth-m	> 5 m	0.20	0.89	0.31	1.5	0.65	0.36	0.8	0.32	0.70
Bank full width	–	91	70	15	65	110	40	71	36	92
Maxim mepth -m	–	0.35	2.3	0.8	3.0	1.1	0.85	1.2	0.76	1.0
Width/ Depth ratio	> 10 m	32	48	23	20	62	30	40	28	67
Entrenchment ratio	–	14.4	2.12	2.14	2.13	2.8	3.7	2.2	4.1	2.3
Substratum	–	G, S	C, G, S, B	R, L, B, C, G, S	C, G, R, S	B, C, G, R, S	R, B, C, G, S	R, B, C, G, S	R, B, C, G	R, C, G, S
Habitat	P	Rf, P	Rp, Rf, P	Cs, Rp, Rf	Rf, P, R	Rp, Rf, P	Cs, P, Rp, Rf	Rf, Rp, P	Cs, Rp, Rf, P	Rn, Rf, P
Encroachment type	–	Bed material extraction	Bed material extraction	Agriculture practices	Agricultur practices					
Valley type	–	Wide valley	U shape valley	Confined stream	Confined valley	Confined stream	Confined valley	Confined stream	Confined valley	Confined stream
No. of fish species	4-6	4-6	6-6	4-5	8-14	7-10	4-4	5-5	3-4	7-13
Stream type	–	D	B	A	B	B	A	B	A	B

Table 8: Correlation of fish communities occurring during monsoon and post monsoon.

M	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII	Site VIII	Site IX
Site I	1	*	*	*	*	*	*	*	*
Site II	0.74	1	*	*	*	*	*	*	*
Site III	0.41	0.90	1	*	*	*	*	*	*
Site IV	0.31	0.81	0.92	1	*	*	*	*	*
Site V	0.22	0.77	0.93	0.92	1	*	*	*	*
Site VI	0.27	0.64	0.77	0.69	0.87	1	*	*	*
Site VII	0.49	0.88	0.94	0.89	0.95	0.91	1	*	*
Site VIII	0.27	0.66	0.79	0.70	0.86	0.97	0.90	1	*
Site IX	0.34	0.79	0.89	0.77	0.91	0.94	0.95	0.96	1
PM	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII	Site VIII	Site IX
Site I	1	*	*	*	*	*	*	*	*
Site II	0.70	1	*	*	*	*	*	*	*
Site III	0.45	0.8237	1	*	*	*	*	*	*
Site IV	0.46	0.9463	0.8194	1	*	*	*	*	*
Site V	0.41	0.9167	0.9292	0.96	1	*	*	*	*
Site VI	0.18	0.7184	0.9439	0.80	0.92	1	*	*	*
Site VII	0.27	0.8499	0.9275	0.93	0.99	0.95	1	*	*
Site VIII	0.10	0.4374	0.8443	0.47	0.67	0.89	0.72	1	*
Site IX	0.41	0.9109	0.9308	0.95	0.99	0.93	0.98	0.70	1

Habitat Inventory

a. Habitat structure and river morphology

The variables related to the channel morphology such as their width, depth, channel slope, substratum, habitats, and the source of water has been taken into account for the study of habitat inventory in the Giri River basin u/s and d/s sites and the details are depicted in tables 3-5 and figures 3-4. On the basis of stream morphology, the sites are classified into type A, B, C and D categories. The fish diversity is found maximum in the type B channel. The river Giri falls in this category and supports maximum aquatic life with the presence of maximum number of fish species (16). The type streams, which are present on the left bank of Giri, support 3-4 fish species only. A similar result was observed in D type channel present on its right bank, where only five fish species were reported.

Habitat essential for fish were pools, riffles, rapids, runs and cascades. Pools are the sites having minimum water flow with maximum depth (< 10 cm/s water current). Riffles are formed near the zone with gradient less than 4% and comparatively fast current and shallow water. Rapids are found in the areas having gradient > 4% with fast water current forming water waves. Cascades have step pools morphology and have been observed in side streams i.e. Joggar, Palar and Nait streams due to high gradient > 10%. The habitat structures observed at selected sites are illustrated in table 7. The results show that maximum habitat complexity in the river Giri upstream whereas minimum variation near the Jateon barrage area.

Results of habitat inventory showed an association with change in species richness as the change in habitat. During rains, the rapids were a common habitat and river was flooded. After the monsoon season natural restoration of habitat took places.

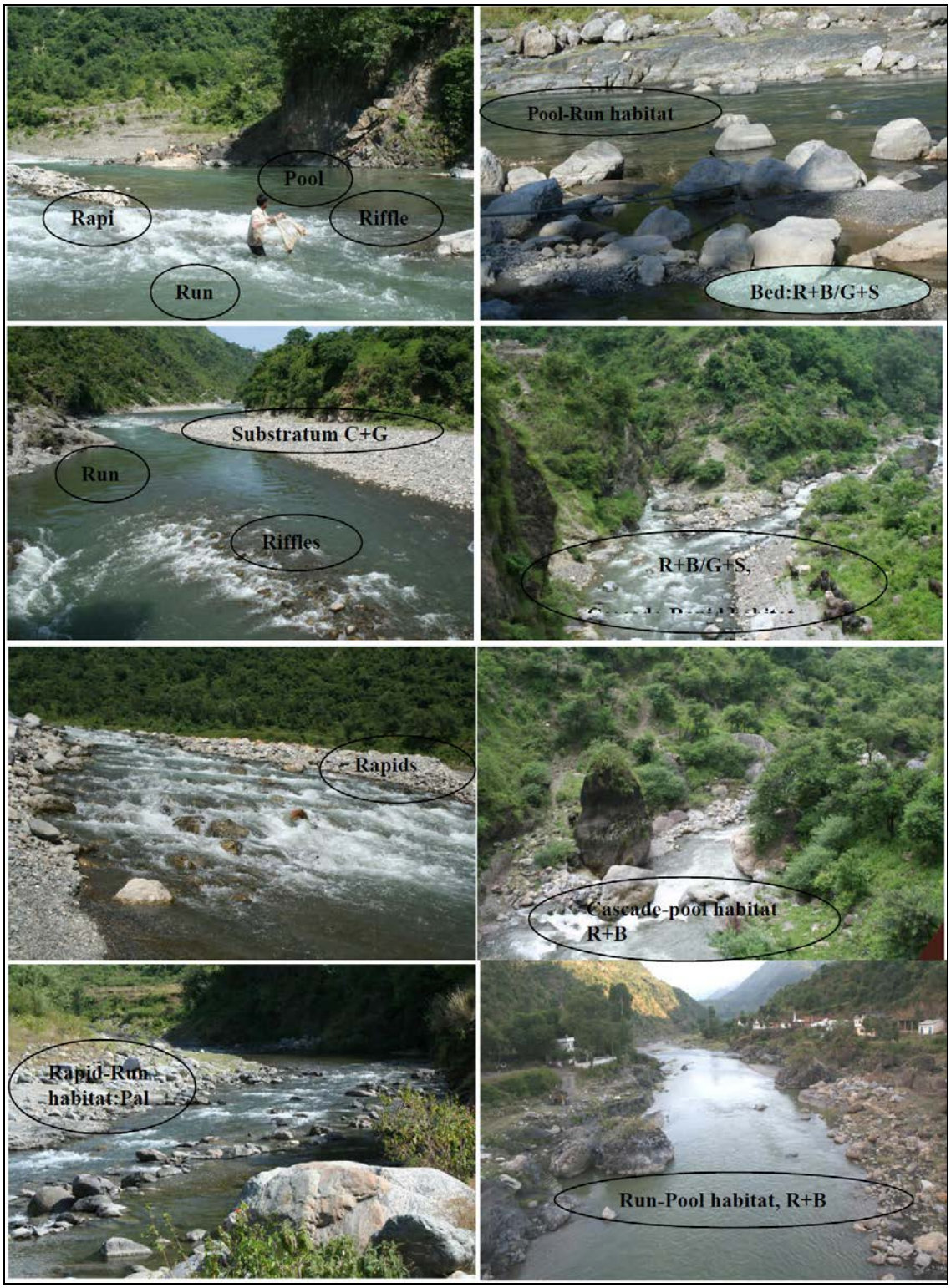

Figure 3: Habitats structure as Pool, Riffle, Run, Rapid and Cascade and substratum as rocks (R), boulders (B), cobbles (C), gravells (G) and sand (S) in the river course.

Figure 4: Habitats structure – heterogeneous habitat with formation of sand bars u/s barrage and homogenous habitat at barrage site.

b. Fish assemblages

The data collected for ichthyofauna also show an increasing trend from monsoon (eight sp.) to post monsoon months (16 sp.). Out of the 16 species, the order cypriniformes (carps, minnows and loaches) are the dominant group, five species of cyprinids, three species of chaniformes, one species each of siluriformes, sisroide and mastecemblide were found. The results of calculation of Shannon Weiner diversity index clearly indicate increasing trend of species richness and dominance from monsoon months to post monsoon months.

16 species represented by 11 genera, six families and four order were recorded in the study sites of Giri River basin, western – central Himalayan region. Of these, cyprinids were found to be the most dominant group represented by 10 species of seven genera. Of the order Cypriniformes, *Barchydanio rerio* was recorded from site IV. Out of the three, *Barilius* ssp., *B. bendelisis* (Ham.) is the most common at all sites. Other species like *B. barila* (Ham.) and *B. vagra* have been recorded at the sites but not regularly. *Tor putitora* (Ham.) was present at all sites. Species of *Puntus* i.e. *P. ticto ticto* (Ham.) and *P. sarana sarana* (Ham.) were observed at site IV. *Schizothorax richardsoinii* (Gray) is again typical hillstream forms with reduced scales and occur in II, V, VII, VIII and X sites. *Schistura* ssp. was recorded from site II. *Glyptothorax* ssp. is a true hillstream fish with well developed adhesive organs on the thorax. Mastembelus armatus (Lacepede) (Order Synbranchiformes) reported from all sites except site II and *Channa punctatus* (Bloch) (Order Perciformes) though are not true hill stream fishes but also harbour among hillstream fishes.

Most common and predominant fish were the endemic tiger fish-golden mahseer whereas the other fishes identified were *Channa* ssp., *Glyptothorax* ssp., *Bagarius* ssp., *Barilius* ssp., *Puntius* ssp. and *Mastecemblus* ssp. Among loaches *Noemacheilus* sp. was present and found in the crevices of cobbles, pebbles, and gravels in riffle habitat and slow flowing aquatic zones and prefer from deep to shallow water pools riffles, and rapid habitats.

During monsoon period fingerlings of the above mentioned species were observed. These young ones are present in the small ditches and shallow pools which are formed due to rains waters along the channel side during peak flow period or flood times. These are found rich in algal and detritus matter with insect larvae. The abundance of fingerlings was observed in post monsoon months in slow flowing water riffles. The present investigations in Giri River reveals that the population of the golden Mahseer contributes significantly to the fishery only in the main river where it comprises 37-40% of the total catch. The brooders, yearlings, fry and fingerlings of the golden mahseer were observed in the river Giri only.

The Giri ganga is a low gradient river, where the water runs all along the river except of some pools and riffles that are observed often along the course of the river. Many small pocket pools were noticed during the monsoon season alongside the river bank. These pools were predominantly found with fingerlings of variety of fishes, more particular the golden mahseer *Tor putitora*. In the upper reaches presence of Schizothoprax richardsonii was identified. The habitat distribution with feeding habits of the collected fish species are depicted in table 4.

C. Water Quality

Water quality was assessed during monsoon and post monsoon season (2007). The water quality analysis was carried in covered sections of the river Giri u/s and d/s of Giripul, Dadahu to have a holistic view. The physical and chemical characteristics of water quality are described in table number 6. The studied parameters clearly showed the difference between the running water in the river and impounded water at the barrage site. The temperature is higher in the impounded water along with higher concentration of migrate, phosphate, other cations and anions, BOD, COD and Ca and Mg hardness indicates accumulation of nutrients. These all variable were found in low concentration at all sites upstream. The difference was quite

significant during monsoon season. Air temperature during monsoon months was recorded 19.5°-33.5°C in August and 18°C to 32.0°C in September, 2007. Average range was 26.0°C (August) to 24.5°C (September). The air temperature of the post monsoon months was 12.8°-30.2°C (average 23.5°C) in October and 8.0 to 27.5°C (average 21.0°C) in November months.

The change in water chemistry is due to impoundment of water at Jatoun barrage. The water is diverted through tunnels from the barrage for power production at Giri Nagar. Finally water flows into Bata River which joins river Yamuna near Pounta Sahib. The average flow since last ten years is illustrated in table 9. The monthly average surface discharge data i.e. hydrology series was based on the records available for a period of 10 years from 1991 to 2001 at Gauge and Discharge site Dadahu on river Giri as cleared by Hydrology (N), Directorate of Centre Water Commission (CWC, Delhi). The data shows in decline of water level after rainy season during lean period from November to May and minimum was during summers i.e. months of April and May. It can be inferred that the most quantity of available water was diverted for power generation. This resulted in the deficiency of water in downstream and river bed remains dry except during the wet season. It is necessary that a minimum of 10% flow of water is required throughout the year to maintain ecological integrity.

Table 9: Yearly and monthly average (Avg.) discharge (m^3/sec.) of Giri River.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan.	0.00	13.03	14.09	9.51	17.60	19.45	15.00	14.98	14.92	10.06	9.88
Feb.	0.00	25.14	13.76	13.62	20.15	34.01	13.67	21.07	12.22	12.21	8.56
March	0.00	15.19	22.38	10.09	19.48	39.20	12.03	50.88	9.43	9.47	7.50
April	0.00	10.32	15.29	11.59	16.34	18.79	18.04	21.22	7.16	8.33	6.30
May	11.60	7.21	8.81	10.03	9.31	10.22	15.20	15.78	11.07	7.65	6.21
June	10.24	6.19	10.42	9.52	7.34	18.12	14.19	35.22	8.62	46.12	9.76
July	11.13	30.47	175.56	107.46	66.76	40.06	17.40	64.74	102.17	113.29	60.55
Aug.	35.75	165.73	52.86	214.88	171.78	73.38	186.89	84.97	124.73	39.90	58.37
Sep.	41.96	147.91	134.85	89.44	159.28	141.42	102.59	98.80	71.43	29.94	20.22
Oct.	14.40	35.54	19.06	22.44	60.25	34.44	26.08	154.66	36.86	17.37	10.26
Nov.	11.05	17.44	12.45	18.18	24.46	19.91	17.77	28.87	13.65	12.35	6.62
Dec.	10.00	14.18	9.91	15.69	18.41	15.77	25.41	16.47	10.67	10.21	6.46
Avg.	18.27	40.70	40.79	44.37	49.26	38.73	38.69	50.64	35.25	26.41	17.56

Physical chemical characteristics show a low concentration of alkalinity, hardness, other cations and anions, which was likely due to the dilution factor of increased water level from rains. Other factors like high turbidity, heavy sedimentation rate and torrent flow were observed during monsoon season. Post monsoon months show higher concentration of alkalinity, hardness, dissolved oxygen, anions and cations were recorded but the water current, sedimentation rate and turbidity recede down. Almost the same trends were observed at Jateon barrage site, but higher level of physical and chemical variables as compared to the sites located on flowing watercourse were observed. This clearly indicates the difference between impounded water and stream/river water quality, though the results at all sites were found within the limit of drinking water standards. During rains, streams flow to their full capacity. In the post monsoon months rivulets in head water regions of these streams become dry and water is restricted to pools and shallow tanks along the course of the streams.

DISCUSSION

The rich fish diversity of the Giri River is due to spring fed river substratum that consists of bed rock, boulders, cobbles and gravels, which supports the survival, growth and reproduction of macro-benthic organisms. Observations further show a close relationship between the abundance of fish presence and population density of macro-zoobenthos in a particular area of the river. The richness of phytobenthos makes this riverine system supportive of many aquatic organisms such as macro invertebrates and fishes. The variables related to the channel morphology such as their width, depth, channel slope, substratum, habitats and the source of water were taken into account and shows a significant association of diversity with habitat structures (Tab. 7; Figs. 3-4). On the basis of morphology of the streams, the sites are classified into A, B, C and D-categories (Figs. 3 and 4). The fish diversity was found maximum in the type B channel. The river Giri falls under B category and supports maximum aquatic life with the presence of maximum number of fish species (16). A-type streams, which are present on the left bank of Giri supports only 3-4 fish species. Similar result was observed in D type channel present on its right bank where only five fish species were observed during present survey. Maximum species richness was observed in the Giri River as compared to the side tributaries and barrage side. This could be attributed to the physical and chemical characteristics of water and channel morphology (Tab. 6). Among physical factors, the most important factor is the habitat and channel geomorphology. It was observed that Joggar stream had a steep gradient (10%), than the Giri River (2%). The similar trend was observed in upstream at Palar and Nait stream as compared to river Giri. Changes in the gradient resulted in fast water current at Joggar stream (> two m/s) than the river Giri (< two m/s). Habitat in Joggar Stream is rapid and predominant near the confluence zone with Giri and cascades predominant with scour pools upstream. In Giri River upstream from the Giripul, Dadahu the frequent riffle pool habitat with lesser rapids and runs was observed whereas cascade was absent. Downstream from the Giripul (Dadahu), run predominates whereas at Jeaton barrage the channel completely changes into a small reservoir.

Downstream Dadahu River enters into wide open valley where it receives water from the Jalal channel located on its right bank. Four fish species were found in the downstream with fingerling of Mahseer near confluence of Jalal with Giri during Monsoon season and six species during post monsoon season were recorded. The influence zone of the Giri River recorded five to eight fish species during monsoon and 5-14 species in post monsoon season. The minimum species richness during monsoon may be attributed to the turbid and fast water current, fragmentation of habitat and flooded water channel whereas the maximum species richness during post monsoon could be due to favourable water current, temperature and dissolved oxygen, low sediment load or turbidity, habitat reappearance and availability of food matter. It was observed that the streams joining upstream on its left bank like Joggar, Palar and Nait in the influence zone of dam supported only three-five fish species i.e. low biodiversity which could be attributed to the high gradient, fast water current, rapid and cascade habitat and comparatively low water temperature (16-18^{o}C) than the rive Giri (21^{o}C) with suitable conditions sustaining rich biodiversity (14) due to low gradient, riffle pool habitat with rapids and runs, substratum with gravel and cobbles which support the maximum aquatic biodiversity. Thermal barrier plays an important role in distribution of fish population/fish communities in stream or rivers which change from headwaters to mouth (Shuter, 1992). Longitudinal environment gradients and fine-scale habitat patches are important in regulating fish assemblage structure during the dry season. Floods/rain water result in a dramatic reduction in habitat heterogeneity, which also lead to significant changes in assemblage structure from community dominated by *Tor putitora*, *Barilius bendelisis* and *Schizothorax* sp.

during post monsoon season to one dominated by *Tor* sp., *Barilius* sp. during wet season (monsoon). Torrent flow also results in the mobilization of bed sediments which are deposited near or at the tail region of Jateon barrage. Similar findings were also reported by Thomas et al. (2008). This process might be the major cause of habitat loss in a stretch of about three km where only run was found common due to impounded water at Jateon Barrage. It was evident from the literature also that low habitat heterogeneity correlated with poor species diversity. Increasing communities and habitat diversity after disturbances due to rains such as channelization, seasonal peak diversity attains levels typical of undisturbed stream due to rejuvenation of habitat heterogeneity (Gorman and Karr, 1978).

All three streams at the upstream of the dam site are cold water channels flowing through steep hills of Churdhar and Haripurdhar range whereas downward tributary flow through Saindhar range situated in warm climate zone. The Mahseer species need clean, stable, well oxygenated, gravel habitats to spawn in. After the eggs are laid in the gravel, well-oxygenated water must pass over the eggs (Chaudhary and Sharma, 1999). Adults and juveniles of species such as *Schizothorax* sp., *Tor* sp., and *Labeo* sp. move upstream and downstream respectively in Giri River including its streams Jogaar, Palar, Baga and Jalal. A majority of tributaries serve as the only routes through which the fish can have easy access to congenial environment to breed (breeding grounds) while juveniles move downstream (feeding grounds) during winter season (November-December). There are numerous sites with clean gravelled surface, riffle habitat followed by pools of favourable habitat that are suitable for spawning, breeding and feeding of endemic and migratory fishes which were inferred from the presence of large number of fingerling of migratory fish Mahseer (*Tor putitora*). The large number of fingerlings was observed near confluence or upstream in Giri River supporting the prevailing favourable conditions for fish.

It is important from the present survey that the spawning grounds (24 km) present in upstream of the Giri River will be submerged due to construction of dam. The total river basin area upstream of the proposed dam is 114 km. Thus a quite large area of the river will change into reservoir due to submergence of habitat of endemic fishes. The study carried out in upper reaches 900-1,100 m msl support seven – eight communities with maximum richness (Johal et al., 2002). It was inferred from the present study that the middle lower reaches of Himalayan hill streams are support maximum diversity (14 species) at elevation 650-800 m msl. The low diversity in lower reaches might be due to low habitat heterogeneity and fragmented habitat structures whereas upper reaches due to steep slope and turbulent water flow.

CONCLUSIONS

During monsoon season Hmax'varies between 0.48-0.85 and during post monsoon season from 0.6-1.15 at nine study sites (I-IX) made on river Giri of Yamuna River basin in the western-central Himalayan region. These fish species represented by 11 genera, six families and four orders which were recorded. Of these, cyprinids found most dominant group represented by 10 species of seven genera. Of the order Cypriniformes *Barchydanio rerio* was recorded from site IV. Of the three *Barilius* ssp., *B. bendelisis* (Ham.) is the most common at all sites. Other species like *B. barila* (Ham.) and *B. vagra* were recorded from sites but not regularly. *Tor putitora* (Ham.) was present at all sites. Species of *Puntus* i.e. *P. ticto ticto* (Ham.) and *P. sarana sarana* (Ham.) were observed at site IV. *Schizothorax richardsoinii* (Gray) is again typical hill stream forms with reduced scales and occur in II, V, VII, VIII and X sites. *Schistura* ssp. recorded from site II. *Glyptothorax* ssp. is a true hill stream fish with

well developed adhesive organs on the thorax. *Mastembelus armatus* (Lacepede) (Order Synbranchiformes) reported from all sites except site II and *Channa punctatus* (Bloch) (Order Perciformes) though are not true hill stream fishes but also harbour among hill stream fishes. Change in diversity shows correlation with species richness(r), habitat heterogeneity, and hydrological regimes in a longitudinal stretch of 35 km along river Giri a major tributary of Yamuna River system, in Western Himalayas. The abundance differs with change in habitat structures, habitat preference of fishes and water regimes.

The decrease in diversity in the lower stretch of about 3-4 km upstream of barrage found associated with habitat fragmentation and as well as d/s with loss of biotic integrity of aquatic ecosystem due to water scarcity. The species richness was found maximum at upper and middle reaches (elevation 650-800 m, msl) of river whereas it was low in lower reaches. The change in water chemistry is also noticed at Jatan barrage-low head dam due to impoundment of river water. It is inferred that the regulation of water, impacts the species richness and relative abundance components and habitat heterogeneity, which has decreased due to the change in environmental condition.

Although, this is a small barrage-low head dam, but has resulted defragmentation of habitat as the water is being diverted through a tunnel of approximate six km long for hydropower generation at power house (2X30MW) near Majri Village, Girinagar. Water after tail race channel finally joins one of other tributary of Yamuna named Bata River and therefore, leaving downstream zone of about 25 km stretch of the Giri River till its confluence with Yamuna as water scare most of the period of the year except the monsoon season. For restoration of downstream habitat and maintaining wetted area downstream zone of barrage, a minimal of 10%, 20% or 30% of environmental flow (e-flow) of average of lean season shall be released as per Tennant (1976) approach-also known as Montana method (1976). The riparian flow or e-flow shall be sufficed with lower stream habitat enhancement programme (Rosgen, 1996). That will help to sustain biodiversity and maintain ecological balance as well as river continuum.

Fish ladders constructed on several weirs and barrages to facilitate migration of Tor putitora and other carps were reported ineffective (Sandhu and Toor, 1984). The drawbacks of these fish ladders are their steepness and then narrow and inconspicuous inlets. These ladders were found to function as fish traps and like the ones used by poachers. A high use on the river Sutlej at Bhakhra resulted in a sharp decline in catches of *Tor putitora* in Gobindsagar reservoir from 40% in 1966 to 0.5% in 1979 (Natranjan and Sehgal, 1982). But later an increase in catches of this mahseer has been reported, indicated that the Mahseer has found a way to produce new stocks under the new situation (Kumar, 1988).

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