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Pattern of freshwater fish diversity, threats and issues of fisheries management in an unexplored tributary of the Ganges basin, Northern India

Shailesh Kumar Mishra, Uttam Kumar Sarkar, Braj Kishor Gupta, Sunil Prakash Trivedi[1], Vineet Kumar Dubey and Amar Pal

National Bureau of Fish Genetic Resources,
Canal Ring Road, Dilkusha, Lucknow- 226002, India
[1]Department of Zoology, University of Lucknow, India

Abstract: *The present study was conducted to assess the current freshwater fish biodiversity status of an unexplored river Ghaghara, a major tributary of river Ganga in Uttar Pradesh, India. Altogether, 62 species of fish representing 48 genera and 24 families were described. The various diversity index packages have been used to assess the fish diversity and diversity is also correlated with habitat variables. The Cypriniformes was recorded to be the most predominated order, contributing to 41.8% of fish species followed by Siluriformes (36.4%). The study shows that this river supports considerable percentage of food fish (79.0%), aquarium fish (48.4%), highly priced fishes (33.9%) and also sport fish (9.7%). The threat status as per current IUCN Red List criteria showed that most of the species are under lower risk least concern (LRlc) category, however, Indian assessment shows that about 23% fish species under threatened list (EN= 4, VU=10). Several anthropogenic activities like barrages, waste water dumping, over fishing, sedimentation, change in land use pattern etc. were found responsible to threaten the fish diversity. As the threats to fish biodiversity in the Ghaghara river are slowly becoming serious and conservation of fishes has become urgent, and integrated and sustainable fisheries management plan should therefore be developed.*

Key Words: Fish diversity, Habitat, Ghaghara river, Biodiversity, India

Introduction

There is an increasing concern worldwide for the loss of aquatic ecosystems and associated biodiversity (Georges and Cottingham, 2002), particularly for riverine landscapes (Dunn, 2004). Freshwater fishes, for example, may be the most threatened group of vertebrates on earth after amphibians and the global extinction rate of fishes is believed to be in excess of higher vertebrates (Bruton, 1995). However, conservatory measures to mitigate the impact of the pressures have not only been slow but also inadequate and as a result many of the aquatic species are declining rapidly. The main causes behind the loss of biodiversity in freshwater are habitat degradation and fragmentation, exotic species introduction, water diversions, pollution, and global climate change impacts (Gibbs, 2000). In India, the tributaries of river Ganga basin though support rich biodiversity and offer livelihood and nutritional security, have been less studied (Lakra *et al.*, 2010a).

Conservation programs need guidance for maintaining large river fishes, so they can advance feasible conservation aims (Hoggarth *et al.*, 1996). Survey of literatures revealed that a very little information is available on the pattern

E-Mail: usarkar1@rediffmail.com, uksarkar1@nbfgr.res.in

of fish biodiversity of Northern India (Serajuddin *et al.*, 2004; Sarkar *et al.*, 2008). In order to promote the efficient management of freshwater biodiversity and eventually inverse its decline, there is an urgent need to provide solid estimations of fish species losses under plausible climate change and water consumption scenarios. The study on fish biodiversity in Ghaghara river in particular is not reported so far and therefore, the present study is aimed to assess current status of fish biodiversity, distribution, threats and other management issues in Ghaghara river, which may serve as baseline information.

Materials and Methods

Study Area. The Ghaghara River, a major tributary of the Ganga river system in northern India has been selected for this study. The river Ghaghara is one of the largest affluents of the Ganges and rises in the southern slopes of the Himalayas in Tibet at an altitude of about 13,000 feet (3962 metres) above sea level. In the state of Uttar Pradesh Ghaghara flows in a south-east direction to the town of Chhapra where after a course of 570 miles (917 Km) it joins the Ganges. The Ghaghara river is one of the most important commercial waterways of Uttar Pradesh. The major tributaries of Ghaghara are Rapti, Chhoti Gandak, Sharda and Sarju.

Sampling. The present study encompassed 600 km of the Ghaghra river covering entire stretch from upstream to downstream in Uttar Pradesh. Five representative study sites were selected along the entire stretch of river Ghaghra which have been shown in Table 1 and marked on the stretch (Fig. 1). These sites were chosen on the basis of accessibility and similarity in physical habitat. The study was carried out during May 2009 to September 2010. These study sites were Girijapuri barrage (S-1), Chahlarighat (S-2), Elgin bridge (S-3), Saryughat Gonda (S-4) and Faizabad (S-5). Among these study areas two are located in the upper stream (S-1 and S-2), one in the middle stream (S-3) and two in the lower stream (S-4 and S-5). The locations of sampling sites were recorded by using Global Positioning System

Table 1. Sampling sites and their physical attributes.

Site No.	Name of site	Altitude (ft)	Stream type	Position	Land use pattern / Source of pollution	Habitat type(s)
1	Girijapuri barrage	385	Upstream	N 28° 16.321', E081°05.467'	Protected forest area, Barrage Agriculture, Rural	CC, FW, DP, ShW, SW
2	Chahlarighat	350	Upstream	N 27° 78.525', E 81° 16.621'	Agriculture, Rural	FW, ShW, SW
3	Elgin bridge	284	Midstream	N 27° 05.680', E 081°29.160'	Agriculture, Semi urban, barrage, Domestic sewage	FW, R, DP, OR, SW
4	Saryughat, Gonda	258	Downstream	N 27° 25.416', E 081°48.193'	Agriculture, Rural, Sewage discharge	DP, ShW, SW
5	Faizabad	234	Downstream	N 26° 48.040', E 082°06.941'	Agriculture, Urban , Temples, Domestic and industrial sewage	FW, ShW, SW

OR= open river, SW= slow water, DP= deep pool, SP= scour pool, CC= channel confluence, ShW= shallow water, R= riffle, FW= fast water

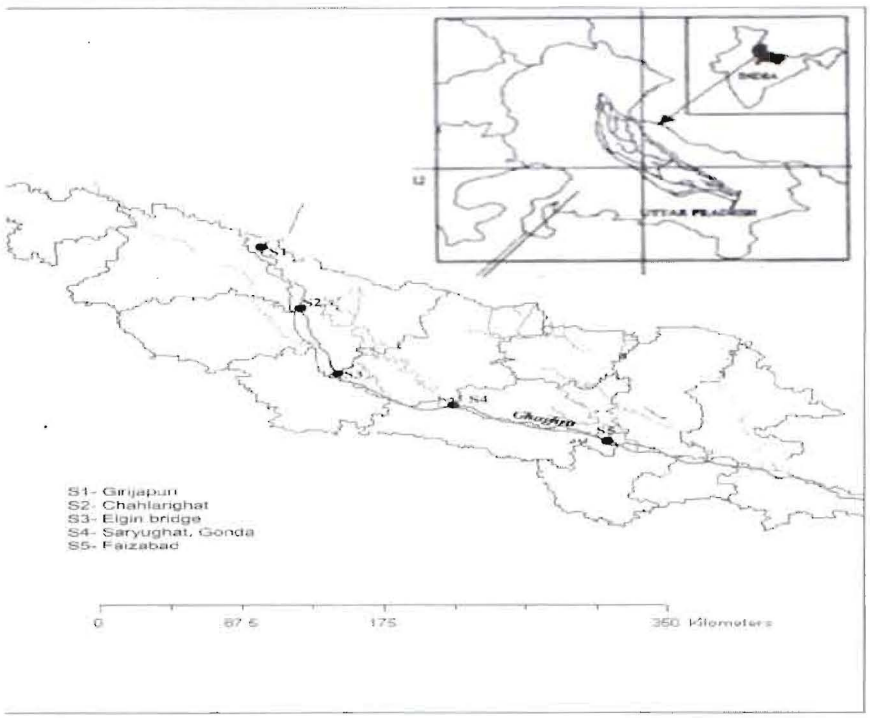

Fig. 1. Drainage map of river Ghaghara showing sampling sites.

(GPS). Experimental fishing was carried out by using the expertise of local fishermen. Fishes were collected with gill nets of different sizes (mesh size 2.5x 2.5, 3x 3, 7 x7 cm; LxB 75 x 1.3, 50x1 m), cast nets (mesh size 6x 6 mm), drag nets (mesh size 7 x7 mm, L xB 80x 2.5 m), and fry collecting nets (indigenous nets using nylon mosquito nets tied with bamboo at each ends). At each site, four gill nets were deployed overnight. Fish sampling was done in channel and near shoreline as per Bain and Knight, (1996).

In the laboratory all samples were counted and measured for total length (TL), standard length (SL), fork length (FL), and body weight (BW). Lengths were measured with a digital caliper to the nearest 0.1 cm and body weight was determined with a digital balance to the nearest 0.1 g. Identifications done were based on keys for fishes of the Indian subcontinent (Jayaram, 1999; Talwar and Jhingran, 1991). We also visited fish markets and landing centers associated with the river system to monitor and look for the presence of any species which were not available during our experimental fishing. Data regarding threats faced by the fish fauna were obtained from both primary (direct observations and interactions with local stake-holders and fishermen) and secondary sources. In the present study, the conservation status of the fishes was assessed as per Lakra *et al.*, (2010b). Their assessment was also carried out according to World Conservation Union or International Union for the Conservation of Nature and Natural Resources (IUCN Red List, 2011).

Biological Indices

Shannon-Weiner Index: Shannon index (H') was calculated by following formula:

$$H = - \Sigma (ni /N) \log2 (ni/N)$$

Where, *H* = Shannon–Wiener index of diversity, *ni* = total numbers of individuals of species and *N* = total number of individuals of all the species.

Table 2. Diversity of freshwater fishes from some of the major tributaries of the River Ganges

Sl. No.	Tributaries	Species reported	Source
1.	Gomti	56	Sarkar et al. 2009
2.	Betwa	63	Lakra et al. 2010
3	Betwa	61	Joshi et al. 2009
4.	Gerua	87	Sarkar et al. 2008
5.	Ramganga	43	Atkore et al. 2011
6.	Ken	57	Lakra et al. 2011 (in press)
7.	Yamuna	70	NBFGR (INDFISHDATABASE 2009)

Jaccard Similarity Index: The Jaccard index, also known as the Jaccard similarity coefficient is a statistic used for comparing the similarity and diversity of sample sets.

Similarity index (*Sj*) was calculated as per standard methods

$Sj = j/(x + y - j)$

Where *Sj* is the similarity between any two communities X and Y, *j* is the number of common species to both communities X and Y, x the total number of species in community X and y the total number of species in community Y.

Evenness (Pielou Index) (E): This expresses how evenly the individuals are distributed among the different species. Pielou's evenness index is commonly used.

$E = H' max/ log S$

Where: $H'max$ = maximum value of Shannon's index and S = total number of species

E is constrained between 0 and 1. The less variation in communities between the species, the higher E is.

Results and Discussion

Species Diversity, Abundance and Distribution Pattern. Altogether 62 species (under 8 orders, 24 families and 48 genera) were collected from the 5 sites of river Ghaghara which is lesser than111 species reported by Srivastava (1988) from states of Uttar Pradesh and Bihar, 87 species from river Gerua of the Katerniaghat Wildlife Sanctuary, 70 species from Yamuna river and 63 species from Betwa river but at the same time it is higher than 43 species from the river Ramganga, 46 species described from Samaspur Bird Sanctuary in Uttar Pradesh, 56 species from the Gomti river, 61 species from Betwa river and 57 species from the river Ken (Table 3).

Table 3. Site wise data of Species diversity, Shannon-Weir index, Species richness, Pilou's evenness.

Parameters	Sampling sites				
	S-1	S-2	S-3	S-4	S-5
Species diversity	55	29	34	30	34
Shannon - Weiner index	2.85	3.07	2.85	3.09	2.62
Dominance index	0.10	0.05	0.09	0.05	0.10
Evenness index	0.71	0.91	0.80	0.91	0.74

The most abundant family was Cyprinidae, contributing 30.6% of the fish fauna followed by Bagridae (9.7%), Siluridae and Schilbeidae (6.5% each) (Fig. 2). Cyprinids were found to be the most dominant group (13 genera and 19 species) with a wide distribution. Similarly, studies on several Indian rivers also showed

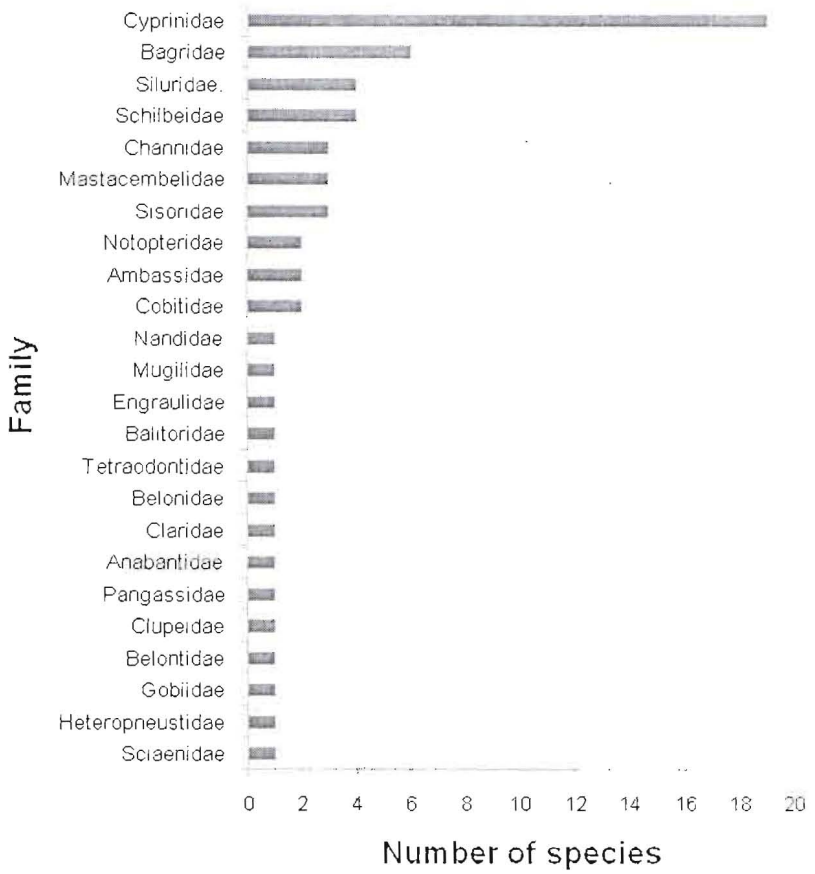

Fig. 2. Diagrammatic representation of the number of fish species occurring in each family.

that fish communities were dominated by Cyprinidae (Sarkar *et al.*, 2008). The species richness in five sampling sites of the river Ghaghara showed considerable variation and highest richness was recorded in site S-1 (55 species). The second richest site was S-3 and S-5 (34 species each) while lower species richness was recorded in sites S-2 (29 species), S-4 (30 species) and respectively. Low species richness at sites S-2 and S-4 may also be correlated with low water depth and water scarcity due to low rainfall. The decreased species richness in the sites (S-2, S-4, S-3 and S-5) may be related to reduction of aquatic vegetation, mainly floating macrophytes, changes in substratum type and may also be due to the relatively reduced area of the basin of the sites. It has been well documented that in riverine ecosystem, the fish populations typically follow a pattern of increasing species richness, diversity and abundance from upper to lower stretches (Welcomme and Peter, 2004). However, the present trend of species richness, diversity and abundance of fishes contrasts sharply with this typical pattern and were recorded lower in the lower area as compare to upper area (Habit *et al.*, 2006). Polluted river water and high fishing intensity were noticed in S-2 and S-4 and this could be the reason for low species richness. The similar observations were made by Sarkar *et al.* (2007) in river Gomti. Overall, the diversity indices indicate a good correlation with species richness across the sites and could be utilized by the biodiversity conservation managers for prioritization of sites for conservation and habitat restoration. The prevailing pattern in this river suggests cumulative temporal and spatial

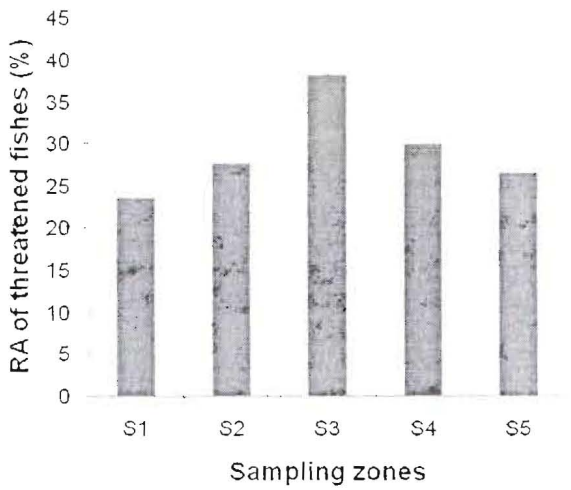

Fig. 3. Site wise relative abundance (RA %) of threatened fishes.

effects of habitat loss or environmental degradation in the lower zone (Scrimgeour and Chambers, 2000). Variations in species diversity at sampling sites indicate impacted sites support less species diversity while less impacted sites are characterized by a diverse fish fauna.

In this study, small indigenous freshwater fishes dominated. At site S-1, species like *Salmostoma bacaila* L., *Puntius ticto*, *Gudusia chapra*, *Ompok pabda*, *Mystus cavasius* and *Nandus nandus* altogether comprised about 65.3% of the total. Similarly, at site S-3 *S. bacaila*, *G. chapra*, *E. vacha*, *M. cavasius*, *O. bimaculatus*, *O. pabda* and *Chanda nama* dominated and constituted 63.2% of the total fish species while at the site S-5 *M. cavasius*, *O. bimaculatus*, *G. chapra*, *Osteobrama cotio*, *Puntius ticto* and *Clupisoma garua* comprise 69.8% of the total. Among the Indian Major Carps (IMC) the RA of *L. rohita* was relatively higher (1.57%) as compared to *C. mrigala* (0.71%) and *Catla catla* (0.55%). The RA of medium carp *L. calbasu* was 1.4% among all the sites. All the four endangered species in the study viz. *Ompok pabo, Chitala chitala, Nangra nangra* and *Chgunius chagunio* showed a relatively low RA which ranged between 0.05% and 0.36%. The RA of some other conservational important species viz. *C. mrigala, Heteropneustes fossilis, C. catla* were medium and their distribution was restricted in the upper and middle stretch. The RA of threatened fishes was recorded highest at Elgin Bridge (S-3) among all the sampling stations (Fig. 3). At the sampling sites more or less aquatic vegetation was also noticed. Four exotic species Common carp (*Cyprinus carpio*), Grass carp (*Ctenopharyngodon idellus*), Silver carp (*Hypophthalmychthys molitrix*) and *Pangasius pangasius* were also collected from the study area with low abundance.

The distribution of fish showed interesting pattern and only 15 species (*B. bagarius, C. nama, C. chitala, C. garua, E. vacha, G. chapra,* L. *calbasu, L. rohita, N. notopterus, O. pabda, O. bimaculatus, P. pangasius, Puntius sarana, Silonia silondia* and *M. cavasius*) were found common to all the sites indicating long range of distribution. There was a measurable effect of small weirs located in the upper stretch of the river. However, some of the species (*Botia dario, Macrognathus aral, Macrognathus pancalus, Mystus vittatus, Nemacheilus botia* and *Tetrodon cutcutia*) showed restricted distribution. Among the three Indian Major Carps (*L. rohita, C. catla* and *C. mrigala*) *L. rohita* was present in all the sites while *C. catla* and *C. mrigala* were absent in Elgin bridge (S-3). The distribution of *Sperata aor* was restricted to the sites S-1 and S-3 of the river whereas, *O. pabo* was noticed only in midstream while *B. bagarius, O. pabda, C.chitala, N. notopterus* and *O. bimaculatus* were recorded throughout the river except *Wallago attu* which was recorded in all the sites except S-3. The occurrence of *W. attu* in the upstream and downstream could be due to its capability of swimming and passing over the weirs (constructed in site S-2) during high flow conditions.

Commercial Utilization Pattern, Trophic Niche and Threat Status. Evaluation of the

commercial utilization of fishes of river Ghaghara indicated that river Ghaghara is rich in supporting 79.0% food fishes (like *C. catla, L. rohita, Channa marulius, N. notopterus* etc), 48.4% aquarium fishes (like *Rasbora daniconius, P. ticto, C. nama* etc), 33.9% highly priced fishes (like *C. chitala, L. rohita* etc.) and 9.7% sport fishes (like *Sperata seenghala, M. tengara,* etc.). The analysis of trophic niches of the available fish species in different sampling sites of river Ghaghara indicated dominancy of carnivorous species (61.3%) followed by omnivores (25.8%) whereas the herbivores and planktivorous contributed only 8.0% and 4.8%, respectively.

Dominancy of carnivorous fishes was observed in the Western Ghats (Das and Chakrabarty 2007) and Ganga basin (Sarkar *et al.,* 2008). Assessment of the threat status of 62 fish species of river Ghaghara as per recent Lakra *et al.*, (2010b) showed 4 fish species as endangered (EN), 10 species vulnerable (VU) and rest 48 under the not evaluated category(Fig. 4). The fishes were also assessed according to the World Conservation Union or International Union for the Conservation of Nature and Natural Resources (IUCN) (Fig. 5).

Diversity, Evenness and Similarity Indices. The Shannon–Weiner diversity index of the different sampling sites showed considerable variation and ranged from 2.62 to 3.09 (Table 4). Shannon Weiner index (H) is the value that combines species diversity and evenness where >3.99 is considered as no-impacted; 3.00-3.99, slightly impacted; 2.00-2.99, moderately impacted and <2.00, severely impacted (Namin and Spurny, 2004). Based on this scale, the studied sections of Ghaghara river are categorized as slightly and moderately impacted. The higher diversity index shows the existence of a balance between total species and total individual of every species. However, a region which has higher species richness does not necessarily have a higher index of diversity. It will depend on the total individual of each species, on the evenness. The evenness index varied from 0.71 to 0.91 being the highest at sites S-4 and S-2, while the lowest was found at S-1 indicating the frequencies of dominant species present at this site. The data showed that *C. punctatus*, *C. reba*, *M. tengra*, *L. calbasu*, *L. rohita*, *G. chapra*, *O. bimaculatus* were the dominant species there. The similarity in species composition among the sites was analyzed using the Jaccard index for calculating

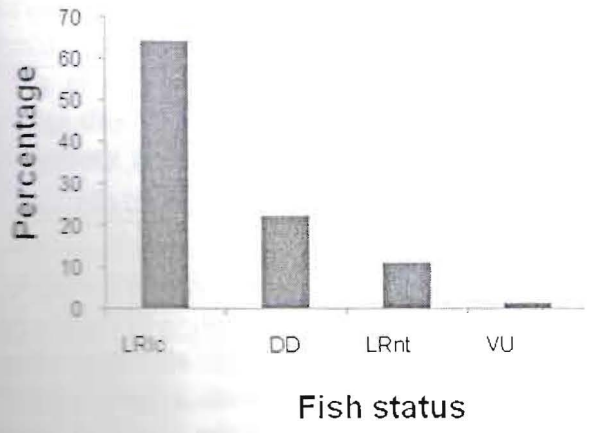

Fig. 4. Conservation categorization of fish the (as per IUCN Red list, 2011)

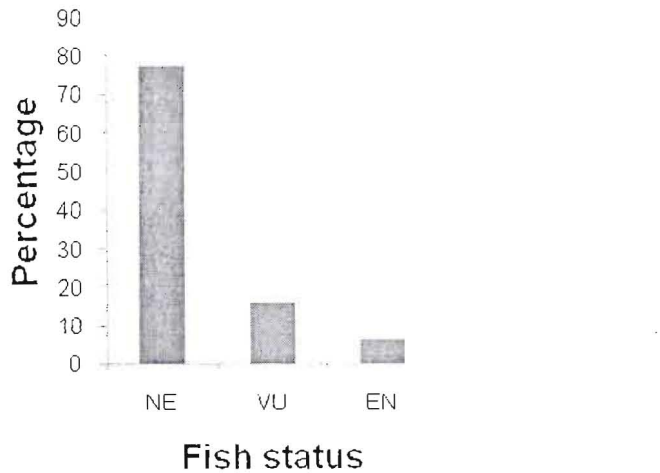

Fig. 5. Conservation categorization of fish species (as per Lakra *et al.,* 2010b).

the extent of similarity between the pairs of data sets. The similarity index between pair wise comparisons of sites ranged from 0.523 to 0.531. The JI value between the sites S-3 and S-4 was the highest while it was the lowest for the comparison between site S-1 and S-3. The similarity in species composition across sites is shown as a dendrogram in Fig. 6, obtained from the JI coefficients of similarity using the average linkage method. The dendrogram shows that sites S-1 and S-3 are similar to each other while site S-4 is isolated from other sites. This may be due to unequal number of fish species and abundance. Similarity within the sites was generated by using the EstimateS (version 7.5.2.) software. Other analyses were carried out using the Statistica package. Sarkar *et al.*, (2007) found that the higher relative abundance and distribution of exotic species indicate threat to the other local species due to their establishment in the river. These species may pose a serious concern for indigenous fish species particular for migratory and threatened species having smaller size groups.

Major Threats and Fisheries Management. In the present study, threats to fish diversity in different sampling zones of Ghaghara were identified. The lower part of upstream segment is relatively more impacted by habitat degradation since the anthropogenic threats are less; however, due to low rainfall, deforestation and siltation, water depth becomes very shallow and discontinuous. The changes in fish diversity and community structure are mainly due to human-induced disturbances, which have affected fish biodiversity at a variety of scales. The anthropogenic activities include hydrological alteration, exotic species invasion, over fishing, rapid sedimentation, dumping of waste water like sewage and industrial effluents leading to eutrophication, changing land use pattern, deforestation and land erosion (Table 4). Among them, hydrological alteration may exert the

Table 4. Site wise representation of prevailing threats for valuable fish fauna.

Site No.	Name of site	Threats	Important genera
1	Girijapuri barrage	Small dams, over fishing	*Channa punctatus, Cirrhinus mrigala, Rita rita, Ompok bimaculatus, Ompok pabda, Labeo calbasu, Labeo rohita, Labeo bata, Eutropichthys vacha, Chitala chitala, Catla catla ,Notopterus notopterus,Rita rita*
2	Chahlarighat	Weirs, discharge of sewage, over fishing, deforestation, siltation	*Cirrhinus mrigala, Eutropichthys vacha, Chitala chitala, Catla catla, Labeo calbasu, Labeo rohita, Ompok bimaculatus, Ompok pabda, Notopterus notopterus,Rita rita*
3	Elgin bridge	Domestic pollution, semi urban, discharge of sewage	*Eutropichthys vacha, Chitala chitala, Labeo calbasu, Labeo rohita, Ompok bimaculatus, Ompok pabda, Ompok pabo*
4	Saryughat Gonda	Domestic pollution, semi urban, discharge of sewage, over fishing	*Eutropichthys vacha, Chitala chitala, Ompok bimaculatus, Ompok pabda, , Labeo calbasu, Labeo rohita*
5	Faizabad	Temple, cremation, discharge of sewage and other domestic wastes, factories, over fishing	*Eutropichthys vacha, Chitala chitala, Catla catla , , Labeo calbasu, Labeo rohita, Notopterus notopterus, Ompok bimaculatus, Ompok pabda*

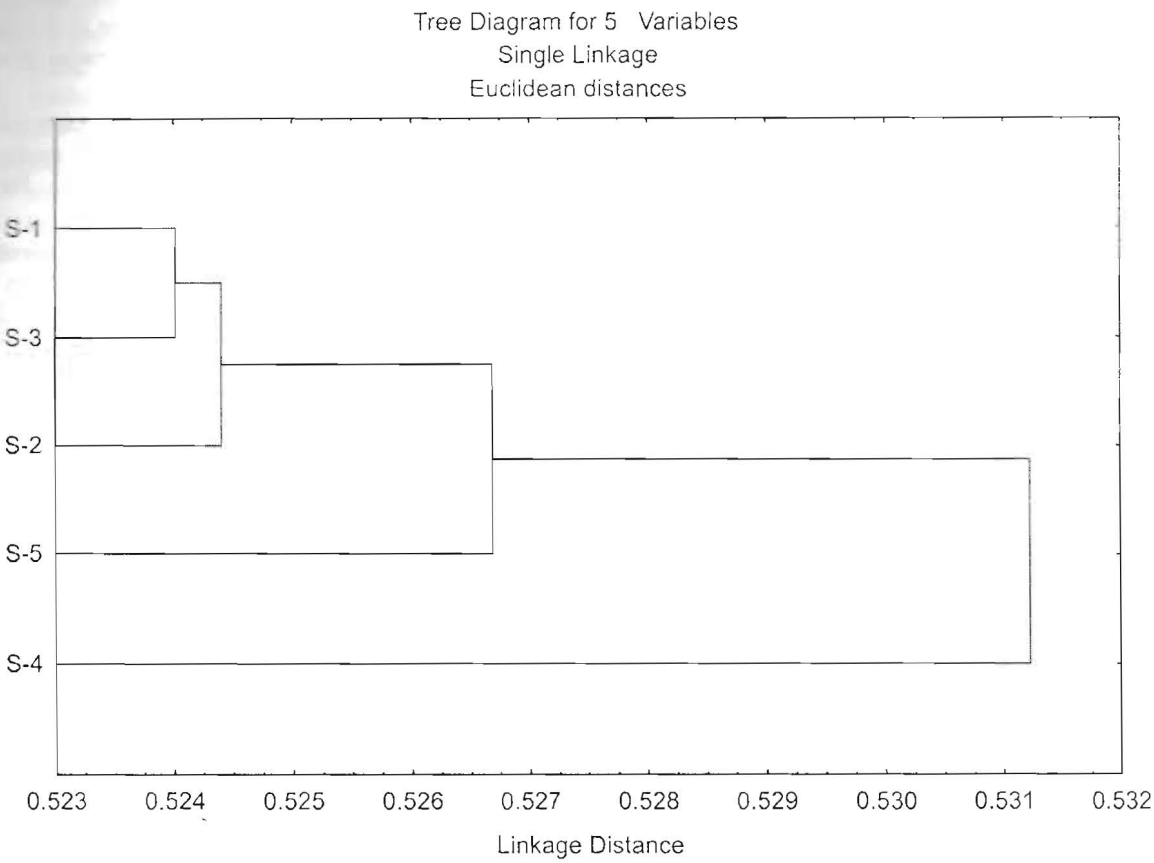

Fig. 6. Dendrogram showing similarity in species composition across five sampling station based on Jaccard index.

largest effects on the changes in fish biodiversity in the Ghaghara river basin. Some of the important ecohydrological alterations are construction of weirs and barrages on the river, loss of wetlands and floodplain habitat and water diversions which are of concern for the migratory species.

Increasing pressure on riverine aquatic resources indicate that fish conservation can no longer be treated in isolation and an integrated approach to aquatic resources management is required (Cowx, 1998). Methods of prioritization of conservation areas (Bergerot *et al.*, 2008) for fish and riverine ecosystems need to be developed soon for effective conservation. For the protection of aquatic resources, flora and fauna of the rivers and tributaries various stresses on the aquatic resources need to be handled. The conservation process of the aquatic biodiversity requires identification of some suitable segments of the rivers for declaring them as Aquatic Reserves, so that the population of native fish fauna may be conserved at regional level. Additionally, priority of conservation should be given to species of river Ghaghara listed under endangered category and accordingly intermediate priority should be given to species of vulnerable category.

Our results presented herein provided an assessment of fish diversity of river Ghaghara which not only largely supports commercially important fishes but also signify a promising habitat of aquarium and highly valued fish-fauna. Moreover, the presence of higher percentage of

carnivore species indicates a relatively healthy, trophically diverse community. As the quality of the river declines, these populations may decline and disappear. The decline of the diversity and the loss of some fishes will have potential impacts on the national fish biodiversity, so potential areas of fish biodiversity in the Ghaghara River should be identified as nature reserves. As the threats to fish biodiversity in the Ghaghara River are slowly becoming serious and the conservation of fishes has become urgent, an integrated and sustainable fisheries management plan should therefore be developed.

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