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A SYSTEMATIC CHECKLIST OF FISHES IN HIMALAYAN RIVER GHAGHARA, EMERGING THREATS AND CONSERVATION MANAGEMENT ALONG WITH IUCN STATUS

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ABSTRACT : The present study illustrates a systematic checklist of the fishes of Ghaghara River, as one of the richest ecosystem of fish diversity within the Northern Himalayan region of India, including notes on vernacular names and IUCN conservation status. This checklist includes 78 finfishes belonging to 11 orders, 27 families and 56 genera. Among these, 67 species belong to the Least Concern (LC). Two species are listed under Near Threatened (NT) and Endangered (EN), whereas *Hypophthalmichthys nobilis* listed in Data Deficient (DD) category of the IUCN Red list in 2023. Major threats to Ghaghara basin are destructive fishing, using small size mesh net, over-exploitation of fishes, juvenile & brooder fish, sand mining, erosion, sedimentation, Pollution, habitat loss, spread of Invasive species and infestation of Water hyacinth *(Eichhornia crassipes)* etc. This result is expected to contribute skeletal information for future studies in this river basin. Thus, an urgent need exists for taking up research on fish fauna and their habitat. Restoration measures have been proposed based on an ecosystem-scale approach to biodiversity conservation. Moreover, there is a need to maintain this valuable ecosystem to be ecofriendly for the aquatic flora and fauna to thrive. The authors recommend a complete survey of this riverine ecosystem for biodiversity and conservation point of view.

Key words : Riverine ecosystem, fish biodiversity, Uttar Pradesh, IUCN status, conservation.

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INTRODUCTION

The freshwater ecosystem is one of the most vulnerable and threatened habitats in the world (Cooke *et al*, 2016). Several substantive anthropogenic threats such as habitat destruction, fast-changing habitat conditions, fragmentation, species introduction (biological invasions), impaired flows, water extraction, pollution, climate change and to a lesser extent, indiscriminate fishing, overexploitation as well as competition for resources (Dudgeon *et al*, 2006; Sarkar *et al*, 2008). Consequently, global freshwater biodiversity declining at an alarming rate of 76% much faster than marine (39%) and terrestrial (39%) population (Living Planet Report, 2014).

Fishes are the largest vertebrate group with more than 34,000 known species worldwide have been recorded from various ecosystems. According to Eschmeyer's Catalog of Fishes (2023), a total number of approximately 36,383 valid species, of which 18,426 are found in freshwater ecosystems. NBFGR has developed a database on Indian fish diversity comprising information on 3183 indigenous finfishes including 1548 marine, 917 freshwater and 394 brackish water species (https://aqgrisi.nbfgr.res.in/#/). This bewildering fish fauna resource of this region have been attracting many ichthyologists both from India and abroad too.

As a landlocked state, UP has abundant freshwater resources such as rivers, streams, reservoirs, wetlands, pools, tal and tanks, with rivers covering a basin area of 7,20,000 hectares and traversing 28,500 km (Lakra, 2010; Sahu and Pramila, 2021). These water bodies harbour considerable diversity of aquatic bio-resources and offer good potential for fisheries and aquaculture production

(Kumar and Pandey, 2012). Rivers and tributaries flowing through the state are Ganga, Yamuna, Ghaghra, Rapti, Gandak, Ramganga, Gomti, Hindan, Chambal, Saryu, Sai, Kosi, Betwa, Belan, Dhasan, Tons and Son, etc, which are the rich source of genetic diversity.

Several researchers investigated fish diversity, composition structures, population dynamics and conservation status of major important rivers such as Ganga, Gomti, Yamuna and their tributaries. The Ghaghara river of UP makes one of the richest fish germplasm of India. Documentations on fish fauna from the Ghaghara River were examined and reported by few authors (Mishra *et al*, 2011; Kumar *et al*, 2020). However, comprehensive information and considerable knowledge gap on fish groups of this region are really scanty. Also, lack of definite information on varous threats faced by the fishes has hampered the planning and implementation of appropriate conservation and management strategies. So, detailed studies are required for the conservation and management of this river. Considering this lacuna, the present study focuses on presenting a checklist, current status of fish in Ghaghara River, along with their systematic position & conservation status, identify the major threats and suggest suitable conservation strategies, which may serve as baseline information for future studies.

MATERIALS AND METHODS

Study area

The Ghaghara River, also known as the Karnali River, is a major left bank tributary of the Gangetic Riverine system of northern India and Nepal. However, the river's literal meaning is "Turquoise River" and it is a trans-boundary perennial river. It originates from the Southern slope of the Himalayas in Tibetan Plateau near Mansarovar Lake, in the glaciers of Mapchachungo (elevation- 3,962 m above sea level). After passing through the Himalayas in Nepal, it joins the Sharda River in India at Brahma Ghat, Bahraich. After a 970-kilometer journey through Uttar Pradesh and Bihar, it confluences with Ganges below Chapra. The catchment area of Ghaghara River is 127,950 km^2. It is distributed across India and Nepal, with about 55% in Nepal and 45% in India.

Collection of samples

The present study was carried out between January 2020 to December 2020 at different sites of the Ghaghara River. For studying the fish diversity, various data and information were collected by secondary data, physical validation and interview with the local fisherman of the study area. Experimental fishing was carried out by local fishermen. Generally, fish samples were caught using standard fishing gear like cast net, gill nets, drag nets, scoop nets and hook & line. We also visited fish markets and landing centers associated with the river stretch to assess and verify the presence of fish species which did not come to our net. Fish samples were collected on a quarterly basis. Collected samples were immediately preserved in 5% formalin for further study. Fishes were identified following Day (1878), Talwar and Jhingran (1991), Jayaram (1981, 1999), Kottelat (2001), Gopalji Srivastava (2000). The colour, banding patterns, morphometric and meristic characters were studied as fin formulas of each species. Updated taxonomic framework and nomenclature were collected from the

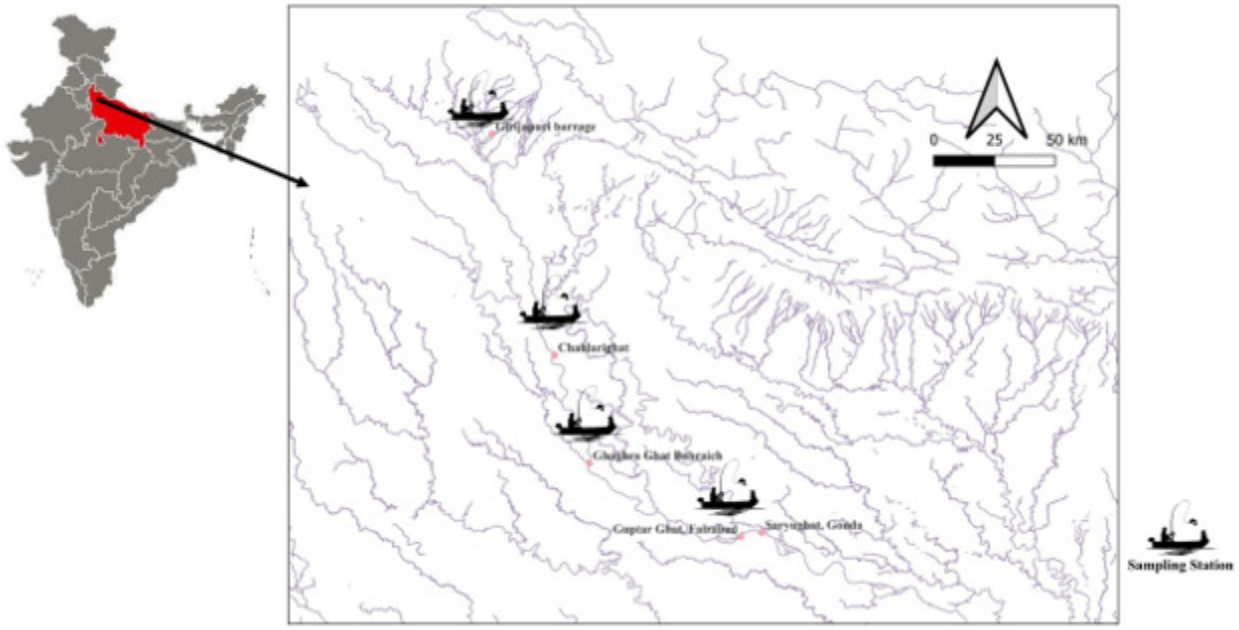

Fig. 1 : Map showing the sites of Ghaghara River Basin.

Table 1 : Sampling sites and their physical attributes.

S. no.	Sampling site code	Sampling station	Stream reach	Longitude	Latitude	Elevation
1.	S-1	Girijapuri barrage, Bahraich	Upper stretch	28° 27' 23'' N	81° 05' 07'' E	150
2.	S-2	Chahlarighat, Bahraich	Upper stretch	27° 32' 39'' N	81° 20' 38'' E	136
3.	S-3	Ghaghra Ghat Bahraich	Middle stretch	27° 05' 55'' N	81° 29' 17'' E	125
4.	S-4	Saryughat, Gonda	Lower stretch	26° 48' 45'' N	82° 12' 07'' E	110
5.	S-5	Guptar Ghat, Faizabad	Lower stretch	26° 47' 44'' N	82° 06' 54'' E	120

FAO, Fish base database, Eschmeyer's Catalog of Fishes, World Register of Marine Species (WoRMS) and Aquatic Genetic Information System of India (AqGRISI). It is very important to know the conservation status of fish diversity for taking future strategies to maintain the sustainability of this riverine ecosystem. To serve this purpose, the conservation status of the fish species was listed based on IUCN red list data 2023.

RESULTS AND DISCUSSION

The inventory of finfish identified species from Ghaghara River along with IUCN conservation status are presented in Table 2. A total of 78 finfish, belong to 13 orders, 27 families and 56 genera. Among these, 67 species belonged to the Least Concern (LC), four species to vulnerable (VU), 2 Not Evaluated (NE), 2 fishes listed under Near Threatened (NT) and endangered whereas *H. nobilis* listed as Data Deficient (DD) category of the IUCN Red list. All the identified species are recorded under Plates 1, 2, 3, 4 and 5. The fish diversity recorded in the present study is higher than that recorded for fishes from Ghaghara stretch by Mishra *et al* (2011) and Kumar *et al* (2020). The Ghaghara River is home of several commercial, ornamental and small indigenous fishes (SIF). Present study indicates changing scenario of fish diversity of Ghaghara basin. Mishra *et al* (2011) and Kumar *et al* (2020) also had a similar observation in present investigation, while we listed seven new additions to the GR (Fig. 2).

Eleven orders of finfishes, Cypriniformes, Siluriformes, Perciformes, Anabantiformes, Synbranchiformes, Clupeiformes, Osteoglossiformes, Mugiliformes, Gobiiformes, Beloniformes and Tetraodontiformes were recorded from the study area. Order Cypriniformes (35.90%), Siluriformes (26.92%) and Perciformes (10.26%) comprised of the maximum number of species whereas order Gobiiformes, Beloniformes, Tetraodontiformes formed 1.28% of the total recorded finfish (Fig. 3).

The present studies revealed that 27 families of finfish were represented in the Ghaghara basin. They included Cyprinidae, Danionidae, Cobitidae, Siluroidae, Pangasidae, Bagridae, Ailiidae, Sisoridae, Heteropneustidae, Claridae, Channidae, Sciaenidae, Ambassidae, Anabantidae, Badidae, Nandidae, Osphronemidae, Mastacembelidae,

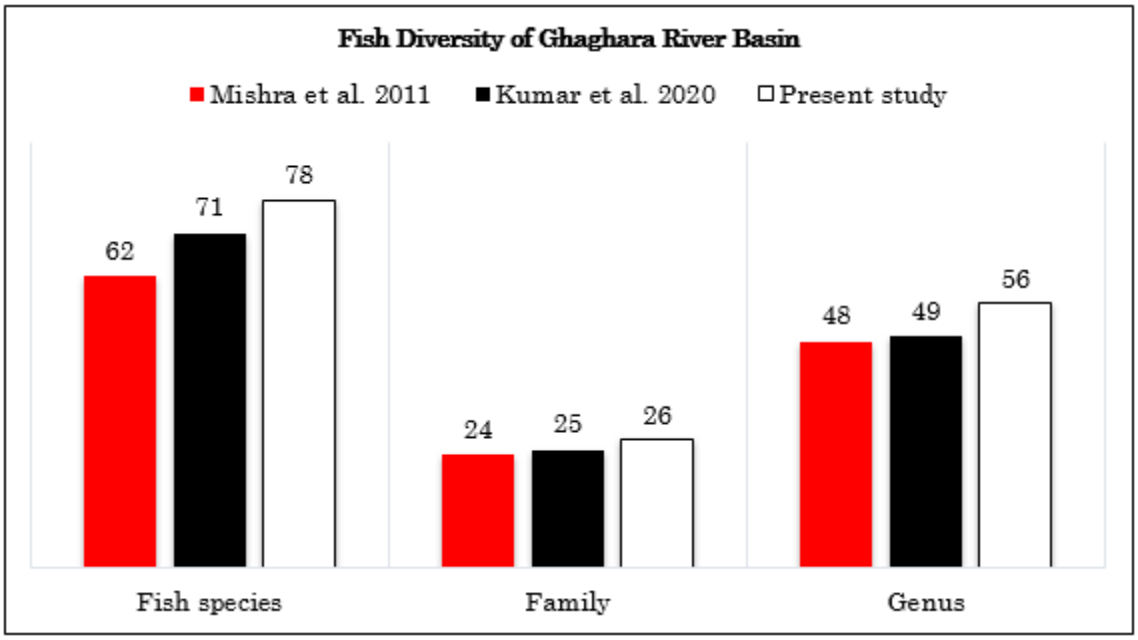

Fig. 2 : Comparison of fish diversity between the previous and present study.

Table 2 : Systematic checklist of fishes recorded from Ghaghara River, their taxonomic position, common and vernacular names, Distribution along with IUCN Red List status.

S. no.	Scientific name	Vernacular name	English name	Distribution	IUCN status	Current population status	Human uses	Relative abundance
Order: Cypriniformes								
Family: Cyprinidae (Minnows and Carps)								
1.	*Gibelion catla* (Hamilton, 1822)	Bhakur, Katla	Catla	Pakistan, India, Bangladesh, Nepal and Myanmar	LC	Unknown	FF	Common
2.	*Labeo rohita* (Hamilton, 1822)	Rohu	Rohu	Bangladesh; India; Myanmar; Nepal; Pakistan; Sri Lanka	LC	Unknown	FF	Common
3.	*L. bata* (Hamilton, 1822)	Bata	Bata	Bangladesh; India; Myanmar	LC	Unknown	FF	Common
4.	*L. dyocheilus* (McClelland, 1839)		Ghora mach	Asia: Bhutan, Pakistan, India, Bangladesh, Nepal, Myanmar	LC	Unknown	FF	Rare
5.	*L. gonius* (Hamilton, 1822)	Kuria, Kurai	Kuria labeo	Asia: Pakistan, India, Bangladesh, Myanmar, Afghanistan, Nepal	LC	Unknown	FF	Moderate
6.	*L. calbasu* (Hamilton, 1822)	Karaunchi/ Karaunchh/ Karaunchar/ calbasu	Calbasu, Orangefin labeo	Bangladesh; China; India; Myanmar; Nepal; Pakistan; Thailand	LC	Unknown	FF	Common
7.	*Cirrhinus mrigala* (Hamilton, 1822)	Nain	Mrigal	Pakistan, India, Nepal and Bangladesh	LC	Stable	FF	Common
8.	*Cirrhinus reba* (Hamilton, 1822)	Raia	Reba carp	Pakistan, India, Nepal, Bangladesh, and Myanmar	LC	Stable	FF	Common
9.	*Ctenopharyngodon Idella* (Valenciennes, 1884)	Grass carp	Grass carp	Eastern China, Russia, India	LC	Unknown	FF	Common
10.	*Hypophthalmichthys molitrix* (Valenciennes, 1844)	Silver carp	Silver carp	China, India, Bangladesh	NT	Decreasing	FF	Common
11.	*H. nobilis* (Richardson, 1845)		Bighead carp	Afghanistan, India; Indonesia, Sri Lanka, China, Bangladesh	DD	Decreasing	FF	Common
12.	*Cyprinus carpio* (Linnaeus, 1758)	China rohu	Common carp	Afghanistan, China, India, Bangladesh	VU	Unknown	FF	Common
13.	*Systomus sarana* (Hamilton, 1822)	Sidhari/ Darahee	Olive barb, Peninsular olive barb	Bangladesh; India; Nepal; Pakistan	LC	Unknown	FF	Moderate
14.	*Puntius sophore* (Hamilton, 1822)	Sidhari, Putia	Spotfin Swamp Barb	Bangladesh; China; India; Myanmar; Nepal; Pakistan; Thailand	LC	Unknown	FF, OF	Common

Table 2 continued...

Table 2 continued...

15.	*Pethia ticto* (Hamilton, 1822)	Sidhari, Punti, Putia	Two spot barb, Ticto Barb	Bangladesh; India; Nepal; Pakistan; Sri Lanka	LC	Unknown	FF, OF	Common
16.	*Pethia conchonius* (Hamilton, 1822)	Sidhari, Putia	Rosy barb	Afghanistan; Bangladesh; India; Nepal; Pakistan	LC	Unknown	FF, OF	Common
17.	*P. chola* (Hamilton, 1822)	Putia	Chola Barb, Swamp barb	Pakistan, India, Nepal, Bangladesh, Sri Lanka and Myanmar, Bhutan	LC	Unknown	FF, OF	Common
18.	*Osteobrama cotio* (Hamilton, 1822)	Gurda		Pakistan, India, Nepal and Bangladesh.	LC	Unknown	FF, OF	Common
19.	*Tor putitora* (Hamilton, 1822)	Mahseer mahseer	Putitor	Afghanistan, Pakistan, India, Nepal, Bangladesh, Bhutan and Mynmar	EN	Decreasing	FF, OF	Rare
Family: Danionidae								
20.	*Devario aequipinnatus* (McClelland, 1839)		Giant danio	India and Nepal to Indochina, Sri Lanka	LC	Unknown	FF, OF	Common
21.	*D. devario* (Hamilton, 1822)		Sind danio	Pakistan, India, Nepal and Bangladesh	LC	Unknown	FF, OF	Very common
22.	*Esomus danrica* (Hamilton, 1822)	Dendua	Indian flying barb	Bangladesh; India; Myanmar; Nepal; Pakistan; Sri Lanka	LC	Stable	FF, OF	Very common
23.	*Amblypharyngodon mola* (Hamilton, 1822)	Moa/ Dhawai	Mola carplet	Bangladesh; India, Pakistan, Myanmar, Afghanistan	LC	Stable	FF, OF	Very common
24.	*Raiamas bola* (Hamilton, 1822)		Trout barb	India, Bangladesh, Myanmar and Nepal, Bhutan, Thailand	LC	Unknown	FF	Rare
25.	*Aspidoparia morar* (Hamilton, 1822)		Morar, Morari, Moraki	Iran, Afghanistan, Pakistan, India, Nepal, Bangladesh, Myanmar and Thailand	LC	Unknown	FF,OF	Very common
26.	*Laubuka laubuca* (Hamilton, 1822)		Indian glass barb	Pakistan, India, Bangladesh, Sri Lanka, Myanmar, Malay Peninsula and Indonesia	LC	Unknown	FF,OF	Common
27.	*Salmostoma bacaila* (Hamilton, 1822)	Chilwa	Large razorbelly minnow	Pakistan, India, Bangladesh, Nepal, Afghanistan	LC	Stable	FF	Very common
Family: Cobitidae (Spined loaches)								
28.	*Lepidocephalichthys guntea* (Hamilton, 1822)	Nataki	Guntea loach	Pakistan, northern India, Bangladesh, Nepal, Myanmar and Thailand	LC	Stable	FF, OF	Common

Table 2 continued...

Table 2 continued...

Order: Siluriformes Family: Siluroidae								
29.	*Wallago attu* (Bloch et Schneider, 1801)	Padhani/ Pardni	Freshwater Shark	Bangladesh; Cambodia; India; Indonesia; Lao People's Democratic Republic; Myanmar; Nepal; Pakistan; Sri Lanka; Thailand; Viet Nam	VU	Decreasing	FF	Common
30.	*Ompok bimaculatus* (Bloch, 1794)	Jalkapoor	Butter catfish	Indian subcontinent and Myanmar	NE	Unknown	FF	Common
31.	*O. pabda* (Hamilton, 1822)	Pabda	Pabdah catfish	Afghanistan, Pakistan, India, Bangladesh and Myanmar	NE	Decreasing	FF	Common
Family: Pangasidae								
32.	*Pangasius pangasius* (Hamilton, 1822)	Pangus, Pagasi	Pangas catfish	Indian subcontinent and Myanmar	LC	Decreasing	FF	Moderate
Family: Bagridae (Bagrid catfishes)								
33.	*Mystus tengara* (Hamilton, 1822)	Tengara	Tengara catfish	Pakistan, India, Nepal and Bangladesh	LC	Unknown	FF,OF	Very common
34.	*M. vittatus* (Bloch, 1794)	Tengana	Striped dwarf catfish	Indian subcontinent, including Pakistan, India, Sri Lanka, Nepal, Bangladesh and probably Myanmar.	LC	Decreasing	FF,OF	Very common
35.	*M. cavasius* (Hamilton, 1822)	Sutahawa tengra, Dariai	Gangetic mystus	Pakistan, Nepal, India, Sri Lanka and Myanmar	LC	Decreasing	FF,OF	Very common
36.	*M. bleekeri* (Day, 1877)		Day's mystus	Pakistan, India, Bangladesh, Nepal, Myanmar and Indonesia.	LC	Unknown	FF,OF	Very common
37.	*Sperata aor*	Dariai Tengar	Long-whiskered catfish	Pakistan, India, Nepal, Bangladesh and upper Myanmar	LC	Sable	FF, OF	Very common
38.	*S. seenghala* (Sykes, 1839)	Dariai Tengar	Giant river-catfish	Afghanistan, Pakistan, India, Nepal and Bangladesh, Thailand, China	LC	Unknown	FF	Very common
39.	*Rita rita* (Hamilton, 1822)	Belgagara, Ritha, Hunna	Rita	Afghanistan, Pakistan, India, Nepal, Bangladesh and Myanmar	LC	Decreasing	FF	Very common
Family: Ailiidae								
40.	*Silonia silondia* (Hamilton, 1822)		Silond catfish	Pakistan, India, Bangladesh, Nepal and probably Myanmar	LC	Unknown	FF	Moderate
41.	*Eutropiichthys vacha* (Hamilton, 1822)	Batchwa	Batchwa vacha	Pakistan, India, Bangladesh, Nepal, Myanmar and Thailand	LC	Decreasing	FF	Moderate

Table 2 continued...

Table 2 continued...

42.	*Clupisoma garua* (Hamilton, 1822)	Baikari, Bakeri	Garua bachcha	Pakistan, India, Bangladesh and Nepal.	LC	Decreasing	FF	Moderate
Family: Sisoridae (Sisorid catfishes)								
43.	*Bagarius bagarius* (Hamilton, 1822)	Gonch	Goonch	Restricted to the Indian subcontinent and Bangladesh; Bhutan; India; Nepal; Pakistan	VU	Decreasing	FF, OF	Rare
44.	*Nangra nangra* (Hamilton, 1822)			Pakistan, India, Bangladesh and Nepal	LC	Stable	FF	Rare
45.	*Gagata cenia* (Hamilton, 1822)	Baghi	Indian gagata	India	LC	Unknown	OF	Rare
46.	*Sisor rabdophorus* (Hamilton, 1822)			Pakistan, India and Bangladesh, Nepal	LC	Unknown	OF	Rare
Family: Heteropneustidae (Airsac catfishes)								
47.	*Heteropneustes fossilis* (Bloch, 1794)	Singhi	Singee, Stinging catfish	Bangladesh; India, Lao People's Democratic Republic; Myanmar; Nepal; Pakistan; Sri Lanka; Thailand	LC	Stable	FF, OF	Common
Family: Claridae (Airbreathing catfishes)								
48.	*Clarias magur* (Hamilton, 1822)	Mangur, Deshi magur	Walking catfish	India and Bangladesh	EN	Decreasing	FF	Moderate
49.	*C. gariepinus* (Burchell, 1822)	Bidesi magur	Thai mangur, North African catfish, African catfish		LC	Unknown	FF	Moderate
Order: PerciformesFamily: Channidae (Snake headed fish)								
50.	*Channa marulius* (Hamilton, 1822)	Souri, Saur, Saul	Great snakehead	Asia: India to China, south to Thailand, Cambodia and Pakistan	LC	Unknown	FF, OF	Very Common
51.	*C. punctata* (Bloch, 1793)	Girohi/ Girai	Spotted snakehead	Afghanistan, Pakistan, India, Sri Lanka, Nepal, Bangladesh, Myanmar and China	LC	Stable	FF, OF	Very Common
52.	*C. striata* (Bloch, 1793)	Souri	Snakehead Murrel	Bangladesh; Cambodia; China; India; Indonesia; Lao People's Democratic Republic; Malaysia; Myanmar; Nepal; Pakistan; Thailand; Viet Nam	LC	Stable	FF, OF	Very Common

Table 2 continued...

Table 2 continued...

53.	*C. orientalis* (Bloch & Schneider, 1801)		Walking snakehead, Smooth-breasted Snakehead	India, Afghanistan, Sri Lanka and Indonesia.	VU	Decreasing	FF, OF	Moderate
54.	*C. gachua* (Hamilton, 1822)	Chanaga, Chiranga	Dwarf Snakehead	Afghanistan; Bangladesh; Bhutan; Cambodia; China; Hong Kong; India; Indonesia, Malaysia; Myanmar; Nepal; Singapore; Sri Lanka; Thailand	LC	Unknown	FF, OF	Rare
Family: Sciaenidae								
55.	*Johnius coitor* (Hamilton, 1822)		Big-eyed Jewfish, Coitor Croacker, Coitor Croaker, Ganges Croaker	Bangladesh; India; Indonesia; Malaysia; Myanmar	LC	Unknown	FF	Moderate
Family: Ambassidae (Asiatic glassfishes)								
56.	*Chanda nama* (Hamilton, 1822)	Chanari	Elongate Glass Perchlet	Pakistan, India, Nepal, Bangladesh and Myanmar	LC	Decreasing	FF, OF	Very Common
57.	*Parambassis ranga* (Hamilton, 1822)		Indian Glassy Fish, Indian Glass Perch	Bangladesh; Cambodia; India; Myanmar, Nepal; Pakistan	LC	Stable	FF, OF	Very Common
Order: Anabantiformes								
Family: Anabantidae (Climbing gouramies)								
58.	*Anabas testudineus* (Bloch, 1792)	Kawai	Climbing perch	India, Bangladesh, China, Malaysia; Myanmar; Nepal; Pakistan; Singapore; Sri Lanka; Thailand; Viet Nam	LC	Stable	FF, OF	Very Common
Family: Cichlidae								
59.	*Oreochromis niloticus* (Linnaeus, 1758)	Jalebi	Nile tilapia	India, Bangladesh, Sri Lanka	LC	Unknown	FF, OF	Common
Family: Badidae (Chameleon fishes)								
60.	*Badis badis* (Hamilton, 1822)	Sumha	Badis	Bangladesh; Bhutan; India,	LC	Unknown	FF, OF	Rare

Table 2 continued...

Table 2 continued...

				Nepal; Pakistan				
Family: Nandidae (Asian leaffishes)								
61.	*Nandus nandus* (Hamilton, 1822)		Gangetic leaffish	India, Bangladesh, Pakistan to Thailand.	LC	Unknown	FF, OF	Very Common
Family: Osphronemidae (Gouramies)								
62.	*Trichogaster fasciata* (Bloch & Schneider, 1801)	Khosti, Khesua	Banded gourami	Pakistan, India, Nepal, Bangladesh and upper Myanmar	LC	Unknown	FF, OF	Very Common
63.	*T. lalius* (Hamilton, 1822)	Khosti, Khesua	Dwarf gourami	Pakistan, India, Bangladesh	LC	Unknown	FF, OF	Moderate
64.	*T. chuna* (Hamilton, 1822)	Bulla, Khesua	Honey gourami	India and Bangladesh.	LC	Unknown	FF, OF	Moderate
Order: Synbranchiformes								
Family: Mastacembelidae (Spiny eels)								
65.	*Macrognathus pancalus* (Hamilton, 1822)	Bam/ Malga	Barred spiny eel/ Indian spiny eel	Bangladesh; India, Nepal; Pakistan	LC	Unknown	FF, OF	Common
66.	*Mastacembelus armatus* (Lacepède, 1800)	Bam	Zig-zag eel	Bangladesh; India, Nepal; Pakistan	LC	Stable	FF, OF	Common
67.	*M. aculeatus* (Bloch, 1786)		Lesser spiny eel	Indonesia; Malaysia, India, Bangladesh	LC	Unknown	FF, OF	Moderate
Family: Synbranchidae (Swamp-eels)								
68.	*Ophichthys cuchia* (Hamilton, 1822)	Andhasanp/Cuchia/ Andhawa	Cuchia, Gangetic mudeel, Mud eel, Rice eel, Swamp eel	Pakistan, India, Nepal, Bangladesh, Myanmar	LC	Unknown	FF, OF	Very Common
Order: Clupeiformes								
Family: Dorosomatidae (Gizzard shads and sardines)								
69.	*Gudusia chapra* (Hamilton, 1822)	Suhia/ Suiya/ Chapla	Indian River Shad	Bangladesh; India, Nepal	LC	Decreasing	FF, OF	Moderate
70.	*Gonialosa manmina* (Hamilton, 1822)		Ganges river gizzard shad	Bangladesh; India, Sri Lanka	LC	Unknown	FF, OF	Rare

Table 2 continued...

Table 2 continued...

Family: Engraulidae (Anchovies)								
71.	*Setipinna phasa* (Hamilton, 1822)		Gangetic hairfin anchovy	Bangladesh; India, Nepal	LC	Unknown	NEFF, OF	Rare
Order: Osteoglossiformes (Bony tongues)								
Family: Notopteridae (Featherbacks or knifefishes)								
72.	*Chitala chitala* (Hamilton, 1822)	Moya/ Moi	Clown knifefish	Bangladesh; India, Nepal; Pakistan	NT	Decreasing	FF, OF	Rare
73.	*Notopterus notopterus* (Pallas, 1769)	Patra	Bronze featherback	Bangladesh; Cambodia; India; Indonesia Malaysia Myanmar, Nepal; Pakistan; Thailand; Viet Nam	LC	Stable	FF,OF	Common
Order: Gobiiformes								
Family: Gobioidae (Gobies)								
74.	*Glossogobius giuris* (Hamilton, 1822)	Bulla	Bareye Goby, Bar Eyed Goby, Bar-eyed Goby, Flat-headed Goby, Flathead Goby, Forktongue Goby, Fresh Water Goby, Gangetic Tank Goby, Tank Goby, White goby	Bangladesh; China; India; Indonesia; Malaysia; Myanmar; Nepal; Pakistan; Singapore; Sri Lanka	LC	Unknown	FF, OF	Common
Order: Beloniformes Family*:* Belonidae (Needlefishes)								
75.	*Xenentodon cancila* (Hamilton, 1822)	Kawwa machli/ Kauwa	Freshwater garfish	Bangladesh; Bhutan; India Myanmar; Nepal; Pakistan; Thailand	LC	Unknown	FF, OF	Very common
Order: Tetraodontiformes								
Family: Tetraodontidae (Puffers)								
76.	*Leiodon cutcutia* (Hamilton, 1822)	Galfugani, Petfulani	Ocellated Pufferfish	India, Bangladesh, Sri Lanka, Myanmar	LC	Unknown	OF	Rare

Table 2 continued...

Table 2 continued...

Order – Mugiliformes								
Family: Mugilidae (Mullets)								
77.	*Rhinomugil corsula* (Hamilton, 1822)	Hunra, Corsula	Corsula, Corsula Mullet	India, Bangladesh, Nepal and Myanmar.	LC	Unknown	FF, OF	Rare
78.	*Minimugil cascasia* (Hamilton, 1822)		Yellowtail mullet	Pakistan, India and Bangladesh.	LC	Unknown	FF, OF	Very rare

Note: NE: Not Evaluated; EN: Endangered; NT: Near threatened; LC: Least Concern; CR: Critically endangered; DD: Data Deficient; VU: Vulnerable: FF: Food fish: OF: Ornamental fish

Source of information: Fish base (https://www.fishbase.se/search.php); IUCN Red list (https://www.iucnredlist.org/); WORM (https://www.marinespecies.org/index.php); Eschmeyer's Catalog of Fishes.

Synbranchidae, Dorosomatidae, Engraulidae, Notopteridae, Gobioidae, Belonidae, Tetraodontidae and Mugilidae. Among these Cyprinidae contributed the highest number with 24.68% followed by Danionidae (10.39%), Badidae (9.09%) (Fig. 4).

Documentation of the conservation status following the IUCN Red List of Threatened Species has revealed that among the 78 fish species, four species are under 'Vulnerable' (VU) category and 67 species are under 'Least Concern' (LC) category. However, only one species is under 'Data Deficient' (DD) category. *Hypophthalmichthys molitrix* and *Chitala chitala* are listed under 'Not Evaluated' (NE) category (Table 2) as well as *Clarias magur*, *Tor putitora* are categorized into Endangered (EN) (Fig. 6). The percentage representation of the conservation status of these fish has been presented in Fig. 5.

Lakra (2010) confirms the occurrence of about 123 fish species in Uttar Pradesh. Sixty-three fish belonging to 20 families and 45 genera were listed from river Betwa, UP. As per the study of NBFGR, the Gangetic riverine system is home to 92 fish species belonging to 58 Genera and 24 Families. In the present study, a similar diversity of Gomti River has been found (Sarkar *et al*, 2010; Bano and Serajuddin (2016), Krishna (2022), Gupta and Tripathi, 2017). Radhakrishnan and Kurup (2010) reported 54 fish species belonging to six orders and 19 families from Periyar Tiger Reserve, Kerala. Out of 54 species, 13 fishes were reported in the present study also.

Maximum catch of exotic fishes (Invasive species) like *Clarias gariepinus*, *Cyprinus carpio*, *Oreochromis niloticus*, *Aristichthys nobilis*, *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella* was recorded in present study. Due to competition between exotic and indigenous fishes, we can say that the Indian Major Carps (IMC) have declined sharply since the last decade, while forage and catfishes are increasing drastically in Ghaghara basin. During assessment of the fish utilization pattern of UP, out of 123 species about 57% are considered as commercial food fishes, nearly 33% fishes contributing in ornamental value and rest 10% fishes are evaluated under potential sport fishes (Lakra, 2010). A good number of ornamental fishes were also recorded during the present study. Due to insufficient knowledge of the value and marketing of ornamental fishes, fishermen sold these fishes at a very low price, while broker sell them in local fish markets at higher rates.

According to fishermen and other stakeholders, riverine fish production declined from last two decades, may be due to climate changes, indiscriminate fishing,

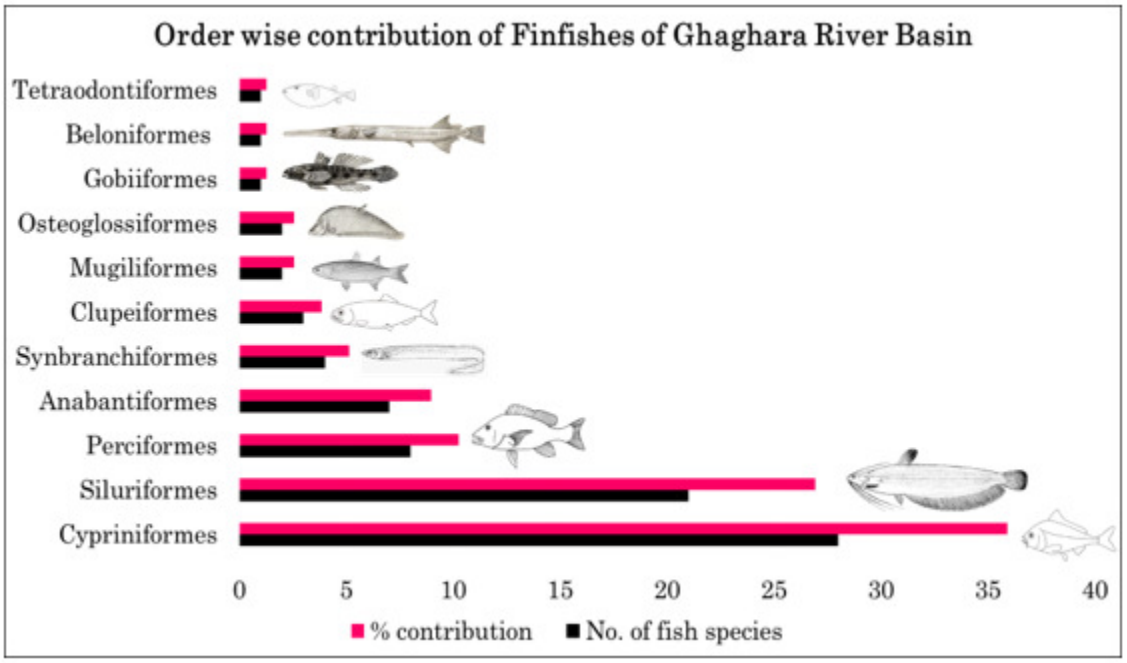

Fig. 3 : Order-wise contribution of finfishes of Ghaghara River Basin.

recruitment overfishing of brooder in the spawning season, use of smaller mesh size of fishing net and pollution were found to be the main reasons. Water pollution and recruitment overfishing could be major problems of the Ghaghara River basin.

Major emerging threats to the Ghaghara Riverine ecosystem

The freshwater ecosystem diversity of northern Himalayan region is highly diverse, unique and of immense importance to livelihoods and economies. According to Dudgeon *et al* (2006), freshwater biodiversity is facing five major threats such as over-exploitation, water pollution, flow modification, destruction or degradation of habitat and invasion by exotic species. These globally escalating threats have led to freshwater biodiversity falling into crisis phase (Vorosmarty *et al*, 2010) and becoming more imperiled than marine or terrestrial ecosystem (Strayer and Dudgeon, 2010).

In Northern India, the Ghaghara River is one of the vulnerable ecosystems of all aquatic ecosystem. The dependence on riverine water of Ghaghara River has placed enormous pressures resulting in direct impacts to fish populations. Due to several environmental threats (natural and anthropogenic) could be responsible for cascading and interlinked impacts on fishes that can range from loss of genetic diversity; populations and even consequences leading to the extinction of some species. Human activities that directly or indirectly threaten fish include destructive fishing, using small size mesh of net, over-exploitation of fish and juveniles, inappropriate management practices, destruction or modification of habitats, pollution and tourism activities. This high population density and growth will continue to create a huge demand on the freshwater ecosystems of the northern river and will increase deforestation, damming and water abstraction, mining and quarrying, pollution and over-exploitation. In the present study, threats to fish diversity in three stretch of Ghaghara were identified. Here, we describing major emerging threat to Ghaghara River, which are responsible for drastic declines in recent years.

Water pollution

Riverine pollution remains a pressing issue in India. All stretch of Ghaghara River are affected by pollution from industrial and municipal waste, agricultural runoff, urban sources and improper disposal of solid waste contribute to the pollution of rivers. Contamination from chemicals, pesticides, sewage and fertilizers which can degrade water quality, harm aquatic life, and disrupt the balance of the ecosystem.

Habitat loss and alteration

Anthropogenic activities such as dam construction, channelization and land development lead to alteration of this riverine habitats. Dams fragment rivers, interrupt natural flow patterns and impede the migration of fishes. Channelization and straightening of rivers can disrupt natural processes and destroy habitat diversity. The lower stretch of Ghaghra River are affected by habitat degradation due to low rainfall, deforestation and siltation, water depth are very shallow and discontinuous (Sarkar

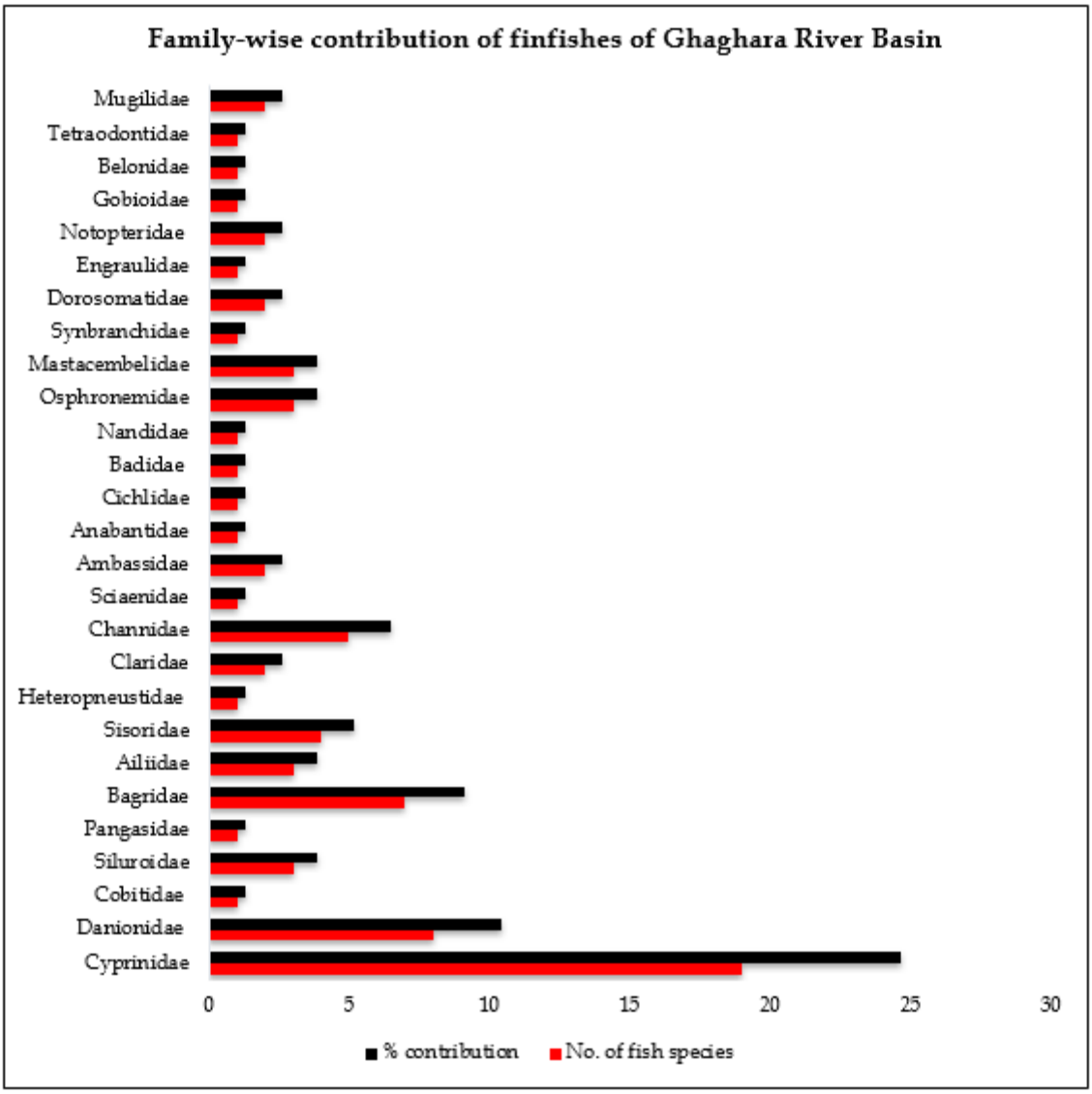

Fig. 4 : Family-wise contribution of finfishes of Ghaghara River Basin.

et al, 2010).

Invasive and other problematic species

Invasive species have been identified as another major threat to the fishes of the Ghaghara River. Invasive species, both flora and fauna, have detrimental effects on entire stretch of riverine ecosystem. These species can outcompete native species for resources, alter food webs, and disrupt the overall balance of food web. They often thrive in disturbed habitats and can spread rapidly. Seven species of exotic fish, including *Clarias gariepinus*, *Cyprinus carpio*, *Oreochromis niloticus*, *O. mossambicus*, *Aristichthys nobilis*, *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella* are currently distributed across Ghaghara river basins in the UP part of the Northern Himalayan. These exotic fishes proliferate rapidly, compete with native species, disrupt ecosystems and leaving an impact on the livelihoods of fishermen communities' dependent on riverine resources. An invasive aquatic plant *E. crassipes* (water hyacinth) native to South America cover the river surface, reducing DO level, creating ideal habitat for disease-carrying organisms.

Several of fish species were introduced during the colonial times for enhancing fisheries in reservoirs, while others are typical invaders which may have escaped from illegal aquaculture practices. Of the 7 species, two (*C. carpio* and *O. mossambicus*) are listed in the '100 of the World's Worst Invasive Alien Species' database (Lowe *et al*, 2000). The African catfish, *C. gariepinus*, is one of the best examples of an invasion enhanced by illegal aquaculture. African catfish escapees from aquaculture facilities located in various parts of UP have now started to appear in fish catches in all aquatic bodies of UP (Jitendra *et al*, 2013). Several authors have reported *C. gariepinus* in different river of north India

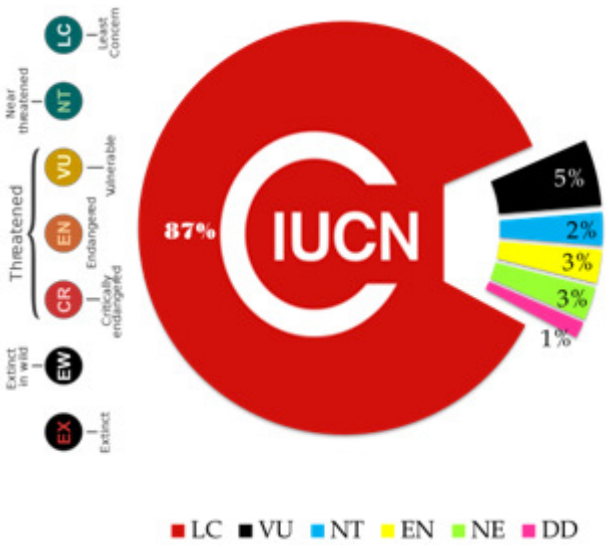

Fig. 5 : Percentage representation of IUCN conservation status of freshwater fish species recorded from Ghaghara River Basin.

methods, can deplete fish populations and disrupt the ecological balance in rivers. This can have cascading effects on other species that depend on fish for food or have symbiotic relationships with them. Local fishermen are using small mesh size net (locally called "Fardi jal") for collecting all size of fishes.

Climate change

Climate change poses a growing threat to India's rivers and poses significant threats to this riverine system also. Rising temperatures can alter water availability, affect flow patterns and exacerbate drought conditions also. Changes in precipitation patterns could be lead to flooding or low water levels, impacting the health and functioning of riverine ecosystems. Climate change can also influence the timing of biological events, such as

Fig. 6 : Infestations of water hyacinth prevent river transport, fishing operation, operation of boat, and clog dams.

(Sarkar *et al*, 2010; Sarkar *et al*, 2012; Jitendra *et al*, 2013; Kumar *et al*, 2020).

Residential and commercial development

Residential and commercial developments in urban areas, tourism and recreational areas are affecting many freshwater fishes of Ghaghara River.

Illegal fishing and Overfishing

Unsustainable fishing practices, including brooder and juvenile overfishing and the use of destructive fishing migration and reproduction, causing mismatches in species interactions.

Erosion and sedimentation

Excessive erosion due to deforestation, agricultural practices and land development result in increased sedimentation in rivers. Sedimentation could be smother aquatic habitats, degrade water quality and harm fish and other aquatic taxa by reducing oxygen levels.

Water extraction and water scarcity

Fig. 7 : An alien invasive species tilapia, *O. mossambicus*, *C. carpio* and *H. molitrix* dominates the fish catches in Ghaghara Rivers in northern UP and collected in Ayodhya fish market.

Over-extraction of water from rivers for human consumption, irrigation, and industrial use can disrupt natural flow patterns and reduce water availability downstream. This could be also responsible for habitat degradation, loss of species and reduced ecosystem resilience.

Natural system modification (Dams and hydropower projects)

The construction of dams and hydropower projects in rivers has both positive and negative consequences. While these projects can provide clean energy and water storage, they also lead to the fragmentation of river systems, alteration of flow regimes, habitat destruction, and impacts on migratory fish species. Dams can also block the migration of fishes, downstream water scarcity and affect the livelihoods of communities dependent on river resources. These natural system modifications caused by large dams and deforestation leading to siltation and sedimentation, and sand mining can adversely affect fish diversity by destroying habitat conditions (breeding and feeding area) and impacting species life cycles.

Sand mining

Sand mining is another threat affecting the breeding grounds of fishes, and is common in Ghaghara River. For sand mining, Uttar Pradesh government running a project of "Sand Mining at Ghaghara River bed", Sharwa Manjha, Dist. Ayodhya, UP. Unregulated sand mining, particularly from Ghaghara riverbed is a significant emerging threat. Excessive sand mining disturbs river ecosystems, depletes sediment supply, erodes river banks, and increases the vulnerability of river channels to flooding. It can also lead to the loss of aquatic habitats and negatively impact fish populations also.

Conservation actions, recommendations and Management of Ghaghara River Resources

This riverine ecosystem provides feeding and breeding ground for several residential & migratory birds, fishes, molluscs as well as crustaceans also. We reported the maximum number of the species but as per expectation, we did not get too many fishes because the riverine habitats are affected due to several threats. In recent years, it was realized that the Ghaghara river is one of the most vulnerable resources on UP. The fishes of these areas are under threat due to canalization, siltation, pollution and invasive species and infestation of water hyacinth; hence authors also recommend a practical conservation action plan and regular cleaning of this productive ecosystem and protection of breeding grounds of the aquatic animals to prevent the species from extinction.

In spite of high endemism and threat levels, the fish fauna of Ghaghara basin are still poorly known. There is a lot of knowledge gap and few information available in term of life history traits, population and ecology of this basin. This lack of knowledge has greatly impeded our ability to conserve these species and their habitats.

Policymakers and general public have perceptions that freshwater fishes hold only a minor role. In Northern Himalayan areas multiple use of water for drinking, irrigation, and hydroelectric power generation are valued more than fish fauna protection. All of this has resulted in few investments in freshwater resources and their aquatic animal conservation and management. Conservation and management of freshwater biodiversity is very challenging and long-term process (Dudgeon *et al*, 2006). Conservation actions and management strategies for rivers play a crucial role in protecting and sustaining these valuable ecosystems. Here, we are discussing some key actions and recommendations for Ghaghara basin.

Riparian Zone Protection, reforestation and restoration

Maintain and restore the vegetation along the riverbanks, known as the riparian zone. This helps stabilize the banks, prevent erosion and filter pollutants from entering the water. Because of the importance of riparian zones and allochthonous food sources to biota of river, there is a need to encourage the replantation of riparian vegetation along the river basins (Dudgeon, 1999 and

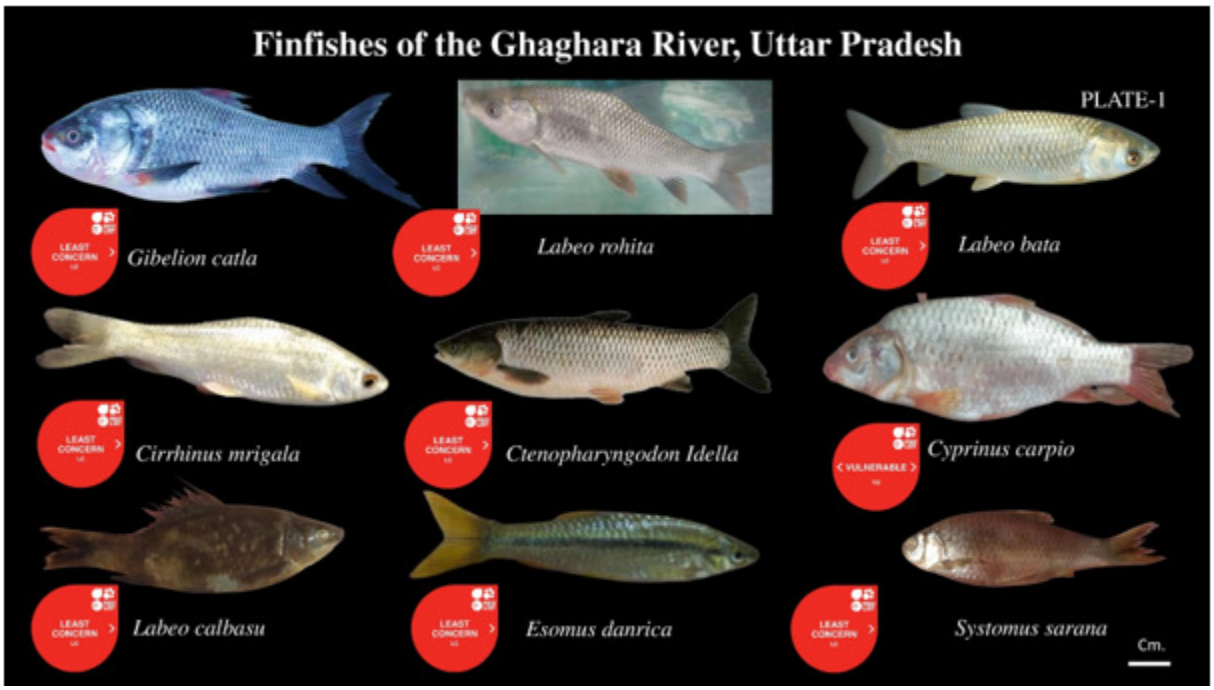

Plate 1 : Fish species recorded from the Ghaghara River. © Sahu A.

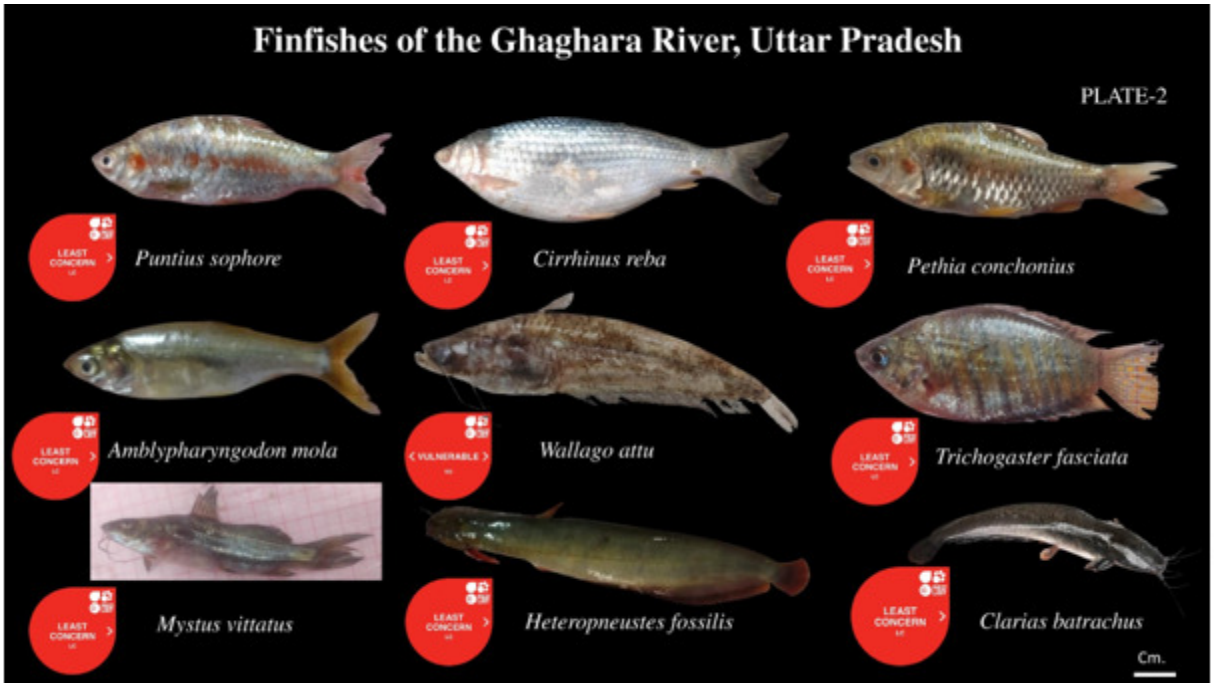

Plate 2 : Fish species recorded from the Ghaghara River. © Sahu A.

Molur *et al*, 2011). Planting indigenous tree and shrubs along river banks can help prevent erosion and stabilising the watercourse. This needs to be immediately followed by social forestry and afforestation initiatives.

Better control of water pollution

Uttar Pradesh is the most populated state (Kumar *et al*, 2020) and population pressure, pollution from anthropogenic activities will no doubt increase. Implement measures to reduce pollution from point sources (*e.g.*, industrial discharges) and non-point sources (*e.g.*, agricultural runoff). This includes promoting responsible waste management practices, controlling nutrient inputs, and implementing water treatment technologies. There are three Acts in India that have some regulatory trigger for fish habitat preservation (River Boards Act, 1956; Water Cess Act, 1977 and Water Act, 1974 revised in 1979).

As per rule and regulations of River Boards Act, River Boards have to regulate and develop interstate rivers and river valleys. River Boards are responsible for: i)

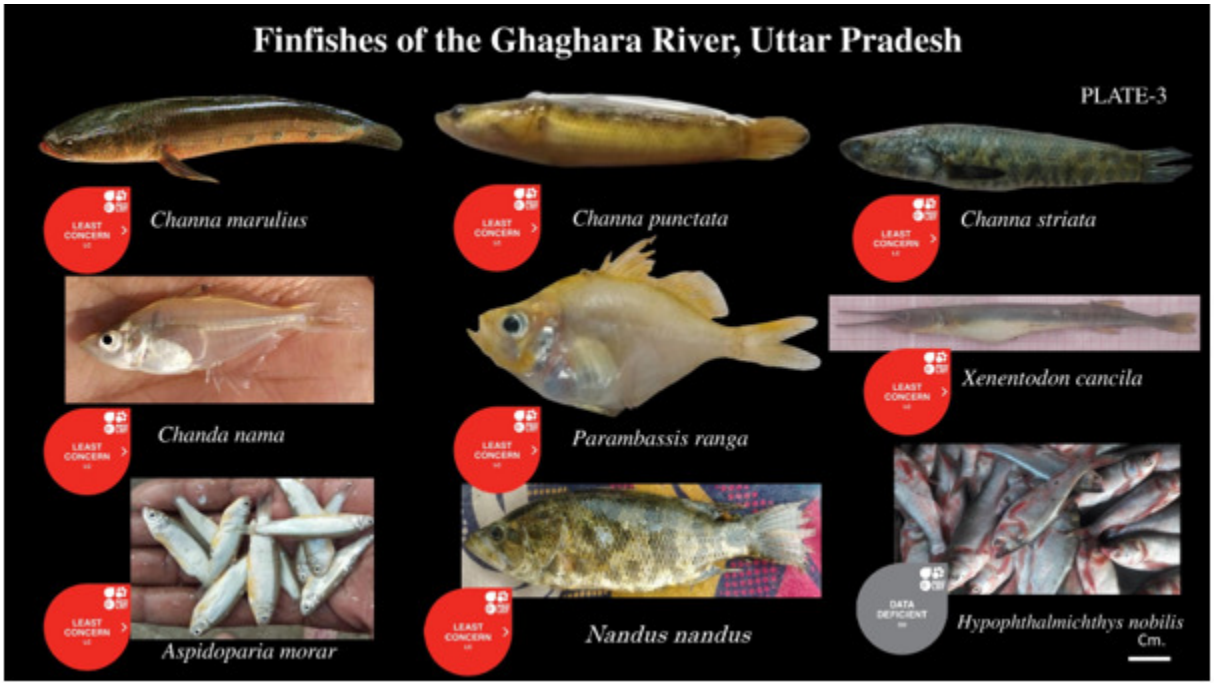

Plate 3 : Fish species recorded from the Ghaghara River. © Sahu A.

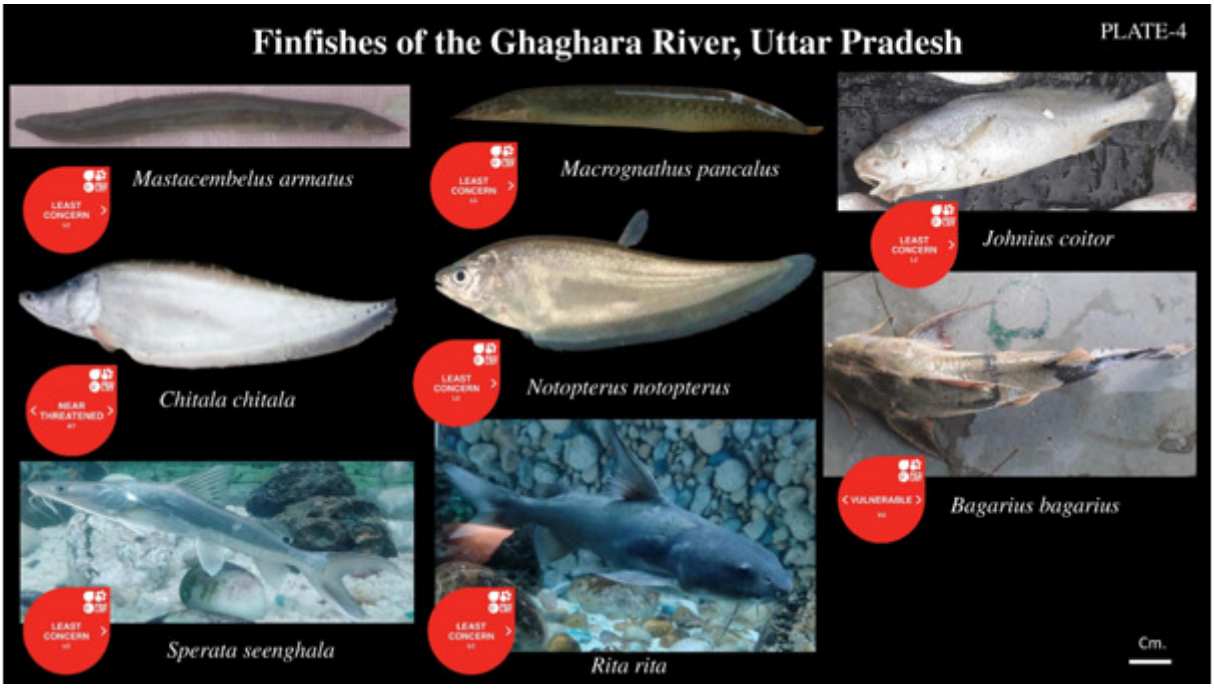

Plate 4 : Fish species recorded from the Ghaghara River. © Sahu A.

conservation, prevention and sustainable use of interstate rivers; ii) promotion of schemes for irrigation, water supply, drainage, flood control, reforestation and navigation system and iii) prevention of soil erosion and pollution of interstate rivers.

The Water Cess Act (prevention and control of pollution) authorizes collect water cess or levy, who are engaged in certain industries, to augment their resources. The purpose of this Act is to generate revenue for the government or designated authorities to fund water resource management, conservation and pollution control measures.

The Environment (Protection) Act, 1986 is an umbrella legislation that empowers and provides the legal framework for the protection and conservation of the environment. The Act empowers the central government to take measures for the prevention, control, and abatement of environmental pollution and the protection of the environment (Ghosh and Ponniah, 2008).

Invasive Species Management

Detailed investigations on the spread and impact of invasive species in Ghaghara River Basin are urgently needed. Without any permission and regulation, more than 300 exotic aquarium species are imported and traded in India. Communication with aquarium industry plays an essential role for educating buyers, sellers and customers, certifying stock and minimizing the accidental release of aquarium fish. Develop and implement strategies to control and eradicate invasive species that can negatively impact river ecosystems. This may involve monitoring and early detection, implementing biosecurity measures, and using targeted eradication methods. There is an urgent need to create and implement a rule and regulation for Invasive alien species and their management.

Education, awareness and stakeholder engagement

Promote public awareness about the importance of rivers, their ecological value and the need for conservation. Education campaigns can help change behaviours and foster a sense of stewardship among the general public. Involve local communities, government agencies, NGOs and other stakeholders in decision-making processes related to river management. This promotes cooperation, builds consensus and ensures that diverse perspectives are considered.

Species and biodiversity conservation

Protect and restore habitats within and along rivers to enhance biodiversity. This may involve creating protected areas, establishing wildlife corridors and implementing habitat restoration projects.

Ranching of fishes in Ghaghara river

Fish ranching in Ghaghara basin could be helpful in enhancing populations by releasing cultured or captive-bred fishes into the wild. This approach is commonly used to bolster declining or depleted fish stocks and support fisheries management efforts. The Ghaghara River acts as an important aquatic corridor for gharials in UP. Bahraich forest division of UP release Gharials (*Gavialis gangeticus*) in Ghaghara River.

Fish Tissue Banking and DNA Barcoding of Ghaghara Basin

These techniques play a crucial role in scientific research, fisheries management and efforts to protect and sustainably manage fish species and their habitats. Both tissue banking and DNA barcoding contribute to our understanding of fish biodiversity, population genetics, and conservation.

Climate change adaptation

Recognize and address the impacts of climate change on rivers and develop strategies to adapt to these changes. This may include promoting resilient land use practices, restoring natural buffer zones and implementing water management strategies that account for altered precipitation patterns.

Floodplain management

Adopt strategies that reduce the impacts of flooding on human communities and river ecosystems. This can include floodplain zoning, constructing levees or flood barriers, and restoring natural floodplain functions.

Documentation and monitoring of fish diversity

Establish comprehensive monitoring programs to assess the health of river ecosystems, track changes over time and guide management decisions. Research should focus on understanding key ecological processes, identifying threats, and evaluating the effectiveness of conservation actions.

Genetic characterization of fishes

Genetic characterization in fishes relies on various molecular techniques, such as DNA sequencing, genotyping and population genetic analysis. These methods provide valuable insights into the genetic diversity, evolutionary history and conservation status of fish species, contributing to their effective management and protection.

CONCLUSION WITH RECOMMENDATION

The study of Ghaghara river basin is therefore necessary to understand the biodiversity so that an effective conservation action plan can be designed and implemented. Although, the objective of this study is to give recent data regarding fish diversity, aiming to contribute a better knowledge of finfish resources of this river basin. The rich fish fauna diversity recorded under this study can be utilized for decision making in conservation and management in a scientific manner. Also, there is an immediate need of more conservation programme in order to retain this ecosystem of Himalayan region. Addressing these emerging threats requires a multi-faceted approach, including improved pollution control measures, sustainable water management practices, regulated sand mining, integration of climate change considerations in river basin planning and the promotion of community participation in decision-making processes. Conservation and restoration efforts, along with the adoption of environmentally friendly practices, are essential to protect the health and sustainability of this rivers.

Conflict of interest

Authors declare no conflict of interest associated with present publication.

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