

Assessment of Fish Assemblage in Highly Human Managed Reservoirs Located on River Chenab, Pakistan

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Abstract

River Chenab is one of the highly hydrologically managed rivers in South Asia and facing several environmental issues related to human population growth, industrialization, agricultural advancements and rapid urbanization. These issues are the major threat to the fish diversity of the River Chenab. In this regard, the present study was designed to elucidate the fish diversity, distribution patterns, conservation issues at five artificial water reservoirs (barrages) during the pre-monsoon and post-monsoon season in river Chenab, Pakistan. A total of 5715 individuals was sampled belonging to 16 families. The Cyprinidae (56.9%) was most dominant family followed by Bagridae (7.34%), Cichlidae (5.25%), Schilbeidae (4.55%), Siluridae (3.33%), Ambassidae (3.15%), Clupeidae (3.09%). In Cyprinidae family, *Salmophasia bacaila* was the most abundant species with relative abundance (10.70%) followed by *Osteobrama catio* (7.52%), *Puntius sophore* (5.44%). *Ailia coila*, *Bagarius bagarius*, *Ompok bimaculatus* and *Ompok pabda* showed low relative abundance. Highest number of fish individuals were reported from the Qadirabad barrage (27%) and lowest from Khanki barrage (14%). *Oreochromis niloticus* is an exotic species was the fourth most abundant fish species and could be a threat to the local species. Six near threatened species (*Ailia coila*, *Bagarius bagarius*, *Ompok bimaculatus* and *Ompok pabda*) with restricted distribution, and one endangered species (*Tor putritora*) was recorded. Generally, small sized fish species were high in number as compared to large sized fishes indicating over fishing of commercial fishes from the barrages. It was observed that there are several other fishing activities reducing the fish number. Illegal and destructive methods of fishing, pollution, flow reduction, water diversion, habitat reduction and human population growth are putting pressure on the fish diversity of River Chenab. Illegal fishing and discharge of effluents without treatment must be addressed to improve the ecological balance of fish assemblage and water quality of the river Chenab.

Keywords: River Chenab; Anthropogenic stress; Water pollution; Fish diversity; Illegal fishing

Introduction

Rivers provide transportation, power generation, food for the local population and act as sinks for waste produced in catchment area [1]. Most of the human water needs of the catchment area are fulfilled by the rivers. Due to human population growth, per capita water availability is dropping in developing countries [2]. Human activities such as over pollution, urbanization and industrialization are influencing the riparian ecosystems. This situation becomes intensified in developing countries and amplified the pressure on water resources [3]. The urbanization is exerting more pressure than other land use changes [4]. Urbanization disrupts the ecosystem balances by converting the river into polluted drain. Pollution from urban centers has resulted in aquatic biodiversity reduction and minimizes the associated economic and social benefits [3,5]. Aquatic organisms as a biological indicator of water quality, their sensitivity and response to different changes in physical and chemical parameters can be used as a tool for the evaluation of habitat quality. These organisms as an indicator of riverine degradation is an efficient tool within economic constraints [6,7].

The use of biological indicators in the freshwater ecosystem is a well-known approach around the world [8]. One of these indicators is fish, it is cheapest, affordable, valuable and sensitive indicator of water

quality changes. It is visible and easy to identify, extensively used to assess any abnormalities in flowing waters depending on time and space [9,10]. Pristine water quality is favors the complexity and integrity of the fish assemblage as [11]. Assessment of fish diversity and its association in assemblage could be cheap and proficient tools for water quality assessment. Physical structures such as barrages, diversions, reservoir formation for water supply, flow regulation, bank modifications have negative impacts on fish assemblage. Pollution along with other stresses has intensified the problem leading to fish migration, local population extinctions or exotic species introduction [1]. These conditions ultimately degrading the integrity of fish assemblages and favour a few species to flourish, while a majority of species reduced in abundance even become extinct [12]. Fish assemblage in rivers gives an overview of the stress induced by the humans and reflect the visible changes in the presence or absence of the fish species. The change in fish assemblage could be a very effective tool for risk assessment in freshwater ecosystems. Fish diversity and its distribution pattern also serve as an indicator of habitat quality degradation [13,14]. Reduction in diversity of organisms is an indicator of human intrusion in a natural ecosystem. The effect of pollution can be determined in a given area by measuring the diversity of organisms in that area over a specific period of time [15,16]. River Chenab is second largest river of Pakistan and highly managed river for exploitation of its water for irrigation. Major exploitation of Chenab water was started with the independence of Pakistan and India, which was further intensified after Indus water treaty. After this agreement, several barrages and canals were construction resulting

change in flow and discharge of rivers. The River Chenab was also exploited for the same purpose; five barrages were constructed to divert the water for irrigation and distribution. Due to development of several link canals, the original hydrological and biological structure has been changed. This situation is further intensified due to indiscriminate discharge of the effluents from different drains receiving industrial, municipal effluents and agricultural runoff from its catchment area.

In River Chenab, several fishes, which has been affected due to human management and pollution issues. Several authors have highlighted the diversity of fish fauna from River Chenab [17-19]. Unfortunately, there is limited documented record of fish fauna from this riverine tract of the River Chenab before and after the construction of barrages. Most of the fish diversity of fishes has been reported from upstream barrages of the river Chenab, whereas, riverine tract between the barrages often faces the shortage of flowing water, except monsoon season. Extreme drought has been observed in the section of river between Qadirabad and Trimmu. The habitat fragmentation along with the human activities affecting the diversity of fishes. Municipal, industrial effluents and agricultural runoff from its catchment area and illegal fishing practices are deteriorating the water quality and fish assemblage of River Chenab. Baseline data regarding fish diversity and its distribution on spatio-temporal basis in river Chenab. Fish diversity, habitat preferences and trophic composition give information about the level of anthropogenic stress on fish fauna. The present study was aimed to assess the status and ecological parameters of fish assemblage at five barrages located on River Chenab. The results of this study highlighted the existing status of fish fauna and will the help the environmentalist, conservations and ecologist to develop species and habitat restoration in the future.

Materials and Methods

Study area

The present study was conducted on River Chenab which originates from Kangra and Kulu districts of Himachal Pradesh, India and fed by snow and rainfall. This river enters in Pakistan near Diawara village, District Sialkot, Punjab. The total catchment area of River Chenab is 67500 km² before its convergence with river Indus after traversing a total length of about 1240 Km [19].

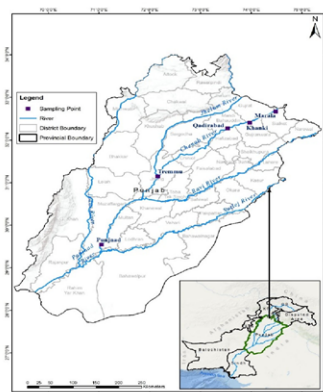


Figure 1: Map of sampling sites on river Chenab, Pakistan.

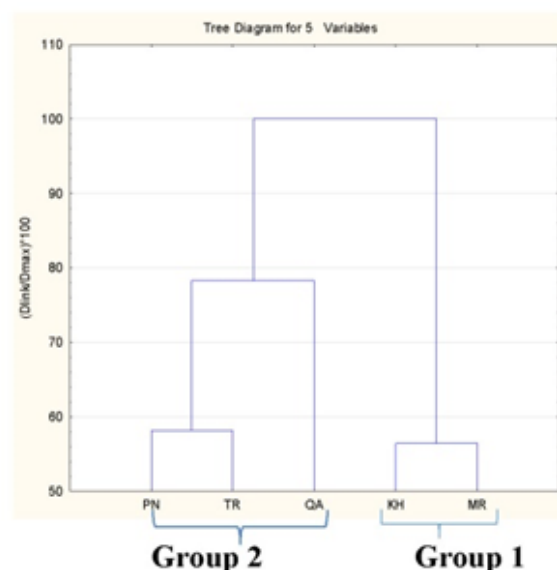


Figure 2: Dendrogram of sampling sites on the basis of fish assemblage data.

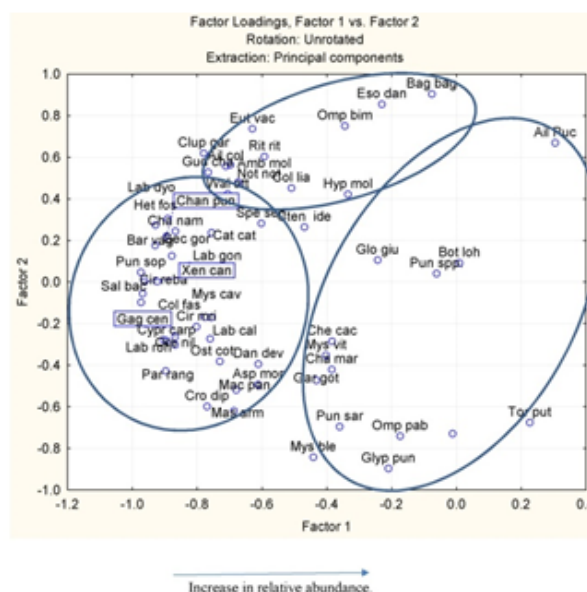
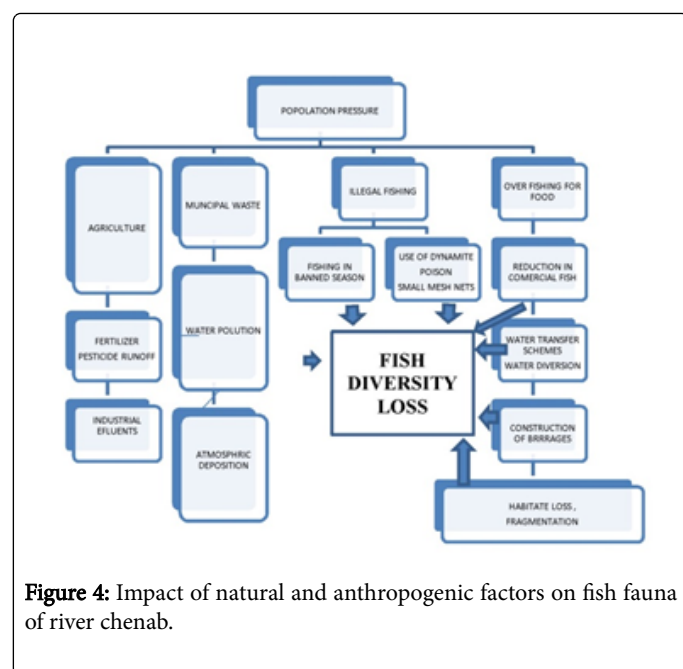


Figure 3: Factor analysis showing different groups on basis of abundance.



There are five barrages on River Chenab Marala, Qadirabad, Khanki, Trimmu, and Punjanad. River Chenab passes along the populated and industrial cities of Punjab and receives waste water from drains coming from Jammu, Sialkot, Gujrat, Gujranwala, Wazirabad, Faisalabad and Multan which deteriorate the water quality of the river [20].

Sampling Strategy

The fish sampling was carried out during the pre-monsoon and post-monsoon season of during 2014 from five 5 barrages, Marala

(S-1), Khanki (S-2), Qadirabad (S-3), Trimmu (S-4) and Punjanad (S-5; Figure 1). Fish sampling points were marked by means of global positioning system.

Fish were collected using the cast net and gill nets. Cast net size 15 m circumferences with mesh size 1.5 cm and the gill net size 50×1 m with mesh size 3×3 cm.

Each site was sampled selecting two points from upstream, two downstream two from the pond area of the barrage. Each barrage was sampled from six sites viz; two sub sites in the upstream area, two downstream and two in the pond area (Figure 2).

For cast net from each point fishing was done within 100 m² and gill nets were placed for a whole night in the water with the help of local fishermen (Figure 3).

For each site fish sampling was done early in the morning and evening, before sampling weather forecasts were considered and the fish sampling was done in sunny and clear days [11].

Fishes were transferred to the stream water filled tubs for counting and identification identification, the fish was released back into the water. The fishes, which were not identified in the field were preserved in 10% formalin and transferred to the laboratory for identification. Fishes were identified by following [21-50] (Figure 4).

Fish species were classified into different ecological groups on the basis of habitat preference, stress tolerance (tolerant, moderately tolerant and intolerant species), origin species (exotic and native species), feeding habits and taxonomic diversity. In habitat preference column and bottom feeder was included (Table 1) [51-100].

Family	Species	Sampling sites					RA (%)	Habitat pref.	Feeding pref.	Eco. Ampl.	IUCN status	Origin
		S1	S2	S3	S4	S5						
Ambassidae	<i>Chanda nama</i>	+	+	+	+	+	0.87(LA)	S D	INS(e)	IT (a)	LC	N
	<i>Parambassis ranga</i>	+	+	+	+	+	2.27(MA)	C D	INS(e)	IT (b)	LC	N
Bagridae	<i>Mystus bleekeri</i>	+	+	+	+	+	1.17(MA)	C D	CAR(a)	MT (a)	LC	N
	<i>Mystus cavasius</i>	+	+	+	+	+	2.99(MA)	C D	CAR(d)	MT (b)	LC	N
	<i>Mystus vittatus</i>	+	-	+	+	+	0.61(LA)	C D	CAR(a)	MT (a)	LC	N
	<i>Rita rita</i>	+	-	+	+	+	1.15(MA)	C D	CAR(e)	MT(b)	LC	N
	<i>Sperata seenghala</i>	+	+	+	+	+	1.38(MA)	B D	CAR(a)	IT(b)	LC	N
Belonidae	<i>Xenentodon cancila</i>	+	+	+	+	+	1.36(MA)	S D	OMN(d)	IT(a)	LC	N
Channidae	<i>Channa marulia</i>	+	-	+	+	+	0.35(PA)	B D	HB(e)	MT (a)	LC	N
	<i>Channa punctate</i>	+	+	+	+	+	2.69(MA)	B D	OMN(e)	T (a)	LC	N
Cichlidae	<i>Oreochromis niloticus</i>	+	+	+	+	+	5.25(MTA)	B D	HB(e)	MT (b)	NE	NN
Clupeidae	<i>Gudusia chapra</i>	+	+	+	+	+	3.1(A)	C D	OMN(f)	IT(d)	LC	N

<i>Cobitidae</i>	<i>Botialohachata</i>	+	-	+	+	-	0.17(PA)	B D	CAR(d)	MT (a)	NE	N
<i>Cyprinidae</i>	<i>Amblypharyngodon mola</i>	+	-	+	+	+	0.35(PA)	B D	HB(f)	IT(d)	LC	N
	<i>Aspidoparia morar</i>	+	+	+	+	+	0.56(LA)	B D	HB(c)	IT (c)	LC	N
	<i>Barilius vagra</i>	+	+	+	+	+	1.87(MA)	B D	OMN(c)	IT(d)	LC	N
	<i>Catla Catla</i>	+	-	+	+	+	0.94(LA)	B D	OMN(e)	MT(d)	LC	N
	<i>Chela cachius</i>	+	+	+	+	+	0.45(PA)	B D	INS(e)	IT(d)	LC	N
	<i>Cirrhinus mrigala</i>	+	+	+	+	+	2.85(MA)	B D	HB(d)	MT(d)	LC	N
	<i>Cirrhinus reba</i>	+	+	+	+	+	3.99(A)	B D	HB(e)	MT(d)	LC	N
	<i>Crossocheilus diplocheilus</i>	+	+	+	+	+	2.34(MA)	B D	DET(d)	MT(d)	NE	N
	<i>Ctenopharyngodon Idella</i>	+	+	+	+	+	0.19(PA)	C D	HB(e)	T(d)	NE	NN
	<i>Cyprinus carpio</i>	+	+	+	+	+	1.84(MA)	B D	OMN(d)	T (c)	VU	NN
	<i>Danio devario</i>	+	+	+	-	-	0.61(LA)	B D	OMN(d)	IT(d)	LC	N
	<i>Esomus danricus</i>	-	-	-	+	+	0.31(PA)	BD	OMN(d)	IT(d)	LC	N
	<i>Garra gotyla</i>	+	-	+	-	-	0.24(PA)	B D	HB(e)	IT (a)	LC	N
	<i>Hypophthalmichthys molitrix</i>	+	+	+	+	+	0.17(PA)	B D	OMN(d)	T(d)	NT	NN
	<i>Tor putitora</i>	+	-	-	-	-	0.12(PA)	C D	OMN(a)	IT (c)	EN	N
	<i>Labeo calbasu</i>	+	+	+	+	-	1.77(MA)	C D	HB(a)	MT (a)	LC	N
	<i>Labeo dyocheilus</i>	+	+	+	+	+	1.8(MA)	B D	HB(f)	MT(d)	LC	N
	<i>Labeo gonius</i>	+	-	+	+	+	1.42(MA)	C D	HB(f)	MT (a)	LC	N
	<i>Labeo rohita</i>	+	+	+	+	+	2.9(MA)	C D	HB(c)	M T (a)	LC	N
	<i>Osteobrama cotio</i>	+	+	+	+	+	7.52(MTA)	C D	OMN(f)	M (a)	LC	N
	<i>Puntius sarana</i>	+	+	+	-	-	3.04(A)	BD	OMN(a)	MT (a)	LC	N
	<i>Puntius sophore</i>	+	+	+	+	+	5.44(MTA)	B D	OMN(a)	MT (a)	LC	N
	<i>Puntius spp.</i>	+	+	+	+	+	4.14(A)	BD	OMN(a)	MT (a)	LC	N
	<i>Salmophasia bacaila</i>	+	+	+	+	+	10.7(MTA)	B D	INS(e)	MT(d)	LC	N
	<i>Securicula gora</i>	+	+	+	+	+	1.43(MA)	B D	INS(c)	MT (b)	LC	N
<i>Gobiidae</i>	<i>Glossogobius giuris</i>	+	+	+	+	+	1.96(MA)	B D	CAR(e)	MT (a)	LC	N
<i>Heteropneustidae</i>	<i>Heteropneustes fossilis</i>	+	+	+	+	+	1.28(MA)	B D	CAR(a)	T (a)	LC	N
<i>Mastacembelidae</i>	<i>Macrognathus pancalus</i>	+	+	+	+	+	0.75(LA)	BD	INS(d)	MT (a)	LC	N
	<i>Mastacembelus armatus</i>	+	+	+	+	+	0.91(LA)	C D	CAR(a)	MT (a)	LC	N
<i>Notopteridae</i>	<i>Notopterus notopterus</i>	+	+	+	+	+	1.26(MA)	C D	CAR(a)	MT (a)	LC	N
<i>Osphronemidae</i>	<i>Colisa fasciata</i>	+	+	+	+	-	0.47(PA)	C D	OMN(e)	MT(d)	LC	N
	<i>Colisa liata</i>	-	-	+	+	+	0.23(PA)	C D	CAR(d)	MT(d)	LC	N
<i>Schilbeidae</i>	<i>Ailia coila</i>	+	-	+	+	+	0.84(LA)	C D	CAR(e)	IT(d)	NT	N
	<i>Ailia punctate</i>	-	-	-	+	+	0.14(PA)	B D	CAR(e)	IT(d)	NE	N
	<i>Clupisoma garua</i>	+	+	+	+	+	2.06(MA)	B D	CAR(e)	IT(d)	LC	N

	<i>Eutropiichthys vacha</i>	-	+	+	+	+	1.5(MA)	C D	CAR(a)	MT (a)	LC	N
<i>Siluridae</i>	<i>Ompok bimaculatus</i>	-	-	-	+	+	0.54(LA)	C D	CAR(a)	MT (a)	NT	N
	<i>Ompok pabda</i>	+	-	+	+	+	0.31(PA)	B D	CAR(a)	IT(d)	NT	N
	<i>Wallago attu</i>	+	+	+	+	+	2.48(MA)	C D	CAR(a)	MT (a)	NT	N
<i>Sisoridae</i>	<i>Bagariusbagarius</i>	+	-	-	+	+	0.23(PA)	B D	CAR(d)	MT(d)	NT	N
	<i>Gagata cenia</i>	+	+	+	+	+	3.83(A)	C D	DET(d)	MT (b)	LC	N
	<i>Glyptothorax punjabensis</i>	+	+	+	-	-	0.72(LA)	B D	OMN(d)	MT(d)	NE	N
Habitat preferences: Surface dweller SD, Column dweller CD, Bottom dweller BD. Relative abundance, Most Abundant MTA, Abundant A, Moderately Abundant MA, Less Abundant LA, Poorly Abundant PA, Trophic level: Carnivore CAR, herbivore HB, insectivore: INS, Omnivore OMN, Detrivore: DET. Tolerance Tol., Intolerant IT, Moderately tolerant MT, Tolerant T. Origin: Native N, non-native NN, IUCN status: Threatened: TH, Near threatened: NT, Vulnerable: VU, Endangered: EN, Not evaluated: NE, Least concern LC [50,98-100].												

Table 1: Fish distribution, relative abundance, habitat preference, feeding preferences, ecological amplitude and conservation status in River Chenab.

Fish feeding habits were determined on the basis of trophic levels and four trophic groups viz; herbivore, omnivore, insectivore, detrivore, and carnivore. The species were ranked with respect to their relative abundance, most abundant (>5%), abundant (4.9%-3%), moderately abundant (2.9%-1%), least abundant (1%-0.5%), poorly abundant (0.49%-0.1) and rare (<0.1%) (Table 2).

Seasons	Barrages	Species Richness	Shannon Index	Simpson Index	Evenness	Margalef Index	Fisher_alpha Index
Overall	Marala	45	3.37	0.95	0.64	6.33	9.59
	Khanki	36	3.15	0.94	0.65	5.18	7.61
	Qadirabad	51	3.54	0.96	0.68	6.80	10.1
	Trimmu	46	3.50	0.96	0.71	6.29	9.33
	Punjnad	41	3.33	0.95	0.68	5.79	8.61

Table 2: Fish diversity indices (Shanon-Weiner, Simpson Diversity, Marglef Richness, Fisher Alpha) calculated at different barrages located on River Chenab.

The fish data were subjected to diversity analysis using Shanon-Weiner, Simpson index, Marglef richness index and fisher alpha using PAST software [24]. Shanon-Weiner diversity index generally assumes all species represented a community randomly sampled and determine the species richness (Table 3).

Sampling Site on River Chenab	Species Richness	Total No. Fish Individual Captured	Reference	Sampling Site on River Chenab	Species Richness	Total No. Fish Individual Captured	Reference
Marala	45	1035	Present study	Trimmu	46	1278	Present study
	32	-	[87]		73	-	[18]
	55	-	[18]		52	-	[88]
Khanki	36	854	Present study	Punjnad	41	997	Present study
	34	1029	[17]		55	-	[18]
	33	-	[18]	Chenab overall	55	5715	Present study
Qadirabad	51	1551	Present study		34	1766	[16]
	33	-	[18]		37	-	[89]

	43	1391	[43]		81	-	[90]
	63	-	[18]		93	1572	[18]
				Munawar tawi	22	-	[91]

Table 3: Comparison of fish Species richness and total no. fish individuals reported from Chenab river by different authors.

Simpson index is a dominance index and gives more weight to common or dominant species present in an ecosystem [25]. Margalef index has good discriminant ability using log series to measure the species richness in a given ecosystem (Table 4)[26].

River	Total no. of species recorded	Abundance of Cyprinidae (%)	No. of species in family Cyprinidae	No. of species in family Bagaridae	References
Chenab, Pakistan.	55	56.9	25	5	Present study
Jhelum, Pakistan.	51		25		[36]
Chenab, Pakistan.	43	44.19	19	4	[35]
Jhelum, Pakistan.	35	67	20		[37]
Chenab, Pakistan	93	44%	41	6	[18]
Indus, Pakistan.	70	47.3	27	8	[24]
Choto Jamuna, Bangladesh.	63	44.91			[48]
Haor, Bangladesh.	46		15	4	[92]
Meghna River, Bangladesh.	69		26	5	[93]
Padma, Bangladesh.	71		23		[94]
Ganga, India	63		26	6	[33]
Bhadra, India.	33	54.55	18	3	[95]
Dudhana Project, India.	43	51	20		[96]
Godavari, india.	18	8			[97]
Gomti, India.	56	32			[32]
Bhadra, India.	56	55		9	[31]
Mahanadi, India.	54	41.3			[34]

Table 4: Total number of species, Abundance of family Cyprinidae (%) and Bagaridae recorded from different regional rivers.

Fisher's alpha is a parametric diversity index that give the information about species abundance using the log series distribution and useful index provide the ratio of the total number of individuals to the species number (N/S) exceeds (Table 5), 1.44 [27,28].

Districts	Drain	Pollution load (tons day ⁻¹)	Discharge (m ³ .s ⁻¹)
Gujrat	Hulsee/ Bollay Wala(D1)	0.3390	0.436
	Bimber Nullah(D2)	33.909	31.14
	Mola Khurd (D3)	0.5945	0.38
Mandi Bahauddin	Hulki Nullah(D4)	0.2193	-

	Budhi Nullah(D5)	5.7543	-
Hafizabad	Ahmad Pur Nakka(D6)	1.4679	-
Jhang	Marh Chiniot (D7)	4.1102	0.99
	Paharang Chakbandia(D8)	14.7967	0.815
	Ahmed Wala(D9)	225.181	0.815
	Khare Wala (D10)	6.1653	1.27
	Buddi Nullah(D11)	22.508	-
Multan	Nawab Pur (D12)	2.569	-

	Suraj Miani (D13)	2.642	-
	Muzaffar Abad Industrial Estate (D14)	2.936	-
Source: http://epd.punjab.gov.pk/system/files/Chenab%20Report%20final.pdf			

Table 5: Drain's entry point, discharge and Organic pollution added to Chenab river.

For the classification of sampling sites, [29] using Statistica 10.2 software. Conservation status of fish species was assessed on the basis of criteria developed by International Union for the Conservation of Nature and Natural Resources (Table 6) [30].

Serial No.	Head works	Canals	Discharge $m^3.s^{-1}$
1	Marala	Marala Ravi link	622
		Upper Chenab	477
2	Khanki	Lower Chenab	477
3	Qadirabad	Qadirabad Balloki link	623
		Rasul Qadirabad Link Canal	538
4	Tarimmu	Tarimmu-Sidhnai link canal	354
		Rangpur canal	76
		Haveli canal	146
5	Punjnad	Taunsa Punjnad link canal	396.45

Table 6: Off taking water and link Canals on River Chenab.

Results and Discussion

A total of 5715 individuals belonging to 16 families and 55 species (Table 1.) were sampled during sampling, among them 3345 individuals were captured in post-monsoon season and 2370 individuals were captured in pre-monsoon season. Fifty-four species were sampled during post-monsoon and 42 species were identified in pre-monsoon season. In the post-monsoon fish species were found more because greater water availability and habitat size as compared to pre-monsoon. The abundance order of each family was recorded as *Cyprinidae*(56.9%)>(7.34%)>*Cichlidae*(5.24%)>*Schilbeidae*(4.55%)>*Siluridae*(3.3%)>*Ambassidae*(3.15%)>*Clupeidae*(3.09%).

About 56.9% Cyprinid individuals were captured during the present study similar results were reported by Shah Nawaz et al. [31] from Bhadra River of Western Ghats (India) with 55% share of family Cyprinidae. Sarkar et al. [32] reported 32% cyprinids from Gomati river, India. Lakra et al. [33] studied 41.3% from Ganga river and Patel et al. (2016) [34] from Mahanadi river 39%, whereas Latif et al. [35] from Qadirabad barrage reported 44.19%, Mirza et al. (2011) [36], Iqbal et al. [37] reported 25% and 67% share of family cyprinidae from river Jhelum and Iqbal and Saleemi [24] and Hussain et al. [101] studied 47.3%, 72.27% contribution from river Indus reported. Cyprinidae was one of the major fish family reported from all rivers of the South Asia. In the present study, family Cyprinidae was followed by Bagridae family with five species contributing 7.31%. A total of 25 species of Cyprinidae family and five species of family Bagridae were identified. Latif et al. [17] reported 18 species of Family Cyprinidae

and two species of Family Bagridae from Head Khanki. Cyprinidae was the dominant family reported from most of the studies (Table 4). There are several reason of abundance of family Cyprinidae, most of its species has wide temperature tolerance range [39] and can survive even at very low dissolved oxygen level [40] Carp species belong the same family has ability to amplify the sound waves and receive a far greater range of auditory stimuli which helps in predation and prey, Cyprinids can easily change or modify its feeding habits depending upon the food availability [41]. Fifteen species were recorded from all sampling points in both seasons, indicating a wide range of species distribution. The most abundant species were *Salmophasia bacaila* (10.7%), followed by *Osteobrama cotio* (7.52%), *Puntius sophore* (5.44%) and *Oreochromis niloticus* (5.24%), while *Cirrhinus reba* (3.99%), *Gudusia chapra* (3.1%), *Puntius sarana* (3.04%), *Puntius spp* (4.14%) *Gagata cenia* (3.83%) were among the abundant species (Table 1.)

Cluster analysis grouped the sites on the basis of fish abundance data. First group comprised of two sites Marala and Khanki, while the other group has rest of the three sites Qadirabad, Trimmu and Punjnad (Figure 2). Qadirabad barrage was recorded with highest species richness 50 fish species in post-monsoon season and 39 species in pre-monsoon due to wide upstream area with periphyton community, shelters, food and breeding sites. The second factor was water availability, Rasool-Qadirabad link canal (Table 6) carry water from river Jhelum increasing water level along with the addition of fish from river Jhelum and seemed to be the major factor along with greatest pond area. The lowest number of species was recorded from Khanki weir 36 species in both seasons. Low water level, reduced pond area and construction activities at the Khanki barrage. Other researchers also reported low diversity from Khanki Barrage. Comparison with other studies is given in Table 3. Nullah Palkhu join the River Chenab before Khanki carrying effluents from Sialkot, Sambrial and Wazirabad city and surroundings, whereas, Bimber Nullah also discharge the effluents in its upstream of Khanki. The pond area of the Khanki is relatively small [16].

Factor analysis was applied to assess the association among the fish assemblages in river Chenab (Figure 4). Factor analysis was utilized to extract the maximum variance. First two varimax factors were further used for Scatter plot. Three groups were identified group 1 had species with small size and high relative abundance and most of them were herbivore. *Salmophasia bacaila*, *Osteobrama cotio*, *Puntius sophore* and *Oreochromis niloticus*, *Cirrhinus reba*, *Puntius spp.* and *Gagata cenia*. The group 2 had most of species with medium size and moderate relative abundance. Group 3 consist of *Ailia punctata*, *Tor putitora*, *Botia lohachata*, *Chela cachi*, *Channa marulius* and *Ompok pabda*, which were poorly distributed and with low relative abundance.

Fish diversity at different barrages of river chenab

The results of Shanon-Weiner, Simpson Diversity, Marglef Richness and Fisher Alpha indices applied on fish data at five barrages given in Table 2. The highest value of Shannon-Weiner Diversity Index was calculated at Qadirabad barrage (3.54) and lowest at Khanki (3.15). Range of Shanon-Wiener index is ranged between 1.5 and 3.5 in most the community studies. High score of the index indicates increase in species richness and evenness [42]. All sites showed comparatively high diversity. Similar results were reported by Altaf et al. [16,43] from Qadirabad barrage (3.11 and 2.83). Hussain et al.[38] calculated the that Shannon-Wiener diversity index 2.75 from Ravi river, whereas, Khan et al. [44] reported high Shannon-Wiener index (1.33) from

river. River Ravi is smaller and highly polluted river in Pakistan as compared to the River Chenab. Sarkar et al. [32] reported Shannon-Weiner index, ranging from 2.3 to 3.25 from river Gomati. Stable communities display the Simpson range (0.6 to 0.9) and under stress communities fall close to zero [45,46]. Simpson's index was higher at Qadirabad and Trimmu (0.96) and 0.94 at Khanki and values of this index ranged between 0 and 1, whereas, These results are comparable with results of Altaf et al., (2015)[16] reported Simpson index and 0.88 at Head Qadirabad (0.91), Khanki (0.87) and Marala Barrage. Khan et al. [47] computed the same index from the river Ravi (0.91) and Jehlum (0.94), whereas, Hussain et al. [38] described 0.92 value from Ravi River. Similar trend of Margalef index was observed as highest at Qadirabad (6.80) followed by Marala (6.33) and lowest at Khanki barrage (5.18). Altaf et al. [16] reported slightly low values 5.14, 4.77, 5.02 from Qadirabad, Marala, khanki. Galib et al. [48] applied the Margalef index and calculated the ranged 6.97 and 8.93 from River Choto Jamuna Bangladesh and it was higher than the present study. Fisher alpha index was also calculated and found highest at Qadirabad (10.1) followed by Marala (9.59), Trimmu (9.33). The rest of the information is presented in the Table 2. The diversity indices help the conservationists in prioritizing the sites for restoration and species for conservation.

Ecological dimensions of fish assemblage in river chenab

Four trophic groups were identified i.e. herbivore, carnivore insectivore and omnivore. The overall order of abundance was omnivore 33% > herbivore 24% > carnivore 22% > and insectivore 17% > detrivore 4%. Marala has maximum herbivore individuals (27%). It is in compliance with the literature that greater numbers of herbivore species are present in upstream [11,49] as the water is clear and enhance the photosynthesis producing more algae, increasing herbivores. Trimmu has a minimum number of herbivore 16.59% herbivore are sensitive species and avoid turbid waters and pollution. Punjnad has maximum number of carnivore individuals 29%. *Ailia punctata*, *Colisa liata*, *Rita rita*, *Ompok bimaculatus* were restricted to downstream, which was also in accordance with literature that carnivore increases downstream [49]. Trimmu has 23% carnivore, Marala and Qadirabad has 16% each. A maximum number of omnivore individuals were recorded at Qadirabad (36.2%) while Khanki has 35.8%. The specialist decreases when stress increases and generalist increases [50]. Trophic composition with dominance of omnivores most probably arises due to degradation of habitat. It was interesting to notice that a maximum number of fish species was also recorded from Qadirabad along with maximum number of omnivore individuals. Insectivore individuals were ranging from 12.5% (Trimmu) to 19% (Qadirabad) while detrivore species contribute only 3.5% (Punjnad), 8% (Marala) and 8.4% (Khanki). Detrivore were maximum near the aquatic vegetation and where plant remnants were maximum producing detritus (Figure 4).

Analyzing the data on tolerance level of fish species 17 species fall under the category of in tolerant. Chanda nama, Xenentodon cancila, Gudusia chapra, Parambasis ranga,, Amblypharyngodon mola, Aspidoparia morar were among the intolerant species. Only five species showed the status of tolerant species. Heteropneustes fossilis , Channa punctata with moderate relative abundance 1.28%, 2.69% was the native species rest of three tolerant species were exotic (*Ctenopharyngodon Idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*). In contrast 33 species were found with moderately tolerant status the detail is given in the Table 1.

Four exotic species *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*, *Oreochromis niloticus* and *Cyprinus carpio* were recorded. Among these exotic species *Oreochromis niloticus* had high relative abundance (5.25%) and distribution, indicate a threat to other species due to their establishment in the river. *Cyprinus carpio* had a moderate relative abundance (1.84%) and had considerable distribution at all sites, can be a threat to other species. The population of *Cyprinus carpio* is expected to increase with current scenario of climate change [51]. The overall population of exotic species is expected to increase climate change and its after effects (increase competition for food, disease, and increase predation) [52]. Introduction of fish in fresh waters has increased many times than ever before. These introduced species were disturbing the dynamics of the ecosystem, stressing native species (i.e. *Tor putritora*, *Ailia coila*, *Bagarius bagarius*, *Ompok bimaculatus* and *Ompok pabda*) towards extinction [53]. Most of the introduced species are for the food production, sports fishing and for the ornamental purposes [54] or accidental introduction. In a river system species are often introduced through water transfer schemes (Bunn and Arthington 2002) [55]. *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella* had poor relative abundance 0.17% and 0.19% respectively and not indicate a threat to native species, *H. molitrix* (Silver carp) and *C. idella* (Grass carp) species were cultivated in aquaculture and in flooding season introduced to the adjacent rivers [56].

Impacts of human activities on the fish assemblage of river chenab

The earth is losing its diversity due to habitat degradation and pollution resulted due to human activities. The loss of any species will mean irretrievable damage the intricate web of life [57]. One endangered species *Tor putitora* was recorded with relative abundance of 0.12%. Construction of several dams in the Indian held Jammu and Kashmir reduced the river flow and increased the human control over the River Chenab. The habitat fragmentation, along with pollution has resulted in the decline of this species [30]. Six near threatened species were identified; most of them have restricted distribution and limited number including *Ailia coila*, *Bagarius bagarius*, *Ompok bimaculatus* and *Ompok pabda*. Among these near threatened species only *Wallago attu* has better distribution and strength. A number of other species was very low, needed immediate attention and conservation measure.

Water Pollution: Freshwater resources are most vulnerable habitat all over the world due to anthropogenic activities in the catchment area of the river. Thousands of synthetic chemicals are damaging the complex food web within river environment, resulting in extinction of sensitive species. Biological assemblages and its structure or composition can be determined by species' intrinsic features, environmental conditions, and temporal dynamics. Species with similar autecology, life history and morphology can exist together in an aquatic environment and their survival depends on resource availability [58]. Natural and anthropogenic factors, their impacts on the fish fauna is presented in figure 4.

Analyzing the environmental factors the data of temperature and dissolved oxygen. The lowest average temperature during sampling was 10.5 °C and highest DO was 11mg.L⁻¹ at Marala and highest average temperature was 19.6°C at Punjnad while lowest DO level was recorded down stream of Trimmu barrage (7.5mg.L⁻¹). Species with small temperature tolerance were vulnerable to temperature increase, the metabolism of the fish increased with temperature increase [59].

Urbanization and industrialization: The Chenab river traverse from most populous, urbanized and industrialized cities [60]. The population of these city exerts environmental and socioeconomic pressures on fish diversity as the local population gets food from the river and dumps its waste in it. In this region, urban sewage and most of the industry do not treat the effluent plants, and most of the sewage is drained directly into [10]. Urbanization is linked to declines in fish diversity, richness and biotic integrity [12]. Any change in water quality such as water temperature, dissolved oxygen level, pH, turbidity, etc. can affect the fish breeding, migration and distribution pattern and survival of fish eventually altering fish assemblage and structure [61].

In Sialkot and its surroundings, almost 264 tanneries, 244 leather processing units and 900 leather sports good manufacturing units, 14 flour mills, and 57 rice husking units are operational. Roughly tanneries alone discharge 1.1 million liters per day of waste water having a big share of heavy metals added to the water of Chenab [62]. Sialkot alone contributes 52 million liters of waste water [63]. From Gujarat three drains enter into the river adding $31.97 \text{ m}^3\text{s}^{-1}$ of waste water carrying 34.84 tons/day of organic load [64]. Jhang district is situated in central Punjab and adjoined by Toba Tek Singh, Faisalabad and Hafizabad etc. Most of the land in this area is cultivated. Mainly has textile industry. Faisalabad is a major producer of superphosphate fertilizer, textiles, dyeing, beverages, pulp and paper, printing, and ghee industry. More than 250 industrial units working in Faisalabad discharge, heavy metals, inorganic salts, aromatic dyes, and organic compounds directly or indirectly to river Chenab [65,66]. The population of Faisalabad is 4.07 million Faisalabad is generating $4.07 \text{ m}^3\text{s}^{-1}$ waste water, including industrial and municipal waste [67]. The drain entering to river Chenab their discharge and contribution to the organic load were presented in the Table 5.

The polluted water of the drains has organic and inorganic components including heavy metals, persistent organic pollutants and pesticides, were the real threats to the biodiversity. Qadir and Malik [11] reported the presence of heavy metals in fish higher than the permissible limit from Nullah Aik and Palkhu (tributaries of river Chenab). Bio-magnifications of the metals in the food chain will ultimately affect the health of its consumers [11]. Tariq et al. [68] also reported elevated level of heavy metals in fish on Chenab river. It was correlated with water contamination. Eqani et al. [69] reported the presence of the Pesticides in the fish of river Chenab. While Mahmood et al. [70] observed the presence of pesticides in the water and sediments of Chenab river which is a potential health risk for the fish and its consumers as well as the biodiversity present in it.

Agricultural activities: The catchment area of Chenab river is Punjab's most intensively farmed areas and huge amount of pesticides are used in agricultural practices. These pesticides are very toxic to the fish and even cause mortality in fish depending upon the age and size of fish [71-79]. Pollutants from different points and nonpoint sources added different kind of pathogens which causes disease in the fish. Iqbal et al. [80] studied the fish of Chenab from Trimmu.

Fish health problems: Fish had signs of different types of acute ulcers on head, abdomen, skin and base of fins and some species like *Salmopasia bacaila*, *Barilus modestus*, and *Aspidoparia morar* were found dead. Which indicate extreme level of pollution threatening the lives of the fish, Qadir and Malik [11] also observed, skin and fin rot diseases in *Channa punctata* and *Mystus cavasius*, *Wllago attu*. Prominent variations in skin color depending on the degree of water pollution were also observed in Nullah Aik and Palkhu.

Construction of barrages and dams: Water diversion reduces the original habitat area of fish, whereas, barrage construction creates another new and artificial habitat in upstream areas. Water is diverted through the construction of hydraulic structures, reducing water level affect the fish diversity adversely. The volume of habitat and optimal thermal conditions are linked to species productivity strongly [81-85]. Changes in environmental conditions sometime cause failure in stimulation in fish reproduction and cause the interruption in fish breeding [86]. The flow of River Chenab is also modified due to an agreement between the two nations known as Indus water treaty (1960). According to the Indus water treaty, the rights of the eastern Rivers Satluj, Bias and Ravi were given to the India. Pakistan has the rights to water of river Chenab. Immediately after entering in Pakistan, the first hydraulic structure on Chenab was constructed for water flow modification and flood control namely Marala, followed by Khanki, Qadirabad, Trimmu and Punjnad. Four link canals and three irrigation canals originate from these barrages and irrigate 2.39 million hectares [60]. A major share of water is diverted from Marala, Khanki, Qairabd and Trimmu and drastically reduces water downstream. The detail of canals and their discharge capacities are given in Table 6. River discharge extremely reduces in dry-season [87]. The construction of barrages and dam blocks the migration rout of fish, [75]. Fish migrate for good quality water and obstacles in their way interrupt their migration upstream. Water quality is fundamental, for eggs and larvae that highly dependent on water rich in oxygen [88-90]. The stretch of the River Chenab studied mainly consist of warm water fishes, whereas, upstream area of River Chenab is mainly hilly terrain with cold water fishes. Some cold water fish species were migrating to the river in plain area during winter season but due to construction of dams in Indian held Kashmir, this migration has been badly affected. A number of dams were constructed on the river Chenab such as Dulhasti, Baglihar and Salal dams in Indian held Kashmir were already functioning well the Himachal Pradesh Government is constructing, implementing and planning 49 hydroelectric projects on the Chenab [91-94].

Illegal fishing practices: Chenab is facing problems like illegal, over fishing etc. It was observed during the fish sampling that the size of the fish was small indicating over fishing. Over fishing is being done for the short term economic benefit. Small mesh size nets were used by fisherman and most of the fishes are captured before reaching the productive age, resulting in loss of fish in density and diversity. Another problem indicated by the locals around the river is fishing in the banned season (breeding season). Over harvesting of fish alter age and size structure, sex ratio, genetics and species composition of the area, also the composition of their connected and dependent species [80,81]. It was reported that the use of dynamite (blast fishing) and poison kills the fishes of the whole area. In shallow waters, some people also use the electric current to stun fish, and to capture the large number of fish [16,82-84].

Natural factors: Climate change has resulted in the change in precipitation pattern significantly on the spatiotemporal basis with uneven distribution of available water [95-98]. Due to change in timing of precipitation, greater rates of evaporation, transpiration, and glacial melt. The size and durability of running and standing waters have changed [86] This phenomenon has a great impact on the Himalayan river including Chenab [85] affecting fish, especially those having a narrow thermal tolerance range [99-100]. This study is an effort to highlight the fish diversity in River Chenab relating to anthropogenic threats. The information presented in this paper will

help the conservationist and managers in prioritizing the sites and species for conservation.

Conclusion

Chenab River is a highly human managed river and its ecosystem is highly fragmented due to construction of dams and barrages, which highly influence the integrity of its ecosystem resulting in decline in species diversity. In this study out of five barrages of Chenab fish species diversity was found highest at Qadirabad barrage and lowest at Khanki barrage. Construction of barrage act as barrier in the movement of fish downstream, only in flood season a connection get established between the species of two sides. Point and nonpoint sources of pollution were extremely destructive towards the fish diversity of Chenab. Small sized fishes were captured from most of the sites indicated that fishing pressure on the assemblage. Fish diversity in Chenab is facing multiple threats to water diversion, water shortage, habitat degradation, destructive methods of fishing, fishing in banning season, etc. Presence of near threatened species in river Chenab strengthens our belief that there is a much need to study about habitat losses, factors contributing to habitat degradation and their rehabilitation requirements. Fish conservational management of the river must be in a comprehensive manner, involving local stakeholders and people.

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