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Fish Abundance and Diversity During Low and High Flow Seasons of River Ravi, Punjab, Pakistan

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HAS and JIQ designed and supervised the study. HMA planned, surveyed, analyzed the data and prepared the manuscript. HAS and JIQ provided their expert guidelines and resources for study. HAS reviewed and finalized the manuscript.

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Biodiversity, Abundance, Ravi Fish fauna, Ballok, Freshwater

ABSTRACT

The present study used multivariate analysis to determine the fish species diversity of the river Ravi, Punjab, Pakistan. Eight sampling sites were surveyed during the year of 2020 to ascertain fish diversity and abundance. Diversity indices computed by using Primer 7 Software for whole study compared seasonally. Cluster analysis (Euclidian distance) and poly component analysis performed by using Origin Software (2016). A total 877 (258 in low and 619 in high flow season) fish specimen was collected using a variety of fishnets and identified by using standard taxonomic keys based on morphometric characters. These fish specimens belong to 10 orders, 21 families, 37 genera and 50 species. The family Cyprinidae was containing 13 genera and 21 species. Eight species (*Amblyceps mangois, Botia lohachta, Botia almorhae, Coptodon zillii, Ctenopharyngodon idella, Parambasis lala, Salmostoma phulo* and *Psilorhynchus nudithoracicus*) were collected first time from river Ravi Pakistan. During high flow season, *Cirrhinus mrigala* and *Captodon zilli* showed highest relative abundance 13.89% and 13.73%, respectively. Highest frequency occurrence (FO) 87.5% was observed for *Labeo rohita* followed by two species *Channa punctate* and *Cirrhinus mrigala* (75%). Maximum Shannon-Weiner index 3.119 and 3.122, Margalef index 2.825 and 3.573, Evenness index 0.9728 and 0.9849 were recorded during low and high flow seasons, respectively. Taxonomic diversity (Delta) and total phylogenetic diversity (sPhi+) was found maximum during high flow season. Head Balloki upstream and Dhnad Balloki showed the highest diversity indices during low and high flow. The decline in number of fish species with less Shannon–Wiener index (<3.5) depicted the alarming situation of natural water body.

INTRODUCTION

Rivers are major parts of freshwater ecosystems. These water bodies are the determining factors in the growth of various civilizations in their vicinages (Benjamin *et al*., 1996). Freshwater fishes (almost 18,000 fish species) are one-fourth of all vertebrates on the world and deliver irreversible goods and services (Villéger *et al*., 2011; Allen and Pavelsky, 2018; Su *et al*., 2021; Laan, 2020). The decline in freshwater biodiversity due to habitat loss, overexploitation, discharge of untreated urban and industrial effluents in water bodies and changes in water flow is more when compared with terrestrial ecosystem (Dudgeon *et al*., 2006). About more than 14% of the world's freshwater fish are currently endangered or extinct (IUCN, 2021).

Rivers, streams, estuaries, man-made reservoirs and lakes, are abundant in Pakistan (FAO, 2003). Pakistan constitutes a transitional zone, which attributed the great influence and variation in fish fauna (Dudgeon *et al*., 2006). Pakistan has about 193 freshwater fish species (Rafique and Khan, 2012). These species were classified as Actinopterygii, Teleostei, 3 cohorts, 6 super orders, 13 orders, 30 families, and 86 genera (Costa and Schulz, 2010).

River Ravi is a small river of Indus water basin system with a total length of 750 km in Punjab province, Pakistan. This river rises from the glaciers in the mid-Himalayas of Himachal Pradesh, India, and flows northwestern through India and enters in Pathankot at Chaundh and forms a 37 km border between India and the state of Jammu and Kashmir before entering Pakistan via the villages of Tadyal and Kot Naina in Sialkot's Shakargarh Tehsil, where it joins the Ujh river. After covering about 450 km, river Ravi joins River Chenab near Head Sidhnai at District Khanewal. The River has been highly affected by various anthropogenic activities like discharging of untreated industrial effluents and urban sewage that cause

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detrimental impacts on aquatic life especially on fish fauna (Shakir and Qazi, 2013; Shakir *et al*., 2013a, b).

Biodiversity is pivotal for outcomes of aquatic ecosystem such as water cleaning, nutrient cycling, livelihood, and food supply (Costanza *et al*., 1997). Therefore, maintaining biodiversity is important for a healthy environment and a good life (Helfrich *et al*., 2009). The study of fish biodiversity has widely been used to categorize habitats variability, diagnose temporal changes in the aquatic environment and helps in formulating the conservation and management plans (Dale and Beyeler, 2001; Lin and Caramaschi,, 2005; Costa and Schulz, 2010; Lakra *et al*., 2010).

Biodiversity refers to the variety of different types of life on Earth. It is the life support system and an important factor for the resilience of an ecosystem (Elmqvist *et al*., 2003; Rawat and Agarwal, 2015). The interaction between different species, as well as the physical and limnological properties of an aquatic ecosystem, may promote the composition and novel structure of the fish fauna (Agnisto *et al*., 2005). Depth, food availability, spawning sites, topography, water current, and water physicochemical properties all play a role in the diversity and distribution of fish in a habitat. Freshwater biodiversity provides a broad variety of valuable goods and services for human societies – some of which are irreplaceable (Covich *et al*., 2004a). The value of biodiversity includes its direct contribution to economic productivity (e.g. fisheries), its "insurance" value in the event of unforeseen events, its worth as a repository of genetic knowledge, and its value in supporting the provision of ecosystem services (e.g. cleaning water) (Pearce *et al*., 1998; Heal, 2000; Covich *et al*., 2004b). As a regular characteristic, precise statistical information on fish biodiversity, population dynamics, and recruitment patterns is essential in developing fish conservation and management plans for our natural fisheries resources (Holmlund and Hammer, 1999). Therefore, it is essential to study fish diversity continuously in various ecosystems across the region. The present study designed to estimate biodiversity and relative abundance of fish species during low (pre-monsoon) and high (post monsoon) flow seasons of river Ravi, Punjab, Pakistan.

MATERIALS AND METHODS

Sampling sites

Fish sampling was carried out at eight sites of river Ravi, Punjab, Pakistan. The sampling start from upstream site Ravi Syphon (31° 72′ N and 74° 46′ E) which is situated near village Ghazi Kakka, district Sheikhupura and approximately 20 Km upstream of New Ravi Bridge Shahdra. No point source of pollution at this site or above was identified after the entrance of river in Pakistan. This site was characterized with relatively good water quality due to least disturbance with respect to urban pollutants from Pakistan side. The downstream sampling site Shahdra (31° 60′ N and 74° 28′ E) is situated near New Ravi Bridge, Lahore. Three major pumping stations (North East, Shadbagh and Shahdra Gauging Station) are throwing untreated municipal sewage effluent of Lahore city into the Ravi between the sites Syphon and Shahdra. Dhand Nanodogar (31° 35′N and 74° 06′E) and Noul village (31° 35′N and 74° 02′E) sites are situated in district Sheikhupura. The water of river Ravi fill up the area of Dhand Nanodogar during monsoon flow and disconnect from mainstream of river during low flow season. There are four major pumping stations throwing untreated municipal effluent of Lahore city in to the river Ravi before these sampling sites (Dhand Nanodogar and Noul village). Site Dhand Balloki (31°25′N and 73° 91′E) situated 7 km upstream from Head Balloki. This is largest Dhand of Ravi River, which fill up due to overflow of river water during monsoon season and disconnect from mainstream of river during low flow season. Head Balloki is located about 75 km southwest of Lahore at river Ravi in District Kasur. There are two off-taking canals from Head Balloki namely Lower Bari Doab Canal (LBDC) and Balloki Sulemanki (B.S) Link Canal. Both canals irrigate a vast area in the southwest of the Punjab. Sampling was also done at Head Balloki about 500 m upstream (31° 25′ N and 73° 91′ E) and 500 m down steam (31° 22′ N and 73° 89′ E) situated in District Kasur. Head Sidhnai (30°.56′N 72°.16′ E) the last Headworks over Ravi River before its confluence into Chanab River about 15 km ahead was the last sampling points. It is situated about 2 km from Abdul Hakeem in District Khanewal (Fig. 1). The lifeline of Pakistan's water resources is monsoon precipitation that falls in summer

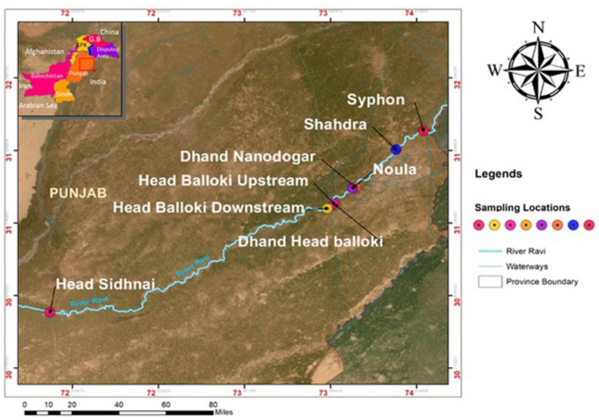

Fig. 1. Fish sampling locations on map with global positioning system (GPS) coordinates.

from July to September (Naheed *et al*., 2013). During present study, each sampling sites were visited during low (pre-monsoon) and high (post-monsoon) flow season of rive Ravi twice for fish sampling.

Fish sampling

Fish specimens were collected using different nets (cast nets, gill nets, and hand nets) with the help of professional fishermen. Mesh size of nets ranged from 0.2–5 cm with length (10 m) and height (1.6 m) was used. Netting performed from 0900 h to 1600 h continuously on each sites. Wooden boats were used to mitigate sound disturbance for aquatic organisms. Fish specimens were kept in ice-box and transported to Fish Lab, Institute of the Zoology, University of the Punjab, Lahore immediately for further analyses. Each specimen of each site was tagged using specific code and separately packed in labeled (date, site, time, and locality) plastics jar in 95% ethanol. Each specimen then identified using local morphometric and meristic characters-based identification key (Mirza and Sharif, 1996; Mirza and Sandhu, 2007).

The relative abundance (RA) of fish species was calculated using the formula as given;

$$RA\ (\%) = \frac{ni}{N} \times 100$$

where, ni is number of individuals of a fish species, N = number of individuals of all fish species.

Occurrence frequency (OF) for all species calculated as following formula:

$$OF\ (\%) = \frac{Si}{S} \times 100$$

where, Si is number of sites in which a species found. S = total sampling sites.

Diversity indices

The diversity indices were calculated using following formulas.

Shannon–Wiener index calculated by;

$$H'\ (Log2) = -\Sigma\ Pi \log 2\ (Pi),$$

H′ is Shannon–Wiener index but for logs to the base two. Where's pi is proportion of total sample represented by species i. Divide no. of individuals of species i by total number of samples.

Species richness was calculated by Margalef's richness (d) as following;

$$\text{Species richness (Margalef)}: d = \frac{(S-1)}{\log (N)}$$

where S is number of species in a sample and N is number of specimens in the sample.

Evenness was calculated by using Pielou's evenness formula as:

$$\text{Pielou's evenness}: J' = \frac{H'}{\log (S)}$$

where's H′ is Shannon Diversity index; S is number of Species.

Taxonomic diversity (Delta) and Total phylogenetic diversity (sPhi+) was also calculated by using Primer software.

Cluster, principal component and similarity percentile analyses

Clustering methods are widely used methods in identifying and recognizing similarity/dissimilarity patterns between sites. The cluster analysis was performed for all sampling sites with low and high flow seasons using Origin (Version 2016) statistical software (Clarke and Warwick, 2001).

The principal component analysis (PCA) is expressed by the following equation:

$$PCi = a_{1i}V_1 + a_{2i}V_2 + \ldots\ldots\ldots\ldots + a_{ni}V_n$$

where PCi is the principal component i and a_{ni} is (n = 1….n) the loading (correlation coefficient) of the original variables Vn (Statheropoulos *et al*., 1998). PCA is a frequently used approach for reducing the number of variables in datasets and interpreting them in a meaningful way (Jolliffe and Cadima, 2016). The PCA was conducted using the statistical software Origin (2016).

Similarity percentile (SIMPER) analysis identified the species mainly responsible for the dissimilarity in abundance between sampling sites. It was determined by using PRIMER (Version 7) statistical software (Clarke and Warwick, 2001).

RESULTS

In present study, total 877 fish specimens were collected from eight sites of River Ravi; 258 during low and 619 high flow seasons. Each fish specimen was identified using morphometric and meristic characters. The sampled fishes belonged to 10 orders, 21 families, 37 genera and 50 species (Table II).

It was observed that the order Siluriformes showed more diversity with 8 (38.10 %) families, followed by Anabantiformes and Cypriniformes with 3 (14.29 %) for each, while order Cichliformes, Gobiiformes, Osteoglossiformes, Clupeiformes, Ovalentaria, Mugiliformes and Synbranchiformes were recorded with single (4.76%) family (Table III). The family Cyprinidae was the predominant representing 21 (42%) species followed by Bagridae with 4 (8%) species, Siluridae and Ambassidae with 3 (6%) each, Botiidae and Osphronemidae with 2 (4%), while other families observed with 1 (2%) species (Fig. 2).

Table I. List of fish spices collected during each season with their relative abundance (RA) and frequency of occurrence (FO).

Family/ Species	Low flow season			High flow season			IUCN status
	n	RA %	FO %	n	RA %	FO %	
Osphronemidae							
Trichogaster fasciata	6	2.33	12.5	27	4.36	50	LC
Trichogaster lalius	7	2.71	25	9	1.45	12.5	LC
Badidae							
Badis badis	1	0.39	12.5	0	0.00	0	LC
Channidae							
Channa punctata	15	5.81	75	12	1.94	37.5	LC
Cichlidae							
Coptodon zillii	7	2.71	37.5	85	13.73	37.5	LC
Botiidae							
Botia almorhae	0	0.00	0	7	1.13	12.5	LC
Botia lohachata	0	0.00	0	2	0.32	12.5	LC
Cyprinidae							
Amblypharyngodon mola	23	8.91	25	80	12.92	12.5	LC
Bangana dero	6	2.33	25	1	0.16	12.5	LC
Barilius modestus	5	1.94	12.5	0	0.00	0	LC
Barilius vagra	0	0.00	0	1	0.16	12.5	LC
Chela cachius	11	4.26	25	0	0.00	0	LC
Cirrhinus mrigala	28	10.85	62.5	2	0.32	12.5	LC
Cirrhinus reba	10	3.88	25	86	13.89	75	LC
Ctenopharyngodon idella	0	0.00	37.5	20	3.23	25	ND
Cyprinus carpio	4	1.55	0	10	1.62	12.5	VU
Esomus danrica	0	0.00	0	5	0.81	12.5	LC
Hypophthalmichthys molitrix	0	0.00	0	4	0.65	12.5	NT
Labeo bata	4	1.55	0	15	2.42	12.5	LC
Labeo boggut	0	0.00	0	31	5.01	12.5	LC
Labeo calbasu	4	1.55	25	4	0.65	37.5	LC
Labeo catla	2	0.78	25	1	0.16	12.5	LC
Labeo dyocheilus	2	0.78	12.5	1	0.16	12.5	LC
Labeo rohita	21	8.14	75	52	8.40	87.5	LC
Osteobrama cotio	33	12.79	50	48	7.75	37.5	LC
Puntius chola	1	0.39	12.5	5	0.81	12.5	LC
Salmostoma bacaila	11	4.26	12.5	0	0.00	0	LC
Salmostoma phulo	0	0.00	25	2	0.32	12.5	LC
Psilorhynchidae							
Psilorhynchus nudithoracicus	2	0.78	12.5	0	0.00		ND
Notopteridae							
Chitala chitala	1	0.39	12.5	1	0.16	12.5	NT
Clupeidae							
Gudusia chapra	3	1.16	25	20	3.23	50	LC
Ambassidae							
Chanda nama	18	6.98	25	7	1.13	25	LC
Parambassis baculis	0	0.00	0	21	3.39	12.5	LC
Parambassis lala	0	0.00	0	2	0.32	12.5	NT
Gobiidae							
Glossogobius guiris	2	0.78	25	5	0.81	25	LC
Mugilidae							
Minimugil cascasia	4	1.55	12.5	0	0.00	0	LC
Amblycipitidae							
Amblyceps mangois	4	1.55	12.5	0	0.00	0	LC
Bagridae							
Mystus bleekeri	3	1.16	12.5	4	0.65	25	LC
Mystus cavasius	1	0.39	12.5	11	1.78	25	LC
Mystus vittatus	0	0.00	0	7	1.13	12.5	LC
Sperata seenghala	3	1.16	25	0	0.00	0	LC
Ritidae							
Rita rita	1	0.39	12.5	0	0.00	0	LC
Heteropneustidae							
Heteropneustes fossilis	0	0.00	0	5	0.81	12.5	LC
Horabagridae							
Pachypterus atherinoides	1	0.39	12.5	0	0.00	0	LC
Schilbeidae							
Eutropiichthys vacha	1	0.39	12.5	0	0.00	0	LC
Siluridae							
Ompok bimaculatus	1	0.39	12.5	0	0.00	0	NT
Wallago attu	9	3.49	50	21	3.39	62.5	VU
Sisoridae							
Bagarius bagarius	2	0.78	25	2	0.32	25	NT
Glyptothorax telchitta	1	0.39	12.5	0	0.00	0	LC
Mastacembelidae							
Macrognathus pancalus	0	0.00	0	3	0.48	12.5	LC

Table continues on next column....

n, number of individuals; RA, realtive abundance; FO, frequency of occurrence.

Table II. Comparative account of various taxonomic studies of icthyofauna at River Ravi.

S. No	Study year	No of fish species	References
1	1943	49	Ahmed (1943)
2	1970	65	Mirza (1970)
3	2002	49	Ahmed and Mirza (2002)
4	2001-2003	50	Khan *et al.* (2011)
5	2011-2013	22	Rathore and Dutta 2015
6	2012-2013	19	Hussain *et al.* (2014)
7	2014-15	38	Pervaiz *et al.* (2018)
8	2020	50	Present study

Table III. Number and percentage composition of families, genera and species of fishes under various orders.

Order	Family n (%)	Genus n (%)	Species n (%)
Anabantiformes	3 (14.29)	3 (8.11)	4 (8)
Cichliformes	1 (4.76)	1 (2.70)	1 (2)
Clupeiformes	1 (4.76)	1 (2.70)	1 (2)
Cypriniformes	3 (14.29)	15 (40.54)	24 (48)
Gobiiformes	1 (4.76)	1 (2.70)	1 (2)
Mugiliformes	1 (4.76)	1 (2.70)	1 (2)
Osteoglossiformes	1 (4.76)	1 (2.70)	1 (2)
Ovalentaria	1 (4.76)	2 (5.41)	3 (6)
Siluriformes	8 (38.10)	11 (29.73)	13 (26)
Synbranchiformes	1 (4.76)	1 (2.70)	1 (2)

The highest relative abundance (RA) were calculated as 13.89 and 12.79% for *Cirrhinus mrigala* and *Osteobrama cotio* during high and low flow seasons, respectively. While *Barilius vagra, Labeo catla, Chitala chitala, Eutropiichthys vacha, Labeo dyocheilus, Bangana dero, Ompok bimaculatus, Pachypterus atherinoides* and presented the lowest RA (0.16%) (Table I). *Barilius vagra, Botia almorhae, Botia lohachata, Ctenopharyngodon idella, Esomus danricus, Heteropneustes fossilis, Hypophthalmichthys molitrix, Labeo boggut, Macrognathus pancalus, Mystus vittatus, Parambassis lala, Parambassis baculis* and *Salmostoma phulo* missed in low flow season while *Amblyceps mangois, Badis badis, Barilius modesticus, Chela cachius, Eutropiichthys vacha, Glyptothorax telchitta, Ompok bimaculatus, Pachypterus atherinoides, Rita rita, Salmostoma bacaila, Minimugil cascasia, Psilorhynchus nudithoracicus* and *Sperata seenghala* missed in high flow season.

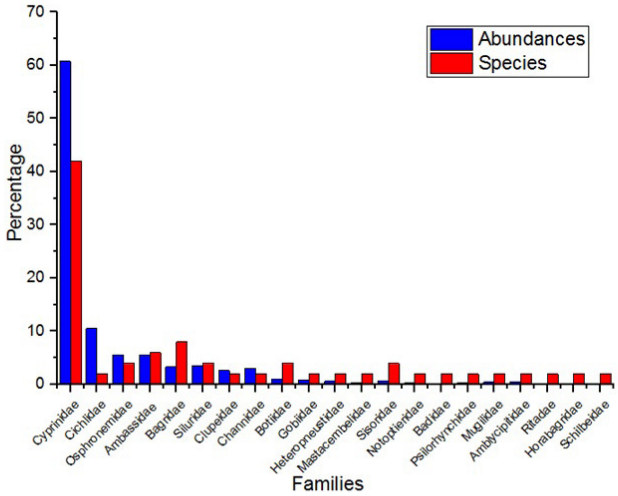

Fig. 2. Percentage composition of abundance and species in families.

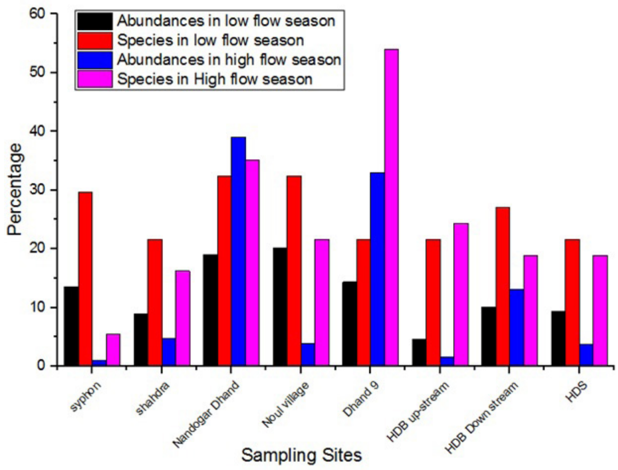

Fig. 3. Site based variations in abundance and species composition of cached samples in both seasons.

The highest frequency occurrence (FO) 87.5% was estimated for *Labeo rohita* in high flow season. While during low flow season highest FO 75% was recorded for two species (*Labeo rohita* and *Channa punctata*), followed by *Cirrhinus mrigala* (62.5%), *Wallago attu* (50%) and *Osteobrama cotio* (50%). *Amblyceps mangois, Amblypharyngodon mola, Barilius modesticus, Barilius vagra, Botia almorhae, Botia lohachata, Labeo catla, Chitala chitala, Ctenopharyngodon idella, Esomus danricus, Eutropiichthys vacha, Heteropneustes fossilis, Labeo boggut, Labeo dyocheilus, Macrognathus pancalus, Mystus vittatus, Ompok bimaculatus, Parambassis baculis, Parambassis lala, Puntius chola, Pachypterus* *atherinoides, Rita Rita, Salmostoma bacaila* and *Minimugil cascasia* had lower FO (12.5%).

Conservation status

The International Union for Conservation of Nature (IUCN) red list is well established, having a long history with the first red data books in the 1960s (Fitter and Fitter 1987). With respect to collected fish species in the present study, 4% are vulnerable (VU), 10% near threatened (NT), 4% not determined (ND) and 82 % least concern (LC) fish species according the Asia region red list by IUCN (2021) (Fig. 4). Moreover, fifteen-years (2007 to 2021) data of IUCN red list for fish species were at compared to assess the trend of annually increasing threatened species (Fig. 5).

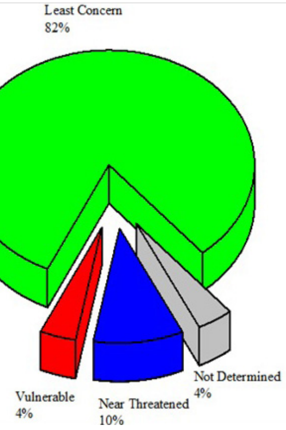

Fig. 4. Conservation status (percentage) of captured fish species as per IUCN red list.

Diversity indices

In the present study, the maximum value of shannon-wiener diversity calculated for Head Balloki downstream (3.119) and minimum for Head Sidhnai (1.835) during low flow season, while the maximum value for Head Balloki upstream (3.122) and minimum for Syphon site (0.65) during high flow season (Table IV).

The maximum species richness (d) recorded up to 2.825 for site Nanodogar Dhand and minimum 1.939 for site Dhand Balloki in low flow season. While maximum for site Dhand Balloki (3.573) and minimum for site Syphon (0.5581) were recorded during high flow season. The highest value of species richness (d) was found (3.573) during high flow season (Table IV).

Taxonomic diversity (Delta) found maximum for site Nanodogar Dhand (63.3) and minimum for site Head Sidhnai (34.86) during low flow season while maximum for site Head Balloki upstream (64.89) and minimum for Site Syphon (20.00) were noted during high flow season. Phylogenetic diversity (sPhi+) recorded maximum for the site Noul village (740) during low flow season and minimum for site Head Balloki upstream (480) while maximum for site Dhand Balloki (1040) and minimum for site Syphon (160) calculated during high flow season (Table IV).

Table IV. Site based diversity indices calculated for the fishes recorded in both (low and high flow) season from River Ravi.

Sites	Low flow season					High flow season				
	Species richness (d)	Species evenness (J′)	Shannon index H′(log 2)	Taxonomic diversity (Delta)	Phylogenetic diversity (sPhi+)	Species richness (d)	Species Evenness (J′)	Shannon index H′(log 2)	Taxonomic diversity (Delta)	Phylogenetic Diversity (sPhi+)
Syphon	2.813	0.8853	3.062	52.2	660	0.5581	0.65	0.65	20	160
Shahdrah	2.233	0.9642	2.893	62.13	500	1.485	0.9034	2.335	59.11	400
Dhand Nanodogar	2.825	0.8609	3.085	63.3	660	2.186	0.7531	2.787	58.7	840
Noul village	2.784	0.7649	2.742	46.59	740	2.203	0.9281	2.784	56.16	500
Dhand Balloki	1.939	0.8053	2.415	45.5	520	3.573	0.7219	3.12	52.06	1040
HDB Upstream	2.817	0.9728	2.918	62.12	480	3.474	0.9849	3.122	64.89	560
HDB downstream	2.762	0.9389	3.119	62.09	640	1.365	0.7926	2.225	36.36	360
HDS	2.203	0.6117	1.835	34.86	520	1.914	0.5892	1.654	30.83	460

HDB, Head Balloki; HDS, Head Sidhnai.

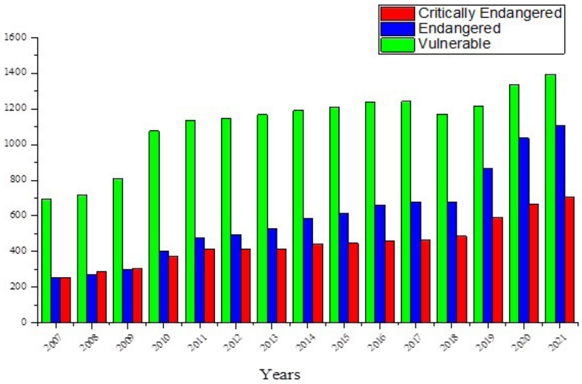

Fig. 5. Comparison of Fifteen year IUCN Status of fish species. (Source; IUCN Red List version 2021-1: Table 2 Last updated: 25 March 2021).

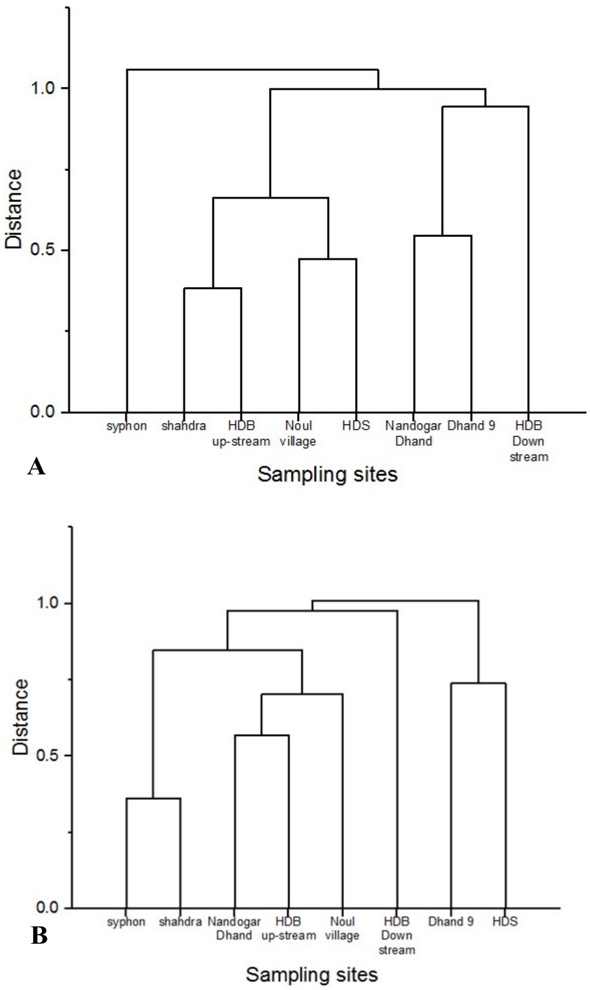

Fig. 6. Dendrogram showing Euclidian Distance in different sites based cached fishes; (A) during Low flow and (B) high flow season.
HDB, Head Balloki; HDS, Head Sidhnai.

Cluster analysis

The dendrogram expressed that there was a prominent separation between samples collected from different sites. Two major clusters were arisen, corresponding to the low and high flow seasons, thus distinguished seasonally in the freshwater fish assemblages. The distance correlation range among sites was around 0.3833–1.059 in low flow season and maximum 0.3594–1.0098 distance in high flow season (Figs. 6).

Poly component analysis (PCA)

The PCA was conducted for the most abundant fish species having RA% >2, using a correlation matrix and standardized variables. During low flow season *Amblypharyngodon mola* and *Chanda nama* showed highest abundance at site Dhand Nanodogar and Dhand Balloki, *Cirrhinus mrigala, Captodon zilli, Labeo rohita* and *Wallago attu* at site Head Balloki upstream, Shahdra and Noul villagea, while during high flow season. *Cirrhinus mrigala, Labeo rohit* and *Wallago attu* showed abundance at site Shahdra and Naoula and *Cirrhinus reba*, *Trichogaster fasciata* and *Labeo bata* at site Head Balloki downstream (Fig. 7)

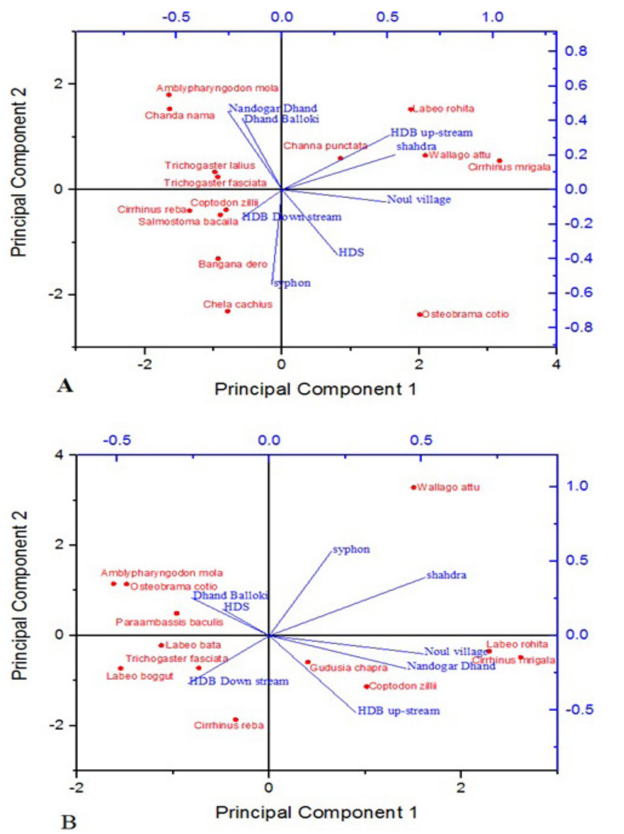

Fig. 7. Principle component analysis of fish Species and sampling sites during low (A) and high (B) flow season.
HDB, Head Balloki; HDS, Head Sidhnai

SIMPER

During low flow seasons sites are divided into three groups (group a, Syphon; group b, Shahdra; Noul village, Head Balloki upstream and Head Sidhnai; group c, Dhand Nanodogar, Dhand Balloki and Head Balloki downstream). The average similarity levels of groups ‘b and c for the samples collected during low flow season were 45.89 % and 36.89 %, respectively while group (a) has less than two sites. The average dissimilarity between groups “a” and “b” was 92.67%; between “a” and “c” was 94.94% and between “b and c” was 79.74 %. During high flow season sites are divided into five groups (group a, Syphon; group b, Head Balloki downstream; group c, Dhand Nanodogar and Dhand Balloki; group d, Shahdra and Noul village and group e, Head Balloki upstream and Head Sidhnai). The average similarity levels of groups “c, d and e” were 40.35%, 65.55% and 26.20%, respectively while group (a and b) has less than two sites. The average dissimilarity (100, 91.77 and 76.31%) of group “a” with groups “c, d and e”; 91.75% between “a and b”; 89.28% (c and b), 85.59% (c and e), 85.23% (d and b), 78.00% (d and c), 76.31% (d and e) and 85.43% between (e and b) was recorded.

DISCUSSION

In this study, we tried to estimate the seasonally (low and high flow season) abundance and diversity of fishes in river Ravi and recorded 50 species. In earlier surveys, Ahmed (1943) recorded 49 fish species, Mirza (1970) reported 65 and Ahmed and Mirza (2002) 49 fish species in river Ravi as discussed by Pervaiz *et al*. (2018). Khan *et al*. (2011) conducted an ichthyofaunal survey of the river Ravi and reported 50 species. Rathore and Dutta (2015) conducted the survey of the river Ujh (an important clean water tributary of the river Ravi, in Kathua district) and recorded the 5 orders, 10 families and 27 genera and 42 fish species. Hussain *et al*. (2014) conducted monthly surveys at floodplain situated on the River Ravi near Balloki Headworks from August 2012 to May 2013 and collected total 1703 fish samples which belongs to 7 orders, 8 families, 14 genera and 19 species. Hussain *et al*. (2015) reported 22 species and 9 families during their study (2011-2013) from river Ravi. Pervaiz *et al*. (2018) surveyed the river Ravi from the period of July, 2014 to June, 2015 and found 381 fish samples consists 38 species, 21 genera and 10 families. Numerically compared the fish species found from river Ravi found in previous studies with present study. Maximum 65 species was found in 1970 followed by 50 species in current study, while minimum 19 species reported during the study period of 2012 -2013.

In the present study, eight species (*Amblyceps mangois, Badia badis, Botia almorhae, Captodon zilli, Glyptothorax telchitta, Hypophthalmichthys molitrix, Parambassis lala* and *Salmostoma phulo*) were collected first time from river Ravi. These species were not reported from earlier studies conducted by (Ahmed, 1943; Mirza, 1970; Khan *et al*., 2011; Pervaiz *et al*., 2018). The 18 species *Ailia punctata*, *Ailia coilia*, *Aspidoparia morar, Chanda ranga, Chanda baculis, Crossocheilus diplocheilus, Gagata cenia, Gara gotyla, Glyptothorax stocki, Glyptothorax punjabensis, Labeo dero, Macrognathus aculeatus, Monopterus cuchia. Nandus nandus, Nemacheilus* sp., *Sisor rhabdophorus* and *Tor putitora,* were missing in the present study in comparison with earlier studies (Pervaiz *et al*., 2018). These differences may have arisen due to stray occurrences, sampling biases or the distribution of pollutants entering the river from various sources as well as other forms of human disturbances. When huge amounts of untreated urban and industrial effluents discharged in water bodies, it may cause rapid mortality of fish fauna (Austin, 1998). and Shakir *et al*. (2013) reported deteriorated water quality of river Ravi due to anthropogenic activities and industrial effluents. The reduction in water flow especially after the indus water basin treaty with India is also one of the cause of decline in fish diversity in river Ravi (Pervaiz *et al*., 2018)

Order Siluriformes was found dominant with 8(38.10%) families followed by anabantiformes and cypriniformes with 3 (14.29%) each. Similarly, Hussain *et al*. (2014) recorded that order Siluriformes was dominant with two families and dominant family Cyprinidae which was represented by six genera, followed by Notopteridae with two genera and Bagridae, Siluridae, Beloninidae, Channidae, Cichlidae and Mastacembelidae each represented with one genera. Rathore and Dutta (2015) expressed that the Siluriformes (4 families) was followed by Cypriniformes (3 families) while others Perciformes, Synbranchiformes and Beloniformes each constituted a single family. The faimily Cyprinidae found dominant with 21 species and 60.32% abundances, followed by Bagridae with 4 species, Ambassidae with 3 species, Botiidae, Mastacembelidae, Osphroneidae, Siluridae and Sisoridae each with 2 species, others with single species in present study. Family Cyprinidae showed dominance in the results of Pervaiz *et al*. (2018).

Cirrhinus mrigala and *Osteobrama cotio* have the maximum RA% (13.89 and 12.79) estimated during high and low flow season, respectively. Almost similar results were reported as highest RA (13.5%) for *Labeo rohita* followed by *Wallago attu* (13.2%) and *Cirrhinus mrigala* (12.6%). Khan *et al*. (2011) catched the more number of individuals *Puntius sophore* (439, RA=24.6%) followed by *Oreochromis aureus* Steindachner (169, RA = 9.5%) from river Ravi at Head Balloki. Latif *et al*. (2016) also calculated the highest (RA = 16.03%) for *Puntius sophore* from river Chenab. Akhi *et al*. (2020) was recorded a significantly higher ($P < 0.05$) number of fish individuals during the post-monsoon season followed by the pre-monsoon season, and the minimum number was reported during the monsoon season. Site based species diversity found highest at Dhand Balloki (54.05%) with population (32.96%) during high flow while during low flow season found highest species diversity (32.43%) at sampling site Dhand Nandogar and Noul village with population (20.16 and 18.99%, respectively) (Fig. 3). *Labeo rohita* showed highest frequency occurrence (87.5%) in high flow season while *Channa punctata* and *Labeo rohita* (75%) during low flow season. The findings of present study is in line with Hussain *et al*. (2016) in which *Labeo rohita* and *Cirrhinus mrigala* showed highest FO (100% for both) and RA (24.18 and 18.73 %) while *Rita rita* showed the lowest FO (20%) and RA (0.22%).

The IUCN provided a baseline information and a global context, to monitor the change in status of species and helpful for establishment of conservation priorities at the local level. In present study, the two VU fish species (*Cyprinus carpio* and *Wallago attu*), five NT species (*Bagarius bagarius, Chitala chitala, Hypophthalmichthys molitrix, Ompok bimaculatus* and *Parambassis lala*), 41 species are counted as LC were captured, while two species are ND (Table I, Fig. 5). *Cyprinus carpio* reported vulnerable speices in the IUCN status (IUCN, 2011, 2014, 2021). Significant decline of population of *Wallago attu* might be due to pollution and overharvesting (Rafique and Khan, 2012). The *Wallago attu* was declared as near threatened in 2014 and vulnerable in 2021 (IUCN, 2014, 2021). Some of the threatened species might become extinct in the near future (Albert *et al*., 2021). Fifteen years (2007 to 2021) data of IUCN red list for fish species showed the average annually increase in critically endangered (30), endangered (57) and vulnerable (47) fish species. The primary drivers of freshwater species reduction and ecosystem degradation are habitat loss and degradation, water withdrawal, overexploitation and pollution, and the introduction of non-native species (Ellison, 2004; Revenga and Kura, 2003).

The Shannon-Wiener diversity H′ ($\log_2$) is a method used widely to compare diversity between seasons and different habitats. Comparison of both season showed the highest value of H′($\log_2$) (3.122) during high flow season. Head Balloki up and down stream both sites showed the highest value of Shannon-Wiener diversity during high and low flow season, respectively. Hussain *et al*. (2014) studied commercial fish community of a floodplain lake situated on River Ravi and reported highest Shannon index (2.67581) in December and lowest (1.80945) in May. Hussain *et al*. (2015) assessed the relative diversity of the river Ravi's commercially significant fish fauna and reported Shannon-wiener diversity index 2.749, 2.706 and 2.654 for the years 2011, 2012 and 2013, respectively. Purusothaman *et al*. (2016) studied the seasonal contribution of fish diversity from southeast coast of India and their findings showed that maximum H′($\log_2$) (5.670) value in premonsoon and minimum (4.666) during monsoon. Ansari *et al*. (1995); and Sathianandan *et al*. (2012) also reported similar seasonal variations. Kindong *et al*. (2020) studied seasonal changes in fish diversity in the Yangtze River Estuary and recorded Shannon index values maximum (2.25) in December 2013. It was described that only in healthy and biodiversity rich areas have the Shannon value of more than 3.5 (Clarke and Warwick, 2001). In present study, the Shannon index was recorded lower than 3.5 indicted that all sampling sites are not healthy and biodiversity rich areas in both seasons. Shakir *et al*. (2013a, b) reported that the discharging of untreated urban sewage and industrial effluents cause detrimental effects on aquatic life especially on fish.

In the present study, the highest species richness index (d) was found (2.825 and 3.573) for the sites Dhand Nanodogar and Dhand Balloki during low and flow seasons, respectively. The species richness was comparatively higher during high flow season. Similarly, Hussain *et al*. (2015) reported species richness 3.515, 3.421 and 3.27 for the years 2011, 2012 and 2013, respectively. Hussain *et al*. (2016) calculated the maximum species richness for the month of February (3.4206) and minimum for the month of April (2.1722). The maximum species richness was reported for the month of December (2.25) (Kindong *et al*., 2020). Aziz *et al*. (2021) reported that fish species diversity indices declined remarkably due to anthropogenic activity. The highest species evenness index (J) up to 0.9728 and 0.9849 were calculated for site Head Balloki upstream during low and high flow seasons, respectively. Minimum species evenness index 0.6117 and 0.5892 was recorded during low and high seasons, respective for the site Head Sidhnai. Our results are in line with Hussain *et al*. (2016) reported maximum species evenness (0.95691) for the month of August and minimum (0.82351) for the month of May. Hussain *et al*. (2015)recorded species evenness 0.7442, 0.7131 and 0.7102 for the year 2011, 2012 and 2013, respectively Highest value of Delta and sPhi+ up to 64.89 and 1040 were recorded during high flow season.

Human impact is usually seen as the primary cause of the reduction in fish population, whether directly through habitat degradation or destruction or indirectly through global warming, eutrophication, pollution, groundwater exploitation, or the introduction of exotic species (Andermann *et al*., 2020; Dudgeon, 2020; Albert *et al*., 2021). The construction of dams on rivers inhibits the movement of fish, which may limit gene flow and create population difference (Meldgaard *et al*., 2003). Human populations have direct and indirect effects and lead to modify local species diversity (taxonomic and phylogenetic) (Leprieur *et al*., 2008; Villeger *et al*., 2011). Taxonomic and phylogenetic diversity determine how organisms affect functioning and stability of ecosystem and are thus important for conservation (Naeem *et al*., 2012; Craven *et al*., 2018; Brun *et al*., 2019; Pimiento *et al*., 2020). Low taxonomic values, i.e., reduced taxonomic/phylogenetic 'breadth' of assemblages for their number of species, can show significant environmental stress instigated by human impacts (Su *et al*., 2021) or fishing impacts (Mohamed *et al*., 2009), whereas higher values point toward normal environmental conditions with no major human impacts.

Seasonal comparison of the various diversity indices showed, the highest value of Shannon index (3.122), species richness (3.573), phylogenetic diversity (1040), evenness (0.9849), taxonomic diversity (64.89) during high flow season. Ansari *et al*. (1995) and Sathianandan *et al*. (2012) also reported similar seasonal variations. Akhi *et al*. (2020) studied the seasonal abundance and diversity indices of fish assemblage and concluded that the values of diversity indices (Shannon–Wiener diversity, Margalef's richness, and Pielou's evenness) varied from season to season.

The most extensively utilized approaches for finding and recognizing similarity/dissimilarity patterns between sites are clustering methods (Ripley, 1996). Cluster analysis proved useful in identifying natural groupings of samples, with samples within a group being more similar than samples from separate groups. It also identified species assemblages, which are groups of species that co-occur in a predictable pattern throughout months. Hierarchical cluster analysis, based on a pairwise distance matrix between all sampling sites was used to find patterns of fish diversity. The percent similarity matrix was used to analyze seasonal variations in the community and the association between species. In the present study, seasonal changes in the occurrence of species resulted in the creation of clusters. There was a clear distinction between samples taken in both seasons from different sites. Similarly, Hussain *et al*. (2014) performed the multivariate cluster analysis for the sampled fishes collected from floodplain of river Ravi. Ansari *et al*. (1995) observed similar groupings due to seasonal fluctuations on the west coast of India, and Purusothaman *et al*. (2016) reported similar groupings. The similarity trends by using Bray-Curtis cluster analysis were performed among the diversity indices and observed three groups of available fish species (Momi *et al*., 2021) and among different indigenous fish families based on the number of individuals belonging to each family from the Mahananda River (Galib *et al*., 2016).

The researchers were framed numerous techniques to determine the number of components to be extracted based on a subjective ground (Dancey and Reidy, 2007). The eigenvalue falls below 1 is a popular stopping criterion to determine the number of components is to be stopped (Jackson, 1993). The eigenvalues ≥1 were employed and extracted the three significant components for both low and high flow seasons data. The first three components have an Eigenvalue ≥ 1, the highest Eigenvalue (2.68 and 2.175) together explaining (33.34% and 27.2%) of the variance in the initial variables in low and high flow season, respectively.

SIMPER analysis indicated that the species mainly responsible for the dissimilarity in abundance between sampling sites. Similarity matrices were examined using Bray–Curtis similarity index (Bray and Curtis 1957). Similar method was reported by elsewhere (Purusothaman *et al*., 2016). Akhi *et al*. (2020) performed SIMPER analysis and reported 52.86% overall average dissimilarity among the seasons. Kindong *et al*. (2020) was performed SIMPER analysis for seasonal changes in fish diversity, density, biomass, and assemblage and reported 74.19% and 81.1% average dissimilarity among stations and months, respectively. Haque *et al*. (2022) studied seasonal analysis of food items and reported the average dissimilarity (30.02%) between summer and monsoon season, was with fish scales (19.71%) being the most prevalent food item making this difference.

CONCLUSIONS

In present study, total 50 fish species were recorded from river Ravi. The decline in number of fish species as compared to past surveys might be consequence of discharging of untreated urban swage and industrial effluents in river Ravi. The reduction of water flow in river Ravi especially after Indus treaty with India also cause detrimental effects on ichthyo-diversity. The present study depicted based on Shannon index (< 3.5) that the river Ravi, Pakistan is not a healthy and biodiversity rich habitat. To save the natural water bodies, the urgent focused strategies of concerned authorizes is suggested.

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Ethical statement

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Statement of conflict of interest

The authors have declared no conflict of interest.

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