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Water Quality Parameters and Fish Diversity at Chashma Barrage, Mianwali, Punjab, Pakistan

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ABSTRACT

Background: Quality of water is an important factor and of critical importance in determining fish diversity of a particular water body. Water quality includes physical, chemical, and biological properties of water.

Objectives: The present research was conducted to study the fresh water quality parameters and fresh water fish diversity in Chashma Barrage, Punjab, Pakistan.

Methodology: The data was collected every Sunday from February, 2020 to May, 2020 for 16 weeks. Recommended official methods of Analysis of the Association of Chemists (AOAC) were used to determine different water parameters such as water temperature, pH, Dissolved Oxygen (DO), nitrite, nitrate and chloride concentration, total dissolved solids, total suspended solids and total hardness of water. The results were compared with standard values of these parameters.

Results: Results showed that the water temperature, pH, DO, concentration of nitrite and nitrate, and other water quality parameters were in proper ratio, where the fish population flourishes to a maximum extent. During this 16-week study, a total of 14610 fishes were captured, out of which 12 species were identified as per following details: 5 species belonged to family Cyprinidae, 2 species represented the family Bagridae, while 1 species of each in the family i.e. Allidae, Channidae, Cichlide, Siluridae, Mastacembelidae, respectively.

Conclusion: Family Cyprinidae is the dominant one in Chashma Barrage having 5 species, and this was the maximum diversity first time recorded in Chashma Barrage. Also, the temperature of the water was optimum to support fish growth and species richness in the Barrage.

INTRODUCTION

Pakistan has an area of 780,000 hectares, out of which 9.7% is wetland area including 73% of freshwater of the country[1]. Almost 21,723 fish species have been recorded globally, amongst which 11,650 species are from marine sources while 8,411 species are from freshwater in distribution[2]. Interestingly, 193 freshwater fish species are present in Pakistan[3] and from this count, the Indus River comprises 180 fish species[4]. Diversity of fish species in the Indus River of Pakistan and all of its tributaries has been studied by various ichthyologists in past decades. It is very difficult to refer all of these efforts to only a few

ichthyologists, but in Pakistan, most of the important contributions are given by ichthyologists referred here[5-16].

Fish growth and diversity is greatly affected by physicochemical parameters of water quality[17]. Water quality includes the physical, chemical and biological properties of water[18]. Various physicochemical factors such as alkalinity, water temperature, ammonia, dissolved oxygen, free carbon dioxide, pH and total hardness are various physiochemical factors which strongly influence fish health[19, 20]. Water quality deteriorates mainly due to O_2 depletion, free CO_2, high ammonia level and temperature changes[21].

Chashma wetland ecosystem is a manmade lake and is situated along Indus river at 32° 25' N, 71° 22' E. This is a wetland of international reputation and is also a RAMSAR site (a wildlife sanctuary of international importance) according to RAMSAR convention (Convention on wetlands of international importance especially as waterfowl habitat). It is an important site for migratory birds, and fish culturing is one of the main activity carried out here[22]. Wetlands have great importance in regulating water cycle by acting as reservoir for rain water and melting snow, holding sediments, and in purification of water. In fact, wetlands also receive wastewater and urban runoff, thus acting as filter and sink for pollutants. These are some of the important ecological services offered by wetlands[23]. Fish farming plays a remarkable role in decreasing poverty in rural areas by giving empowerment to poor people and raising their living standard. Pakistan is a transitional zone between Palearctic and Oriental region fauna, but its freshwater reservoirs are being polluted by anthropogenic activities including the discharge of domestic and industrial effluents, hydroelectric power plants, construction of dams and Barrages etc. Physiological parameters of water must be in optimum limits because any change in these parameters would affect the fish growth and diversity. Poor physiological parameters also cause a decrease in commercially valuable fish products that in turn affect the economy of the country[24].

In order to observe the fish diversity of Chashma Barrage, it was important to understand the significance of water quality parameters and also the significance of Chashma as a wetland because it gives valuable information about the aquatic biodiversity of that region[23]. The topographical features of the surrounding area of Barrage include loamy soil while the dominant crops of the area are rice, wheat, sugarcane, pluses and orchards. The basic aim of this research was to analyze water quality parameters and fish diversity. The parameters of this research include the water temperature, pH, dissolved oxygen, nutrient content i.e. amount of nitrate and nitrite. Chloride concentration is also important because any increase in its amount becomes fatal for fishes. All of these parameters determine the favorability of water for fish growth.

MATERIALS AND METHODS

Study Area Standards

This research focuses on the Chashma Barrage (32.43389°N, 71.37889 °E) which is situated on the left bank of Indus River downstream to the Jinnah Barrage. Chashma Barrage is constructed nearby the Koh-e-Sulieman mountain range as shown in the Fig. **1**. Chashma Barrage is situated about 13.3km away from Kundian town in the southwest of district Mianwali in Punjab province. Mianwali is 200m above the sea level. The climate of Mianwali is dry subtropical with hot dry summers (~ 51°C) and cool winters (~ -2°C). The annual rainfall of the district is 250mm[2]. Chashma wetland was designated as a RAMSAR site, the Wildlife Sanctuary of international importance, on 22nd March, 1996. The water quality parameters make this area more suitable for more than 80 fish species (Pakistan seafood export report-2019). These parameters directly affect fish growth because the fish take their nutrients from the water.

Water Sampling

Sampling data of 16 week was collected from February, 2020 to May, 2020 in Chashma Barrage. Random samples of water were collected on weekends for water quality analysis as the sampling site was quite far away and it was not feasible to travel on daily basis after work. As Chashma Barrage is divided into two banks, so random samples were collected for water analysis from various sites during the day time. Those areas were preferred for water collection that were already used by numerous fishermen for fishing.

Figure 1. Satellite image of Chashma Barrage.

Polypropylene bottles of 1 liter were used for the collection of water samples. All the bottles were washed with ethanol and running water of the barrage before sample collection. Sample bottles were labeled with the exact time of collection and the date for analysis of water parameters. Water samples were collected from the depth of 2 feet below the surface of the water. Polypropylene sample bottles were carried to the Laboratory of Agriculture Tech, Iskandrabad for the analysis of respective parameters of water. All the water quality parameters were measured *in situ*. Dissolved oxygen was measured by dissolved oxygen meter (DO$_2$-9500, Jenway). The pH was measured by a pH meter (pH-0073, TOA). Water temperature was measured by Check-Temp (HI2200, HANNA Instruments). Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness (TH) of water and Chloride (Cl$^-$) concentration were measured by TSS/TDS/TH/NaCl meter (HI 2300, HANNA Instruments). Nitrate and nitrite concentrations were measured by spectrophotometer (UV-6000, R & M Instruments). Hatch kit was used for carrying these sample bottles to the laboratory.

Fish Sampling

In Chashma Barrage various methods were used to capture fish fauna. The fishes were caught with the help of local fishermen who were working under the contractor of Chashma Barrage. Different types of bait (i.e. worms, minnows, or power bait) were used as a food to capture fish species. The fishes were caught by using polyester fishnets with the help of boats on every weekend survey to the Barrage during the daytime. Different diversity indices were applied to calculate the abundance of species. Simpson Diversity Index was used to measure the number of species present as well as the relative abundance of species. It was calculated by using the following formula:

$$D = N (N – 1) / \Sigma n (n-1)$$

Where D is Simpson Diversity Index, n is number of individuals of a particular fish species, and N is total number of individuals in the entire sample. Similarly, Shannon Diversity Index was used to characterize species' diversity in a community. It was found out by following formula:

$$H = \Sigma p_i . \ln p_i$$

Where H is Shannon Diversity Index, and p_i is the proportion of total number of individuals in each species.

Species Richness Index explains the total number of species in the community while Species Evenness explains how evenly several different species are distributed in a community. The diversity and richness of fish species was observed every weekend and data was collected quantitatively on each catch.

Statistical Analysis

The data of fish fauna and water quality parameters was subjected to statistical analysis with the help of Microsoft

Excel-2019, which is a standard statistical tool for the data of biological sciences. For parameters of water, Mean and Standard Deviation were calculated by using Microsoft Excel while t-test and ANOVA were applied to check statistical significance. Different diversity indexes were applied to the data of fish samples for verification and accuracy of results, according to every weekend survey. To calculate the diversity of fish species, Simpson's Diversity Index, Shanon Diversity Index, Species Evenness Index, and Species Richness Index were applied for statistical analysis.

RESULTS

Water Quality Parameters

Normal ranges of all the parameters included in water quality are given in Table **1**, while the detailed result of WQ parameters is given in Table **2**, which represents the fluctuations in water parameters in respective weeks. The weekly mean of water temperature was ranged from 21.8 ± 0.62 to $28.84 \pm 0.85°C$. The weekly mean of pH was found within the range of 7.2 ± 0.33 to 8.05 ± 0.76. The DO was slightly higher within the range of 9.2 ± 0.38 to $11.5 \pm 0.76mg/L$. The concentration of Chloride ions (Cl^-) was ranging from 18 ± 1 to $29 \pm 5ppm$. The concentration of nitrite was low, ranging from 0.39 ± 0.02 to $0.76 \pm 0.37ppm$. The concentration of nitrate was found higher than nitrite, i.e. ranging from 5.31 ± 0.42 to 7.34 ± 0.61 (ppm). Total Dissolved Solids (TDS) in water were ranged from 125 ± 2 to $235 \pm 9ppm$. Total Suspended Solids (TSS) in water were ranging from $112 \pm 3ppm$ while Total Hardness (TH) of water was ranging from 126 ± 1 to $172 \pm 5ppm$.

Table 1. Normal Ranges of Water Quality Parameters.

Parameter	Range
Temperature	25-30
pH	7-9
Dissolved oxygen	5-10
Nitrite	<1 ppm
Nitrate	<5 ppm
Total dissolved solids	50-1000 ppm
Total hardness	>20 ppm

Table 2. Fish Diversity and Population at Chashma Barrage Recorded Each Week (Total 16 weeks).

Parameters	Sampling Weeks							
	Week-1	Week-2	Week-3	Week-4	Week-5	Week-6	Week-7	Week-8
Temperature (°C)	28.46± 0.15***	26.5 ± 0.26***	24.9 ± 1.40***	27.4 ± 2.5***	24.9 ± 4.4***	23.6 ± 4.14***	28.8 ± 6.49***	24.8 ± 6.49***
pH (H+)	8.05± 0.76**	7.4 ± 0.36**	7.9 ± 0.29**	7.7 ± 0.26**	7.65 ± 0.32**	7.8 ± 0.37**	7.6 ± 0.34**	7.7 ± 0.41**
DO (mg/L)	9.5± 0.42*	9.3 ± 0.41*	10.4 ± 0.64*	9.2 ± 0.38*	9.5 ± 0.34*	9.7 ± 0.46*	9.9± 0.51*	10.4 ± 0.69*
Chloride (ppm)	18 ± 1**	24 ± 4**	26 ± 3**	28 ± 5**	22 ± 2**	26 ± 2**	28 ± 4**	29 ± 5**
Nitrite (ppm)	0.41± 0.05**	0.47 ± 0.08**	0.49 ± 0.09**	0.39 ± 0.02**	0.45 ± 0.04**	0.58 ± 0.09**	0.61 ± 0.21**	0.72± 0.32**
Nitrate (ppm)	5.55 ± 0.44**	5.9 ± 0.48**	6.01 ± 0.51**	5.81 ± 0.46**	6.15 ± 0.54**	6.36 ± 0.57**	7.14 ± 0.61**	7.28± 0.63**
TDS (ppm)	163 ± 5***	205 ± 7***	235 ± 9***	190 ± 6***	212 ± 4***	175 ± 3***	180 ± 7***	185 ± 4***
TSS (ppm)	130 ± 9***	235 ± 9***	209 ± 10***	156 ± 8***	182 ± 7***	162 ± 5***	172 ± 3***	177 ± 1***
TH (ppm)	126 ± 1**	190 ± 6**	152 ± 2**	172 ± 5**	136 ± 3**	148 ± 6**	156 ± 1**	144 ± 5**

Contd….

Parameters	Sampling Weeks							
	Week-9	Week-10	Week-11	Week-12	Week-13	Week-14	Week-15	Week-16
Temperature (°C)	26.73 ± 1.09***	24.63 ± 0.91***	28.03 ± 1.35***	21.8 ± 0.62***	26.23* ± 1.95***	22.4 ± 1.1***	25.66 ± 0.95***	28.84 ± 0.85***
pH (H+)	7.3 ± 0.27**	7.5 ± 0.38**	8.01 ± 0.71**	7.2 ± 0.33**	8.02 ± 0.75**	7.9 ± 0.73**	8.04 ± 0.74**	7.2 ± 0.33**
DO (mg/L)	11.2 ± 0.73*	9.9 ± 0.48*	10.5 ± 0.66*	11.5 ± 0.76*	9.72 ± 0.61*	9.81 ±0.52*	10.71 ± 0.69*	11.03 ± 0.71*
Chloride (ppm)	27 ± 3**	28 ± 2**	23 ± 1**	21 ± 2**	24 ± 3**	25 ± 5**	20 ± 1**	21 ± 3**
Nitrite (ppm)	0.71 ± 0.31**	0.59 ± 0.08**	0.64 ± 0.22**	0.42 ± 0.03**	0.74 ± 0.23 **	0.51 ± 0.04**	0.65 ± 0.33**	0.76 ± 0.37**
Nitrate (ppm)	6.42 ± 0.51**	5.31 ± 0.42**	7.23 ± 0.63 **	6.27 ± 0.54**	5.7 ± 0.43**	7.29 ± 0.65**	7.14 ± 0.66**	7.34 ± 0.61**
TDS (ppm)	165 ± 2***	194 ± 1***	210 ± 8***	221 ± 3***	229 ± 1***	234 ± 7***	125 ± 2***	219 ± 6***
TSS (ppm)	180 ± 4***	184 ± 6***	165 ± 3***	179 ± 1***	148 ± 2***	169 ± 3***	206 ± 7***	198 ± 3***
TH (ppm)	159 ± 4**	164 ± 7**	142 ± 3**	154 ± 2**	167 ± 5**	143 ± 4**	157 ± 6**	168 ± 5**

DO (Dissolved Oxygen); TDS (Total Dissolved Solids); TSS (Total Suspended Solids); TH (Total Hardness). Most of the values were statistically different from each other.*($p < 0.2$), **($p < 0.05$), ***(0.0005).

Fish Diversity

During sixteen-week research duration, a total of 14,610 fishes of about 12 species were collected from the study area. The details of the collected fishes from February, 2020 to May, 2020 is given in Table **3**. Among them, 5 species belonged to the family Cyprinidae, 2 belonged to family Bagridae and 1 species belonged to each of Cichlidae, Allidae, Siluridae, Mastacembellidae and Channidae.

For analysis of fish data, different diversity indexes were applied. Amongst them, Simpson Diversity Index (D) was highest in the 7th week (5.89), Species Richness Index was highest during the 5th week (0.45), Shanon Diversity Index (H) was highest during the 7th week (2.08), and Species evenness Index was highest during the 5th week (2.56). The details of these indexes on weekly basis are given in Table **4**.

Table 3. Fish Diversity and Population at Chashma Barrage Recorded Each Week (Total 16 weeks).

Family	Fish Species	1st wk.	2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.
Cyprinidae	*Labeo gonius*	245	311	349	289	216	225	239	301
	Labeo rohita	7	11	18	16	23	18	14	19
	Cyprinus carpio	203	238	217	264	171	340	219	382
	Hypophthalmichthys molitrix	21	27	34	24	15	18	25	15
	Catla catla	12	16	30	27	23	32	41	50
Siluridae	*Wallago attu*	39	30	52	23	44	35	43	52
Channidae	*Channa marulius*	10	14	21	13	10	12	16	23
Ailiidae	*Clupisoma garua*	35	39	46	40	38	44	49	57
Mastacembellidae	*Mastacembelus armatus*	21	26	49	22	20	31	44	53
Cichlidae	*Oreochromis niloticus*	70	74	51	46	40	56	60	72
Bagridae	*Rita rita*	49	53	62	55	49	56	59	66
	Sperata seenghala	33	46	20	35	52	29	39	19
Grand Total	--	745	885	949	854	701	896	848	1109
%age population	--	5.1	6.1	6.5	5.85	4.8	2.71	5.8	7.59

Family	Fish Species	9th wk.	10th wk.	11th wk.	12th wk.	13th wk.	14th wk.	15th wk.	16th wk.	Total
Cyprinidae	*Labeo gonius*	250	310	350	279	220	237	257	320	4398
	Labeo rohita	23	26	18	14	9	12	19	22	269
	Cyprinus carpio	379	346	297	286	300	294	283	312	4531
	Hypophthalmichthys molitrix	20	29	35	42	34	26	19	28	412
	Catla catla	61	55	48	35	29	19	16	50	544
Siluridae	*Wallago attu*	50	46	53	47	39	28	33	47	661
Channidae	*Channa marulius*	25	21	24	29	20	16	19	22	295
Ailiidae	*Clupisoma garua*	40	49	36	42	50	59	44	53	721
Mastacembellidae	*Mastacembelus armatus*	48	32	29	35	46	50	41	55	602
Cichlidae	*Oreochromis niloticus*	80	79	55	48	50	68	73	80	1002
Bagridae	*Rita rita*	26	21	18	10	22	17	23	25	611
	Sperata seenghala	24	32	44	29	36	46	39	41	564
Grand Total	--	1026	1046	1007	896	855	872	866	1055	14610
%age population	--	7.02	7.16	6.89	6.13	5.85	5.97	5.93	7.22	96.58

Table 4. Different Diversity Indexes Calculated from the Samples (Total 16 weeks).

Diversity Indexes	1st wk.	2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.	7th wk.	8th wk.
No. of Individuals	745	885	949	854	701	896	848	1109
Simpson Diversity (D)	4.91	4.67	4.86	4.46	5.63	4.49	5.89	4.76
Species Richness (S)	0.44	0.41	0.38	0.41	0.45	0.4	0.41	0.36
Shanon Diversity (H)	1.92	1.9	1.96	1.87	2.04	1.89	2.08	1.92
Evenness (H/ln(S))	2.34	2.13	2.03	2.1	2.56	2.07	2.33	1.88

Diversity Indexes	9th wk.	10th wk.	11th wk.	12th wk.	13th wk.	14th wk.	15th wk.	16th wk.	Total
No. of Individuals	1026	1046	1007	896	855	872	866	1055	14610
Simpson Diversity (D)	4.73	4.68	4.57	4.68	4.85	4.83	4.72	5.06	77.79
Species Richness (S)	0.37	0.37	0.38	0.4	0.41	0.4	0.4	0.36	6.361
Shanon Diversity (H)	1.92	1.91	1.89	1.91	1.95	1.92	1.91	1.97	33.72
Evenness (H/ln(S))	1.96	1.92	1.95	2.09	2.19	2.11	2.13	1.93	30.96

DISCUSSION

Water Quality Parameters

The primary importance was given to the temperature. Temperature variation can regulate various metabolic activities of fishes and thus, it has vital importance to study ichthyofauna diversity. The water of Chashma Barrage was close to optimum temperature range i.e. 25-30ºC. The maximum temperature was 28.84ºC while the minimum was 21.8ºC (Fig. **2**). It has also been reported previously that Chashma Barrage has characteristic annual temperature, with increased degrees in summer and decreased degrees in winter. Increase in temperature in summer has been observed to be correlated with increased parasite infestation[21].

The measured mean values of temperature were within the optimum range (25-30 ºC) which supports maximum fish growth rate, resistance to certain diseases, and tolerance under unfavorable conditions. The pH values are also supportive for fish growth. The pH of fish blood is 7.4 and it needs a pH range of 7-8.5 for maximum production. Here, the recorded mean pH value range was pH 7.2-8.05 which is suitable for optimum fish growth. An increase in pH also correlates with increased parasite infestation[21].

Similarly, oxygen concentration plays vital role in aquatic system functionality[25] as an increase or decrease in oxygen level in lakes effect many biological, chemical, and physical processes[26]. Dissolved oxygen concentration is mainly added by phytoplankton and it was found slightly higher than normal range in the present study. For the growth and survival of aquatic organisms, a 5.3 to 8.0mg/L of DO levels are satisfactory[27]. Decrease in oxygen levels below normal may restrict fish movement and limit numbers of fish and their variety in the lake's bottom waters[28].

Other than that, sediments can alter water quality and characteristics. Nitrates and nitrites are also present in Chashma Barrage water as indicated in Fig. **2**. Nitrites were not in abundance as their excessive amount is highly toxic for fish growth. As compared to nitrites, nitrates were in more abundance because they are not toxic for the fish and they are produced by the oxidation of nitrites. Previously, it has been reported that an increase nitrite concentration in the month of May was recorded up to

0.26mg/L, which indicates poor water quality. In freshwater fish pond, the tolerable nitrite level is 0.001mg/L to 0.004mg/L[29]. Chloride ions in water maintain osmotic balance within the cells of fish. All these parameters were not always at constant rate and their concentrations fluctuate with the change in environmental factors like temperature and turbidity.

However, water hardness causes stress and osmotic shock which can result in death. Total dissolved solids and total suspended solids were in favorable range and they do not cause much turbidity that hinders light penetration and oxygen availability to the fishes. Figure **3** shows the minimum, maximum and mean values of all these parameters that account for water turbidity.

Diversity of Fish Species

This research was based on a 16-week study which was conducted from February, 2020 to May 2020. During the research period, 12 fish species were identified from Chashma Barrage every week and a total of 14,610 species were collected as indicated in Table **3**. With respect to percent values, 69% of entire sample population belonged to the family Cyprinidae (five species), 8.04% of the entire sample population belonged to family Bagridae

(two species), 6.85% of entire sample population belonged to each of Cichlidae (one species), 4.92% of entire sample population was of Allidae family, 4.52% of entire sample population was of Siluridae family, 4.11% of entire sample population was of Mastacembellidae family and 2.02% of entire sample population belonged to Channidae family as shown in Fig. **4**, hence indicating Cyprinidae family as the dominant one in Chashma Barrage.

Diversity Indexes

Simpson Diversity Index was highest during the 7th week (5.89) followed by 5th week (5.63) and 16th week (5.06), while it was minimum in 4th week (4.46). Species Richness Index was highest during the 5th week (0.45) followed by 1st week (0.44) and (0.41) in 2nd, 4th, 7th, and 13th week, respectively, and was lowest during the 6th, 12th, 14th and 15th week. Shannon Diversity Index (H) was maximum in the 7th week (2.08) and minimum in 4th week (1.87). Maximum value of Evenness Index was recorded highest in the 5th week (2.56) and lowest in the 8th week (1.88). All the mentioned values are given in Table **4**. Shannon Diversity Index values resided between 0-1.
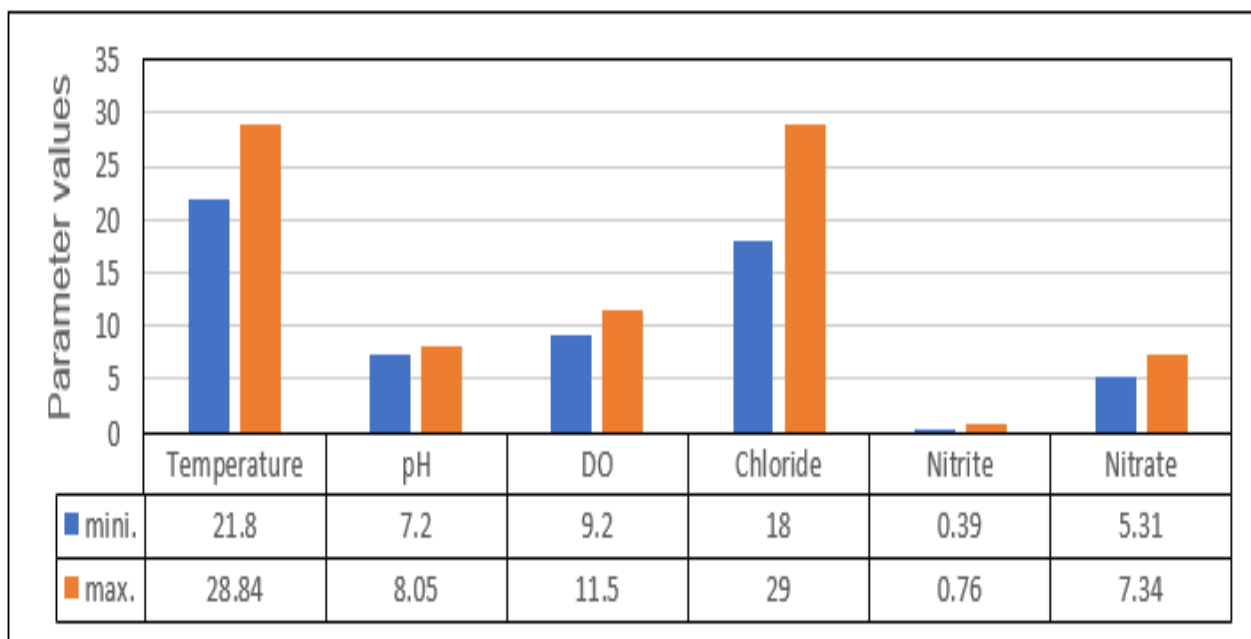

Figure 2. WQ parameters; Temp, pH, DO, Cl-, NO$_2^-$, NO$_3^-$ (mean range from minimum-maximum).
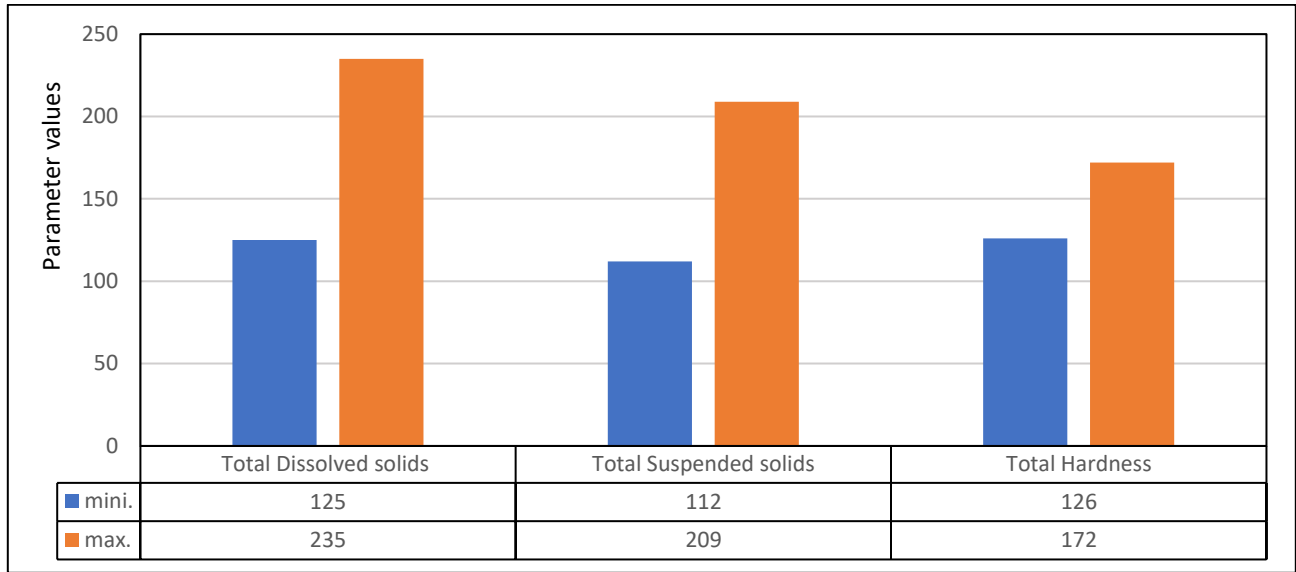
Figure 3. WQ parameters; TDS, TSS, TH (mean range from minimum-maximum).

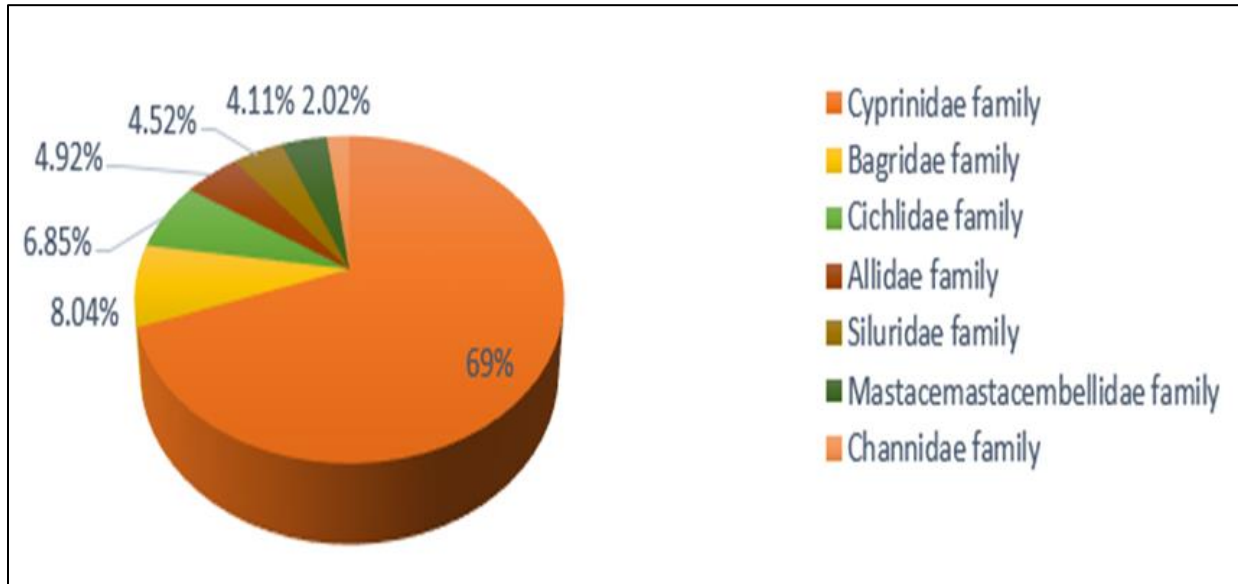|	Total Dissolved solids	Total Suspended solids	Total Hardness
mini.	125	112	126
max.	235	209	172

Figure 4. Family wise catch composition of fish diversity at Chashma Barrage from February, 2020 to May, 2020.

CONCLUSION

The Water quality parameters of Chashma Barrage were highly suitable for fish diversity. The temperature was optimum to support fish growth. Cyprinidae family was dominant having 5 species. Similarly, results of diversity indices showed maximum fish diversity along with significant specie richness and evenness in Chashma Barrage. In future, this research would be useful to study further ichthyofauna diversity as it changes with the WQ parameters. The water characteristics are prone to changings due to anthropogenic activities and fluctuating environmental conditions. Chashma Barrage supports a variety of fish species with maximum richness, proper management and public awareness would optimize fish growth at a rapid rate.

CONFLICTS OF INTEREST

None.

FUNDING SOURCE

None.

ACKNOWLEDGMENTS

LIST OF ABBREVIATIONS

AOAC	Analysis of the Association of Chemists
DO	Dissolved Oxygen
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TH	Total Hardness
Wk.	Week

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