Pakistan J. Zool., vol. 54(6), pp 2791-2799, 2022 DOI: https://dx.doi.org/10.17582/journal.pjz/20211018201037

Fish Diversity and Water Quality in Different Zones of Upper River Indus Basin, Pakistan

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ABSTRACT

Water quality assessment and freshwater fish diversity of cold-water Indus River, along a 400-kilometer stretch from Raikot (upstream) to Tarbela (downstream) was examined during 2019. The river channel was divided into five zones such as Raikot-Basha, Basha-Dasu, Dasu-Pattan, Pattan-Thakot and Thakot-Tarbela. The mean water quality of study site was as follows: pH 7.32, air temperature 21.15°C, water temperature 15.9°C, dissolved oxygen (DO) 6.41 mg/L, Total Dissolved Solids (TDS) 125.62 mg/L total hardness 77.50 mg/L, alkalinity 72.17 mg/L (as $CaCO_3$) and conductivity 129.04 µs/cm. Planktonic study revealed the presence of variety of phytoplankton (n=31) and zooplankton (n=3) species in study area. In total, 37 fish species were found in the study area, with species richness rising from zone one (n =10) to zone five (n =33). Altogether, the fish diversity represents 25 genera and 13 families. To analyze the data, principal component analysis (PCA) was done by using XLSTAT and excel 2019 to study the factors affecting the water quality. The eigenvalues obtained after PCA from zone 1 to zone 5 were 5.40, 2.40, 1.90, 0.28 and <0.28, respectively. The higher eigenvalue of zone 1 suggests large dispersion of data in this region. Furthermore, the findings in the study indicate that warm water, higher conductivity, DO, high nitrate concentration, and high salinity manifested to be the best habitat conditions downstream of Thakot area. To conserve the richness and integrity of fish communities, it is recommended that instream flow evaluations to include target species that occupy flow-sensitive habitat categories.

Article Information
Received 18 October 2021
Revised 23 December 2021
Accepted 11 January 2022
Available online 04 February 2022 (early access)
Published 25 August 2022

Authors' Contribution
ZZ and ZA conceptualized the study. ZZ, RA and IZ collected the data from field. ZZ, ZA and RA analyzed the data and drafted the manuscript. ZA supervised the research.

Key words
Fish diversity, River Indus, Water quality, Conductivity, Salinity

INTRODUCTION

Freshwater ecosystem is home to many threatened species. Therefore, it is essential to understand the factors responsible for affecting these taxa and subsequently causing reduction in the species population size (Dudgeon *et al*., 2006). One of the challenges to these species is low nutrient load and water pollution, which can have both chronic and acute effects on aquatic animals (Dixit, 2015; Boyd, 2010; Hossain *et al*., 2019).

The use of biological indicators to study the quality of freshwater ecosystems is a common strategy (Joy and Death, 2004). Among these biological indicators, fish is the most sensitive and valuable indicator of water quality change (Raja *et al*., 2015; Nazeer *et al*., 2016). Moreover, fish diversity evaluation, as well as the investigation of their connection, might be a low-cost yet effective water quality assessment method (Qadir and Malik, 2009). Also, Planktons are consumed by all freshwater fish species at some point in their lives, and their variety and abundance may be related to fish diversity (Mummert and Drenner, 1986). Additionally, Planktons also serve a significant function in aquatic ecosystems; They not only turn plant material into animal food, but they are also a vital component of fish food and may be used to assess the health of waterbodies (Verma and Munshi, 1987).

Indus River is Pakistan's largest river with total length of 3,180km while the area of basin is 1,165,000 km^2. The river originates from Tibetan Plateau, running from south, it discharges in Arabian Sea (Sobkowiak *et al*., 2020). More than 180 fish species have been found in Pakistan belonging to different classes, orders, families and genera including exotic, endemic and native species. On the basis of International Union of Conservation of Nature (IUCN) status, indigenousness, socioeconomic importance, out of these, 86 species (i.e., 8 exotic and 78 native) have been labeled as the species of special importance (Din *et al*., 2016). The fish diversity of lower Indus Basin was studied by Hussain (1973), while Ahmad *et al*. (1976) published the check list containing Indus River's ichthyofauna. According to Abro *et al*. (2020), nine studies have been conducted on fish fauna from various parts of Indus River including (Urooj *et al*., 2011; Mirza *et al*., 2014; Saeed

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0030-9923/2022/0006-2791 $ 9.00/0

et al., 2013; Muhammad *et al*., 2017; Navid *et al*., 2017; Sheikh *et al*., 2017). However, the relationship between fish diversity, nutrient load and heavy metal concentration are not too well studied in this particular area.

Based on the significance of the area in question, the Indus River Basin, and fresh water ecosystems, it is critical to analyse the factors involving water quality, nutrients, sediment load, and fish variety in the Indus River Basin. The primary goal of this study was to better understand the variation in water quality and fish diversity in the Indus cold-water environment.

MATERIALS AND METHODS

Study area

The study area for current research extended from Raikot Bridge to Tarbela Reservoir (Fig. 1). The area was divided into five zones, such as Raikot to Basha (zone 1), Basha to Dasu (zone 2), Dasu to Pattan (zone 3), Pattan to Thakot (zone 4) and Thakot to Tarbela (zone 5).

Thirty tributaries were chosen from around fifty on the left and right bank of the Indus River (six for each zone), and one sample was obtained from tributary and one from the Indus River (10m downstream of selected tributaries). The study took place over the course of four seasons in 2019. In each season, ten days were spent in the study area. Physico-chemical and biological data were acquired during the field survey for this investigation. In addition to that, water samples were also collected to determine the nutrient load and the levels of heavy metals.

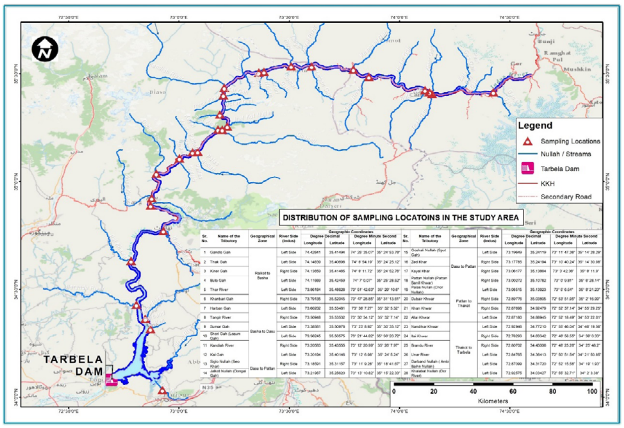

Fig. 1. Map of sampling sites in study area from Raikot to Tarbela Reservoir.

Physico-chemical parameters

Water pH, temperature, Dissolved Oxygen (DO), water depth, color, hardness, sediments, Carbon dioxide (CO_2), Nitrate (NO_3), conductivity and alkalinity were determined with the help of Quick Analysis Kit. Environmental kit was used to determine the titration values of CO_2, alkalinity, hardness, nitrate and other nutrient content. Temperature was measured by digital thermometer while pH of water was measured by digital pH meter (HANNA HI 8314 Membrane pH Meter).

Fish sampling

Local fishermen were hired to collect the fish samples. Gillnets were used to capture fish from main river stream and other tributaries coming from left and right bank. Moreover, Formalin solution (5-10%) was used to preserve the fish samples immediately after capturing for identification purpose. Furthermore, weight and length of fish samples were also recorded.

Phytoplankton and zooplanktons

In the same way, plankton nets with different mesh sizes such as 40mm, 60mm and 80mm were utilized for plankton collection. In order to catch the macrophytes, stones were also turned up and down. Both floating and submerged vegetation were also collected for identification.

Principal component analysis (PCA)

PCA is a linear combination of different factors which is applied to normalize factors for the purpose of comparison. It is further used to find the factors of pollutants affecting the sample and ultimately offers certain explanation for the most valuable component. XLSTAT (14-day trial) and Excel 2019 were used for various analyses in this manuscript.

RESULTS

The current study was carried out to investigate the fish diversity and water quality including nutrient load, heavy metals along with other physiochemical parameters in a 400km stretch of Indus River from Raikot Bridge to Tarbela Reservoir.

The study area was found to be home to a total of 37 species (Table I), including native (27), exotic/introduced (6), and endemic (4) species. Cypriniformes was the most abundant order in the study area with 21 species, followed by Siluriformes with seven species. The fact was also established that the species richness increased from upstream to downstream. Species richness was maximum (33) in Thakot to Tarbela. There were five species that were found exclusively in this region including Nile Tilapia (*Oreochromis niloticus*), silver hatchet chela (*Chela cachius*), two spot barb (*Puntius ticto*), stocki Catfish (*Glyptothorax stocki*), striped gourami (*Colisa fasciata*). The species richness from zone one to zone four was 10, 13, 18 and 29, respectively.

Table I. Fish diversity of study area.

Order/ family	Species (Common name)	Zones (fish presence)					Occurrence
		1	2	3	4	5	
Cichliformes							
Cichlidae	1. *Oreochromis niloticus* (Nile Tilapia)	-	-	-	-	+	Introduced
Cyprinidae	2. *Barilius pakistanicus* (Barila)	-	+	+	+	+	Native
	3. *B. vagra* (Gheur, Korang)	+	+	+	+	+	Native
	4.*Catla catla* (Thaila)	-	-	-	+	+	Native
	5. *Cirrhinus mrigala* (Mrigal carp)	-	-	-	+	+	Native
	6. *Cyprinus carpio* (Common carp)	-	-	-	+	+	Introduced
	7. *Gara gotyla* (Sucker head)	+	+	+	+	+	Native
	8. *Hypophthalmichthys molitrix* (Silver carp)	-	-	+	+	+	Introduced
	9. *H. nobilis* (Bighead carp)	-	-	+	+	+	Endemic
	10. *Labeo caeruleus* (blue rohu)	-	-	-	+	+	Introduced
	11. *L. rohita* (Rohu)	-	-	-	+	+	Native
	12. *Puntius sophore* (Pool barb)	-	-	-	+	+	Introduced
	13. *P. terio* (Onespot barb)	-	-	+	+	+	Native
	14. *Schizothorax esocinus* (Chirruh snow trout)	+	+	+	+	+	Native
	15. *S. labiatus* (Kunar snow trout)	+	+	+	+	-	Native
	16. *S. plagiostomus* (Snow trout)	+	+	+	+	-	Native
	17. *Tor macrolepis* (Indus mahseer)	-	-	+	+	+	Native
	18. *T. putitora* (Golden mahseer)	-	-	-	+	+	Native
Nemacheilidae	19. *Triplophysa hazaraensis* (Hazara loach)	-	+	+	+	+	Endemic
Perciformes							
Channidae	20. *Channa gachua* (Dwarf snakehead)	-	-	-	+	+	Native
Cichliformes							
Cichlidae	21. *Oreochromis mossambicus* (Mozambique Tilapia)	-	+	+	+	+	Introduced
Siluriformes							
Schilbeidae	22. *Clupisoma garua* (Chel-lee)	+	+	+	+	+	Native
	23. *C. naziri* (Naziri Bachcha)	+	+	+	+	+	Native
Bagridae	24. *Mystus bleekeri* (Bleeker's Mystus)	-	-	+	+	+	Native
	25. *Rita rita* (Bengal catfish)	-	-	+	+	+	Native
	26. *Sperata sarwari* (Singhara)	+	+	+	-	-	Native
	27. *S. seenghala* (Tengara)	+	+	-	-	-	Native
Siluridae	28. *Wallago attu* (Helicopter catfish)	-	-	-	+	+	Native
Sisoridae	29. *Glyptothorax punjabensis* (Punjab catfish)	+	+	+	+	+	Endemic
	30. *Glyptosternum reticulum* (Turkestan catfish)	-	-	-	-	+	Native
Synbranchiformes							
Mastacembelidae	31. *Mastacembelus armatus* (Spiny eel)	-	-	-	+	+	Native
Cypriniformes							
Cyprinidae	32. *Chela cachius* (Silver hatchet chela)	-	-	-	-	+	Native
	33. *Puntius ticto* (Two spot barb)	-	-	-	-	+	Native
Botiidae	34. *Botia birdi* (Indian loaches)	-	-	-	-	+	Native
Siluriformes							
Sisoridae	35. *Glyptothorax stocki* (Stocki catfish)	-	-	-	-	+	Endemic
Anabantiformes							
Osphronemidae	36. *Colisa fasciata* (Striped gourami)	-	-	-	-	+	Native
Osteoglossiformes							
Notopteridae	37. *Notopterus notopterus* (Bronze featherback)	-	-	-	-	+	Native

In the current investigation, the maximum mean value of pH (7.34) was recorded in the area between Pattan to Thakot. The mean of DO ranged from 6.0± 2.21 (Dasu to Pattan) to 7.2±3.73 mg/L (Thakot to Tarbela). Naturally, with an increasing tendency in electrical conductivity, the region between Thakot to Tarbela has the highest value (181.89 ± 22.59 s/cm) and the lowest (98± 8.40 s/cm). From Basha to Dasu, the salinity reached a maximum mean of 105± 9.15mg/L. The average of turbidity was likewise at its highest in the Basha to Dasu region, reaching 14.24± 3.67 NTU, while lowest from Dasu to Pattan with mean concentration 3.552±1.29 NTU. Similarly, the maximum concentration of ammonia was found in this zone, with a mean value of 0.900± 0.38 mg/L. In the same way, it is essential to measure total dissolved solids (TDS) in order to assess water quality. TDS increased in value as the same moved from upstream (Raikot) to downstream (Tarbela), reaching a maximum of 146.86±3.41 mg/L. Furthermore, the highest concentrations of carbon dioxide and iron were found in the Raikot to Basha region, with 17.03±1.51 and 2.168±8.27 mg/L of carbon dioxide and iron, respectively. Nitrate concentrations increased from zone one to zone five, with the highest concentration (24.11±6.18 mg/L) occurring in the Thakot to Tarbela region and the lowest concentration (7.68±3.54 mg/L) occurring in the Raikot to Basha region (Table II). Figure 2 shows that almost all water quality parameters had an increasing trend from zone 1 to zone 5.

Principal component analysis

According to PCA, the factor loadings (FL) can be explained and classified into strong, moderate and weak. If FL is more than 0.75 then it is classified as strong while if FL is between 0.75 and 0.50 then it is moderate. FL is classified as weak if it is between 0.50 and 0.30 (Shaw, 2009). The factor loadings for studied water quality parameters are presented in Table III.

The variance corresponding to PCA-1 was 54.04% with strong positive loadings (>0.8) by electrical conductivity, salinity, total dissolved solids (TDS), total hardness, alkalinity and lead. Furthermore, moderate negative loading of TDS and strong negative loading of iron in PCA-2 suggested their negative correlation with the pollution sources. In all PCs, the positive loading of lead and negative loadings of pH are common.

Figure 3 displays the quality parameters in two PCAs and reveals that PCA-1 has strong negative loading on pH, DO, turbidity and lead, moderate loading on total hardness, total alkalinity, and salinity while strong positive loadings on TDS and conductivity.

Table II. Physico-chemical parameters (Mean±SD) of different zones study area.

Parameters	Raikot to Basha	Basha to Dasu	Dasu to Pattan	Pattan to Thakot	Thakot to Tarbela	River Indus
Temperature (°C)	14.30±7.65	14.04±7.29	15.33±8.47	16.70±9.16	**19.56±10.44**	15.99±2.25
pH	7.28±2.95	7.28±3.12	7.39±1.17	**7.34±1.81**	7.31±2.66	7.32±0.04
Electrical conductivity (µs/cm)	98.81±8.40	111.02±2.15	117.97±4.35	135.50±6.52	**181.89±22.59**	129.04±32.39
Salinity (mg/L)	77.08±7.58	86.02±9.45	63.02±4.72	82.46±5.20	**105.72±9.15**	82.86±15.49
T.D.S (mg/L)	140.34±6.45	106.45±7.51	100.18±6.70	134.25±7.49	**146.86±3.41**	125.61±20.95
Turbidity (NTU)	4.71±1.09	**14.24±3.67**	3.55±1.29	7.12±.49	9.01±3.98	7.73±4.21
Total. Hardness (mg/L)	76.20±5.82	60.53±2.11	62.42±3.58	92.21±4.03	**96.13±5.41**	77.50±16.43
Total Alkalinity (mg/L)	68.39±7.60	62.05±2.99	58.17±2.50	79.86±3.13	**92.33±8.78**	72.16±13.94
Ammonia (mg/L)	0.50±0.13	0.68±0.28	0.63±0.27	0.61±0.24	**0.90±0.38**	0.66±0.14
Carbon dioxide (mg/L)	**17.03±1.51**	12.04±8.18	10.02±4.24	9.20±3.03	14.69±6.84	12.60±3.25
Phosphate (mg/L	15.52±1.54	**16.47±1.15**	13.87±3.93	13.52±13.90	14.26±3.68	14.73±1.23
Nitrate (mg/L)	7.68±3.54	8.32±4.15	8.76±5.57	12.77±11.56	**24.11±6.18**	12.33±6.87
Iron (mg/L)	**2.16±8.27**	0.85±0.96	0.63±0.44	0.68±0.60	0.52±0.26	0.97±0.67
Lead (mg/L)	0.03±0.03	0.04±0.04	0.05±0.05	0.04±0.05	**0.06±0.05**	0.04±0.01
DO	6.63±3.13	5.56±0.53	6.00±2.21	6.64±1.42	**7.21±3.73**	6.41±0.63
NO_2	0.01±0.13	0.01±0.04	0.14±0.27	0.11±0.74	**0.30±0.17**	0.11±0.11
Air Temp (°C)	13.21±2.48	17.14±3.71	21.47±3.97	24.81±13.52	**29.14±17.63**	21.15±6.25
Seechi disc. (cm)	**75.74±9.00**	74.55±6.42	67.00±4.72	64.84±8.39	44.45±9.37	65.31±12.57

Note: Bold figure is the maximum mean value.

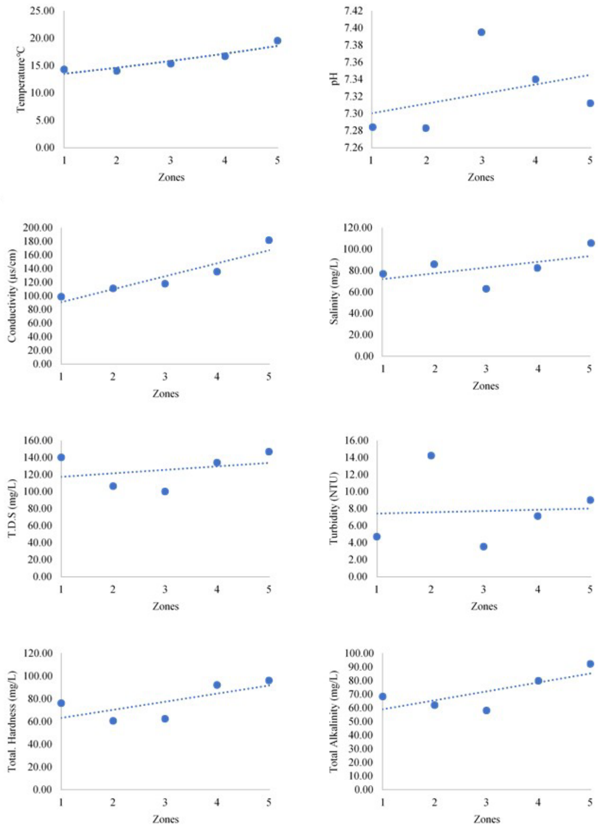

Fig. 2. Trend lines of water quality parameters from zone 1 to zone 5.

Table III. Factor loadings of water quality parameters.

	PCA-1	PCA-2	PCA-3
pH	-0.161	**-0.589**	-0.410
Conductivity (µs/cm)	**0.911**	0.369	0.166
Salinity (mg/L)	**0.843**	-0.232	0.475
T.D.S (mg/L)	**0.811**	**-0.596**	-0.310
Turbidity (NTU)	0.089	-0.220	**0.967**
Total Hardness (mg/L)	**0.927**	-0.094	-0.238
Total Alkalinity (mg/L)	**0.992**	-0.074	-0.006
DO (mg/L)	**-0.884**	-0.125	-0.447
Iron (mg/L)	-0.305	**-0.816**	-0.442
Lead(mg/L)	**0.676**	0.658	0.051
Eigenvalue	5.405	2.405	1.908
Variability (%)	54.048	24.053	19.078
Cumulative %	54.048	78.100	97.179

The eigenvalues obtained after PCA from zone 1 to zone 5 were 5.40, 2.40, 1.90, 0.28 and <0.28, respectively. The higher eigenvalue of zone 1 suggests large dispersion of data in this region. Bipolar plot for water quality parameters in Figure 4 indicates that Zone 5 has strong positive loading with PC-1 and is a least polluted zones having only lead as a notable pollutant while zone 1 had strong negative loading having lead with both PC-1 and PC-2.

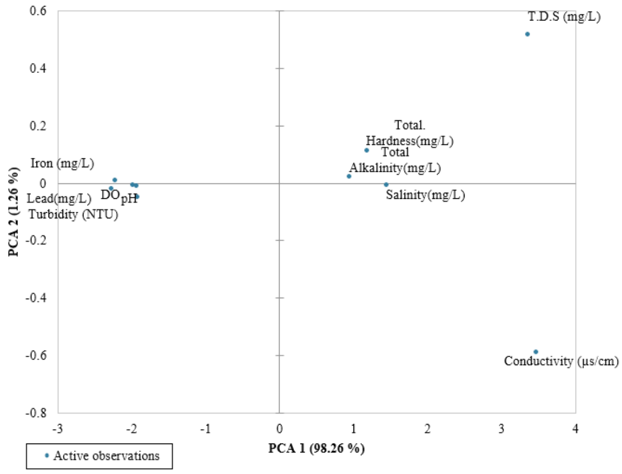

Fig. 3. PCA 1 and PCA 2 loadings of water quality parameters.

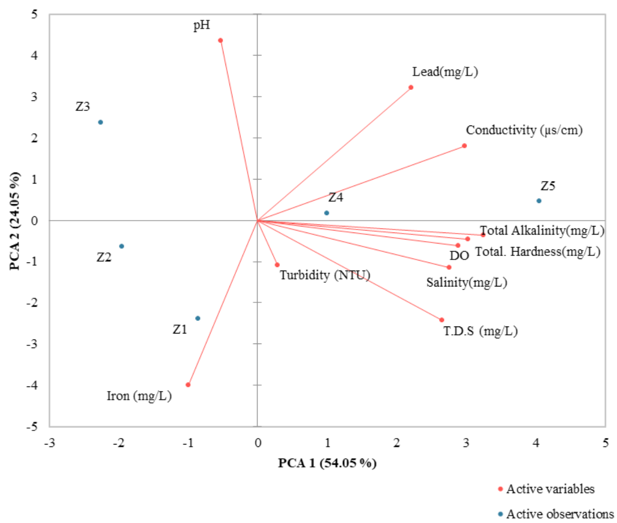

Fig. 4. Bipolar PCA Plot for water quality.

Overall, thirty-four types of planktons including 31 types of phytoplankton and three types of zooplankton were recorded from Raikot to Tarbela. These phytoplankton belonged to Chlorophyta (12 genera), Bacillariophyta (12 genera), Cyanophyta (4 genera), Euglenophyta (2 genera) and Cryptophyta (one genus). Similarly, among zooplankton, Rotifer (2 genera) and Protozoans (1 genus) were recorded. Out of 34, there were 31 types of planktons found in Raikot to Basha zone which were followed by 27 types in Basha to Dasu region. Furthermore, Pattan to Thakot region had the lowest number planktons (19) while the number increased to 29 in Thakot to Tarbela region (Table IV).

Furthermore, total five species of macroinvertebrates were recorded in the study area including: Caddisfly larvae, *Chironomus*, mosquito larvae, *Lymnaea* sp. and *Valvata* sp. These five types were present in the region Thakot to Tarbela (Table V) while only first three types were found in other aforementioned four zones of the study area.

DISCUSSION

During the current research, an increasing trend was observed in species richness from upstream to downstream and the results acquired were in agreement with (Solbe and Cooper, 1975). Maximum, (33) species were observed in Thakot to Tarbela region. According to Mirza *et al*. (2011), downstream from Thakot to Tarbela the fish diversity increases. Elevated conductivity makes this region a better habitat for fish fauna (de Carvalho, 2017) because species prefer habitat that fulfil their specific requirements (Vieira and Tejerina-Garro, 2020). Moreover, the fish diversity was highest at intermediate salinity and high nitrate concentration (Thakot to Tarbela) which indicates that the fish fauna in this region is tolerant to deteriorating water quality (Duque *et al*., 2020).

Indus Mahseer is a game fish found from Dasu to Tarbela. IUCN has declared Mahseer as endangered (Jha *et al*., 2018). Furthermore, Peter (1999) reported that due to overfishing it is becoming very rare and it might disappear due to submergence of its spawning ground. Similar observation was made in the current study as only a few specimens of Mahseer were found in the study area. In addition to that, various developmental projects are planned in the study area including Thakot hydropower project (WAPDA, 2021) which may cause an increase its vulnerability. *Schizothorax* was abundant in study area and according to Khan *et al*. (2018), this species in widely distributed in Indus River and also a major food source for the residents and the results were in accordance to the current study. Furthermore, Ali *et al*. (1980) and Peter (1999) also observed Twospot Barb, Indian Loaches, Striped Gourami, Stocki Catfish and Bronze featherback in and near Tarbela. Among exotic fishes, Turkestan catfish and common carp were also recorded by Akhtar (1991) in the current study area. Gebilion catla, silver carp, common carp, mori, Hazara loach *Schizothorax* and Mahseer were also reported by Rafique and Khan (2012) in the study area.

Table IV. Phytoplankton and zooplankton of study area.

Plankton	Raikot to Basha	Basha to Dasu	Dasu to Pattan	Pattan to Thakot	Thakot to Tarbela
Phytoplankton					
Cyanophyta					
Microcyctis	+	+	+	+	+
Merismopedia	+	+	-	-	+
Nostoc	+	+	-	-	+
Rivularia	-	+	+	-	+
Chlorophyta					
Oedogonium	+	+	+	+	+
Coelastrium	+	+	-	-	-
Chlaymydomonas	+	+	+	+	+
Volvox	+	+	+	+	+
Closterium	+	-	+	-	+
Tetraedron	-	+	-	-	+
Dictyosphaerium	+	+	+	+	+
Ankistrodesmus	+	+	+	-	-
Pyramimonas	-	+	-	-	+
Chaetophora	+	-	-	-	+
Chrysophyta					
Synura	+	-	-	+	-
Bacillariophyta					
Diatom	+	+	+	+	+
Navicula	+	+	+	+	+
Pleurosigma	-	-	-	-	-
Fragillaria	+	-	-	-	+
Cymbella	+	+	+	+	+
Achnanthes	+	+	+	+	+
Cynedra	+	+	-	+	+
Ghomphonema	+	-	-	+	+
Hannea	+	+	+	-	+
Rhoicosphenia	+	+	-	+	+
Cyclotella	+	-	+	+	+
Achnanthedium	+	+	+	-	+
Craticula	+	-	-	-	-
Cryptophyta					
Rhodomonas	+	+	+	+	+
Euglenophyta					
Euglena	+	+	+	+	+
Trachelomonas	+	+	-	-	-
Zooplanktons					
Rotifer	+	+	+	+	+
Moina	+	+	+	-	+
Daphnia	+	+	+	+	+
Protozoans					
Paramecium	+	+	+	+	+

Table V. Macroinvertebrates in different zones of study area.

Macroin-vertebrates	Raikot to Basha	Basha to Dasu	Dasu to Pattan	Pattan to Thakot	Thakot to Tarbela
Caddisfly larvae	186	154	73	86	62
Chironomus	626	414	144	103	105
Mosquito larvae	246	121	21	27	124
Lymnaea species	0	0	0	0	9
Valvata species	0	0	0	0	14

Water quality, pH, temperature, DO and conductivity directly impact the species richness (Oberdorff *et al*., 2001). The oxygen consumption during fermentation at higher rate results in production of organic acid and ammonia that can lead to decreased pH. The negative loading of pH and strong positive loading of lead show in in Table III are also in accordance with this argument. Similar findings were reported by Baluch and Hashmi (2019) in upper Indus Basin.

In the present study, maximum mean value of pH (7.34) was in the zone of Dasu to Pattan. The DO values of each zone were within the DO limits recommended by United Nations Economic Commission of Europe (UNECE) for freshwater quality to maintain the aquatic life (UNECE, 1994). The electrical conductivity had an increasing trend with maximum mean value (181.89 ± 22.59s/cm) value in the region of Thakot to Tarbela. Conductivity, TDS, total hardness, total alkalinity, nitrate, DO and species richness had increasing trend from upstream to downstream and similar conclusions were made by Solbe and Cooper (1975) during the research on freshwater fisheries of River Churnet. Additionally, turbidity and electrical conductivity play a significant role in species diversity and different species prefer variable habitats due to variation in their ecological requirements (Huang *et al*., 2019). Total alkalinity, TDS, DO and hardness in the region of Pattan to Thakot were 92.33±8.78, 146.86±3.41, 7.21±3.73 and 96.133±5.41 mg/L, respectively, in the current research but according to the study conducted by Usman *et al*. (2019) the five-year maximum mean values for these parameters were recorded as 175, 179, 7.6 and 145 mg/L, respectively. With reference to planktons, the following Chlorophyta and Bacillariophyta were the most abundant and the results were in accordance with the study conducted by Ali *et al*. (2003).

Figure 3 showing the quality parameters in two PCs reveals that PCA-1 has strong negative loading on pH, DO, Lead and Turbidity, moderate loading on total hardness, total alkalinity, and salinity while strong positive loadings on TDS and conductivity. The results revealed that PCA-1 is affected by organic as well as inorganic pollution due to soil erosion The strong negative loading of PCA-1 with pH and DO is consistent with the results in published literature (Baluch and Hashmi, 2019). Furthermore, negative loadings of DO suggests the presence of organic acid and the results are in consistence with previous research (Chounlamany *et al*., 2017). Results further confirms that the major source of pollution in study area are either heavy metals such as lead or other anthropogenic pollution sources (Baluch and Hashmi, 2019).

Understanding spatial fish assemblages in relation to their water quality is critical for fish assemblage management and conservation. The findings of this study will aid future efforts to forecast the effects of hydropower projects on the aquatic fish assemblages of the River Indus. In the future, it will be critical to regulate the massive untreated domestic and industrial loads to surface water prior to discharge, as well as to enforce rules and regulations and impose severe penalties on offenders.

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Abro, N.A., Waryani, B., Narejo, N.T., Ferrando, S., Abro, S.A., Abbasi, A.R., Lashari, P.K., Laghari, M.Y., Jamali, G.Q., Naz, G. and Hussain, M., 2020. Diversity of freshwater fish in the lower reach of Indus River, Sindh province section, Pakistan. *Egypt. J. Aquat. Biologia. Fish.*, **24**: 243-265. https://doi.org/10.21608/ejabf.2020.111114

Ahmad, M.F., Khan, S.A. and Mirza, M.R., 1976. A checklist of the freshwater fishes of Indus Plain, Pakistan. *Biologia Pak.,* **22**: 229-295.

Akhtar, N., 1991. *The Northern Areas (Pakistan). Fisheries profile, feasible sites for trout culture and an overall sectoral development perspective*. Report Project, PAK/91/008. Rome: FAO. pp. 29.

Ali, M., Salam, A., Jamshaid, S. and Zahra, T., 2003. Studies on biodiversity in relation to seasonal variations in water of river Indus at Ghazi Ghatt, Punjab, Pakistan. *Pak. J. biol. Sci.*, **6**: 1840-1844. https://doi.org/10.3923/pjbs.2003.1840.1844

Ali, S.R., Ahmad, M., Ansari, M.A.S. and Mirza, M.R., 1980. Hydrobiological studies of the Indus River and its tributaries above and below Tarbela Dam.

Pak. J. biol. Sci., **2**: 15-30.

Baluch, M.A. and Hashmi, H.N., 2019. Investigating the impact of anthropogenic and natural sources of pollution on quality of water in Upper Indus Basin (UIB) by using multivariate statistical analysis. *J. Chem*., **2019**: 13. https://doi.org/10.1155/2019/4307251

Boyd, RS., 2010. Heavy metal pollutants and chemical ecology: Exploring new frontiers. *J. chem. Ecol.,* **36**: 46-58. https://doi.org/10.1007/s10886-009-9730-5

Chounlamany, V., Tanchuling, M.A. and Inoue, T., 2017. Spatial and temporal variation of water quality of a segment of Marikina River using multivariate statistical methods. *Water Sci. Technol.,* **76**: 1510-1522. https://doi.org/10.2166/wst.2017.279

de Carvalho, D.R., Leal, C.G., Junqueira, N.T., de Castro, M.A., Fagundes, D.C., Alves, C.B., Hughes, R.M. and Pompeu, P.S., 2017. A fish-based multimetric index for Brazilian savanna streams. *Ecol. Indic.,* **77**: 386-396. https://doi.org/10.1016/j.ecolind.2017.02.032

Din, A., Saeed, K., Akhtar, N., Khan, A., Rafique, N. and Khan, J., 2016. Exploring the fish fauna of River Chamla District Buner Khyber Pakhtunkhwa, Pakistan. *Acad. J. Sci. Res.,* **4**: 215-219.

Dixit, R., Malaviya, D., Pandiyan, K., Singh, U.B., Sahu, A., Shukla, R., Singh, B.P., Rai, J.P., Sharma, P.K., Lade, H. and Paul, D., 2015. Bioremediation of heavy metals from soil and aquatic environment: An overview of principles and criteria of fundamental processes. *Sustainability,* **2**: 2189-2212. https://doi.org/10.3390/su7022189

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.H., Soto, D., Stiassny, M.L. and Sullivan, C.A., 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. *Biol. Rev.,* **81**: 163-182. https://doi.org/10.1017/S1464793105006950

Duque, G., Gamboa-García, D.E., Molina, A. and Cogua, P., 2020. Effect of water quality variation on fish assemblages in an anthropogenically impacted tropical estuary, Colombian Pacific. *Environ. Sci. Pollut. Res.,* **27**: 25740-25753. https://doi.org/10.1007/s11356-020-08971-2

Hossain, M., Arhonditsis, G.B., Hoyle, J.A., Randall, R.G. and Koops, M.A., 2019. Nutrient management and structural shifts in fish assemblages: lessons learned from an Area of Concern in Lake Ontario. *Freshw. Biol.*, **64**: 967-983. https://doi.org/10.1111/fwb.13278

Huang, J., Huang, L., Wu, Z., Mo, Y., Zou, Q., Wu, N. and Chen, Z., 2019. Correlation of fish assemblages with habitat and environmental variables in a headwater stream section of Lijiang River, China. *Sustainability*, **11**: 1135. https://doi.org/10.3390/su11041135

Hussain, Z., 1973. Fish and fisheries of the lower Indus basin (1966-67), *Agric. Pak.*, **24**: 170-188.

Jha, B.R., Rayamajhi, A., Dahanukar, N., Harrison, A. and Pinder, A., 2018. *Tor putitora*. The IUCN red list of threatened species 2018. available from: https://www.researchgate.net/publication/329626007_Tor_putitora_The_IUCN_Red_List_of_Threatened_Species [accessed Jun 24 2021].

Joy, M.K. and Death, R.G., 2004. Application of the index of biotic integrity methodology to New Zealand freshwater fish communities. *Environ. Manage.,* **34**: 415-428. https://doi.org/10.1007/s00267-004-0083-0

Khan, M.Q., Anjum, M.Z., Akhter, S., Khattak, I. and Ali, A., 2018. Diet composition and seasonal fluctuations in the feeding habit of snow barbel (*Schizothorax plagiostomus*) in River Indus, Pakistan. *Acta Sci. Vet.,* **46**: 8. https://doi.org/10.22456/1679-9216.82439

Mirza, M.R. and Mirza, Z.S., 2014. Longitudinal zonation in the fish fauna of the Indus River in Pakistan. *Biologia Pak.*, **60**: 149–152.

Mirza, Z.S., Mirza, M.R., Mirza, M.A. and Sulehria, A.Q., 2011. Ichthyofaunal diversity of the river Jhelum, Pakistan. *Biology,* **57**: 23-32.

Muhammad, H., Iqbal, Z. and Saleemi, S., 2017. Diversity and distribution of fish fauna of Indus River at Taunsa Barrage in Punjab, Pakistan. *Pakistan J. Zool.,* **49**: 149-154. https://doi.org/10.17582/journal.pjz/2017.49.1.149.154

Mummert, J.R. and Drenner, R.W., 1986. Effect of fish size on the filtering efficiency and selective particle ingestion of a filter-feeding clupeid. *Trans. Am. Fish. Soc.,* **115**: 522-528. https://doi.org/10.1577/1548-8659(1986)115<522:EOFSOT>2.0.CO;2

Navid, M., Rehman, H.U., Saeed, K., Haseeb, A. and Akhtar, N., 2017. The diversity of fish fauna of River Etai District Shangla KP, Pakistan. *Int. J. Pure appl. Zool.*, **5**: 78-84.

Nazeer, S., Hashmi, M.Z. and Malik, R.N., 2016. Spatial and seasonal dynamics of fish assemblage along river Soan, Pakistan and its relationship with environmental conditions. *Ecol. Indic.*, **69**: 780-791. https://doi.org/10.1016/j.ecolind.2016.05.034

Oberdorff, T., Hugueny, B. and Vigneron, T., 2001. Is assemblage variability related to environmental variability? An answer for riverine fish. *Oikos,* **93**: 419–428. https://doi.org/10.1034/j.1600-0706.2001.930307.x

Peter, T., 1999. Coldwater fish and fisheries in Pakistan. FAO Fisheries, Rome. *Tech. Pap.,* **385**: 122-137.

Qadir, A. and Malik, R.N., 2009. Assessment of an index of biological integrity (IBI) to quantify the quality of two tributaries of river Chenab, Sialkot, Pakistan. *Hydrobiologia*, **621**: 127-153. https://doi.org/10.1007/s10750-008-9637-0

Rafique, M. and Khan, N.U.H., 2012. Distribution and status of significant freshwater fishes of Pakistan. *Rec. Zool. Surv. Pak.,* **21**: 90-95.

Raja, M., Ramkumar, R., Kavitha, M. and Perumal, P., 2015. Distribution pattern, threatened status and conservation measures of fishes with relation to water quality and habitat characteristics of bhavanisagar reservoir, Tamil Nadu. *Int. J. Fish. Aquat. Stud.,* **2**: 11-18.

Saeed, K., Khan, S. and Haq, F., 2013. Diversity and population status of fish fauna of river Barandu district Buner Khyber Pakhtunkhwa Province Pakistan. *J. Biodivers. environ. Sci.,* **3**: 83-88.

Shaw, P.J., 2009. *Multivariate statistics for the environmental sciences*. Wiley, Hoboken, NJ, USA.

Sheikh, M., Laghari, M.Y., Lashari, P.K., Khooharo, A.R. and Narejo, N.T., 2017. Current status of three major carps (*Labeo rohita, Cirrhinus mrigala* and *Catla catla*) in the downstream Indus River, Sindh. *J. Fish. Aquac.,* **8**: 222.

Sobkowiak, L., Perz, A., Wrzesiński, D., and Faiz, M.A., 2020. Estimation of the river flow synchronicity in the upper Indus River Basin using Copula functions. *Sustainability,* **12**: 5122. https://doi.org/10.3390/su12125122

Solbe, J.F. and Cooper, V.A., 1975. *Progress report on study of relations between water quality and fish populations in the River Churnet*, *N Staffs*. WRc Tech. Memo., TM, pp. 113.

UNECE, 1994. Standard statistical classification of surface freshwater quality for the maintenance of aquatic life. In: *Readings in international environment statistics*. United Nations Economic Commission for Europe, 1994.

Urooj, N., Sahato, G.A., Lashari, K.H., Korai, A.L., Palh, Z.A. and Naqvi, H.S., 2011. Ichthyodiversity of River Indus, at Jamshoro District, Sindh. *Sindh Univ. Res. J. (Sci. Ser.),* **43**: 13-18.

Usman, K., Rehman, H.U., Ullah, W., Naseem, M., Babar, M.A., Asif, M., Ullah, E., Arif, M., Ayub, M., Tariq, M. and Pervaiz, K., 2019. Heavy metal investigation in River Siranat Khaki site Khyber Pakhtunkhwa Pakistan. *J. Biodiv. environ. Sci.,* **14**: 97-104. https://doi.org/10.31221/osf.io/zpequ

Verma, P.K. and Munshi, D., 1987. Plankton community structure of Badua reservoir, Bhagalpur (India). *Trop. Ecol.,* **28**: 200–207.

Vieira, T.B. and Tejerina-Garro, F.L., 2020. Relationships between environmental conditions and fish assemblages in tropical savanna headwater streams. *Sci. Rep.,* **10**: 1-2. https://doi.org/10.1038/s41598-020-59207-9

WAPDA, 2021. *Water and power development authority*. http://www.wapda.gov.pk/index.php/projects/hydro-power/future/thakot (Assessed on August 31, 2021).