Diversity and community composition of ichthyofauna at Konhaye Stream, district Dir Lower, Pakistan

Article *in* Iranian Journal of Fisheries Sciences · September 2018

DOI: 10.22092/ijfs.2018.119811.

6 authors, including:

Sana Ullah
Nanjing University
38 PUBLICATIONS 205 CITATIONS
SEE PROFILE

Zaigham Hasan
University of Peshawar
24 PUBLICATIONS 116 CITATIONS
SEE PROFILE

Zhongqiu Li
Nanjing University
47 PUBLICATIONS 304 CITATIONS
SEE PROFILE

Amina Zuberi
Quaid-i-Azam University
46 PUBLICATIONS 170 CITATIONS
SEE PROFILE

Iranian Journal of Fisheries Sciences
DOI: 10.22092/ijfs.2018.119811.

Diversity and community composition of ichthyofauna at Konhaye Stream, district Dir Lower, Pakistan

Ullah S.[1,2*]; Hasan Z.[2]; Li Z.[1]; Zuberi A.[3]; Zorriehzahra M.J.[4]; Nabi G.[5]

Received: October 2017 Accepted: September 2018

Abstract

This study was undertaken to investigate the diversity, abundance ratio, and distribution of the fish species and to record the water quality of Konhaye Stream, district Dir Lower, Pakistan. A total of 16 fish species were recorded, belonging to 4 orders (Cypriniformes, Channiformes, Siluriformes and Mastacebilformes), and 5 families including Cyprinidae (*Schizopyge esocinus, Racoma labiata, Cyprinion watsoni, Cyprinus carpio, Barilius pakistanicus, B. vagra, B. modestus, Crossocheilus diplocheilus, Garra gotyla, Puntius ticto,* and *P. sophore*), Channidae (*Channa punctatus* and *Channa gachua*), Nemacheilidae (*Schistura macrolepis*), Sisoidae (*Glyptothorax punjabensis*), and Mastacembelidae (*Mastacembelus armatus*). Different ichthyo-diversity indices [Simpson's biodiversity index (D=0.918), Simpson's reciprocal index (1/D=1.088), Simpson's evenness index ($E_{1/D}$=0.068), species richness (S), Shannon-Weiner's index (H′=3.775), Menhinick's index (D_{mn}=0.804), and Margalef's index (D_{mg}=2.510)] were calculated for the stream. The physicochemical parameters [temperature (23.125±3.514℃), dissolved Oxygen (9.003±0.627 mg L^{-1}), pH (7.333±0.201), turbidity (76.5±6.403 NTU), electric conductivity (201.68±11.31 µs cm^{-1}), free CO_2 (124.75±9.912 ppm), total dissolved solids (126.1±9.477 ppm), total alkalinity (4.325±0.171 mg L^{-1}), total suspended solids (127.1±6.864 ppm), total hardness (5.225±0.341 mg L^{-1}), salinity (42.25±6.292 ppt), calcium hardness (2.975±0.670 mg L^{-1}), magnesium hardness (105±9.954 mg L^{-1}), potassium (0.0145±0.001 mg L^{-1}), sodium (16.55±3.861 mg L^{-1}), chloride (1.825±0.727 mg/l), and nitrate (0.053±0.006 mg L^{-1}) level] were monitored and found to be in varying but permissible ranges. The stream was found to be harboring a number of economically valuable fish species. An exotic fish species, *C. carpio*, was found well flourished, indicating the potential of the stream to be used for mitigating the declining ichthyofaunal diversity in the main nearby rivers. Two species, *P. sophore* and *P. ticto*, were recorded for the first time from the district. Proper management, appropriate fish stocking, and implementing environmental/fishing laws are suggested for the maintenance of the diversity and alleviating anthropogenic stress/threats.

Keywords: Dir lower, Pakistan, Fish diversity, Diversity indices, Water quality, Fish stocking

---

1-School of Life Sciences, Nanjing University, Nanjing, Jiangsu 210023, P.R. China
2-Fisheries Laboratory, Department of Zoology, University of Peshawar, Peshawar 25120, Khyber Pakhtunkhwa, Pakistan
3-Fisheries and Aquaculture Laboratory, Department of Animal Sciences, Quaid-i-Azam University, Islamabad 45320, Pakistan
4-Department of Aquatic Animal Health and Diseases, Iranian Fisheries Science Research Institute (IFSRI), Agricultural Research Education and Extension Organization (AREEO), Tehran, I.R. Iran
5-Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan 430072, Hubei, P.R. China
*Corresponding author's Email: sunyuop@gmail.com

Introduction

Fish, a key vertebrate group, substantially influence human life on account of being a rich source of food – overcoming the nutritional difficulties of the modern world by providing high quality protein and vitamins etc. (Ullah, 2015). Fish are also used to procure by-products such as fish oil, fish glue, and fish meal (Shaikh *et al*., 2011). The fisheries sector is billion dollars business today, as it provides employment to a huge number of people and uplifts the economic status of many countries globally (Nagabhushan and Hosetti, 2010; Khan and Hasan, 2011). Ecologically, fish play a key role in the second trophic level and acting as a valuable feature of fishery perspective of aquatic bodies (Dubey *et al*., 2012). Ichthyofauna also plays a key role in nourishing aquatic systems, affecting their status and composition, and drives their sustainable management (Hasan et al., 2015a). Out of the total 40,000 vertebrates' species, 21,723 species belong to fish (Ullah, 2013). The presence, abundance, and diversity of fish species in aquatic bodies differ around the globe due to different geological and geographical features of the surrounding (Shaikh *et al*., 2011; Joshi *et al*., 2017). Khan *et al*. (2008) reported more than 186 fish species from Pakistan.

Anthropogenic malpractices and harmful activities lead to enormous stress on fish and induce different toxicological effects/endpoints and even death at extreme level, such as excessive use of pesticides, heavy metals, and discharge of untreated effluents to the natural water bodies etc. (Ullah and Zorriehzahra, 2015; Ullah *et al*., 2017; Ullah *et al*., 2018a; Ullah *et al*., 2018b). This has been an issue of serious concern for fisheries sector (wild), because of severe effects on biodiversity, seafood yield, and degradation of water bodies (Ullah *et al*., 2016a; Ullah *et al*., 2016b; Sharma *et al*., 2017). The degradation and change in natural flow systems alter the distribution and pattern of distribution of fish species in these ecosystems (Mirza *et al*., 2011; Joshi *et al*., 2017). That's why, fish assemblages are considered to a useful indicator of the ecosystem's health, more specifically when species of interest and higher values are involved. Keeping in view the importance of natural fish resources, the information on diversity, different diversity indices, and pattern of distribution are widely employed to analyse the temporal and spatial alterations in hydrosphere for distinguishing habitats and developing conservation strategies (Costa and Schulz, 2010; Lakra *et al*., 2010; Sarkar *et al*., 2010; Sarkar *et al*., 2017).

Knowing the zone-wise and chronological distribution, variety and patterns, abundance ranks, and composition of fish fauna provide enough assistance to look for and analyze different factors that affect the community structure (Hasan and Ullah, 2013). The diversity, population, abundance, composition, and characteristics of ichthyofauna depend on various aspects of the water bodies such as physicochemical characteristics, geographic and geologic parameters, available food, water system, water current, depth, size, topographic features, and breeding sites (Ullah, 2013; Bhattacharjya *et al*., 2017). Research concerning biodiversity and water quality of different rivers, reservoirs, streams, coastal areas, and lakes of Pakistan is well documented, but comprehensive studies on fishes biodiversity in association with water characterization of Konhaye Stream is still scanty.

A preliminary and only survey on the stream was conducted by Ullah *et al*. (2014a) regarding the edible ichthyofauna and reported a great economic potential of the stream, but there is no detailed study to show the exact image of its biodiversity and harboring/culturing potential. Moreover, there is a heavy fishing pressure on the stream, which can possibly lead to extinction or lower abundance of different high prized game fish species. Keeping the aforementioned scenario in view, it was felt necessary to assess the ichthyofaunal diversity and water quality of the stream and establish different biodiversity indices in order to provide a better insight of whether it could be utilized in expanding the conservation strategies and mitigating the scenario of biodiversity loss in the nearby river Panjkora and other rivers across the province. Therefore, the current study was aimed at evaluating the diversity, community composition, and water quality assessment of Konhaye Stream at district Lower Dir, Khyber Pakhtunkhwa, Pakistan.

Materials and methods

The study area, sampling, and fish identification

Konhaye Stream is a major tributary of the river Panjkora that merges into it at Koto, district Lower Dir. District Lower Dir (34º, 37′ to 35º, 07′ North and 71º, 31′ to 72º, 14′ East; 820 meters above mean sea level; receives average annual rainfall of 1468.8 mm in December and 253.7mm in March) is surrounded by district Chitral (North), district Swat (East), district Malakand (South), and by Bajaur agency & Afghanistan (West) (Ullah *et al*., 2014b, 2014c). The river Panjkora originates from district Upper Dir at Kohistan (flowing southward, dividing both the districts into two halves) and joins the river Swat at Sharbatti (district Malakand) (Ullah, 2013). The river Panjkora has five tributaries in Upper Dir district, while two tributaries in Lower Dir district. Of these two tributaries, Konhaye Stream is the major one in district Lower Dir (Ullah, 2014). The study area is shown in Fig. 1.

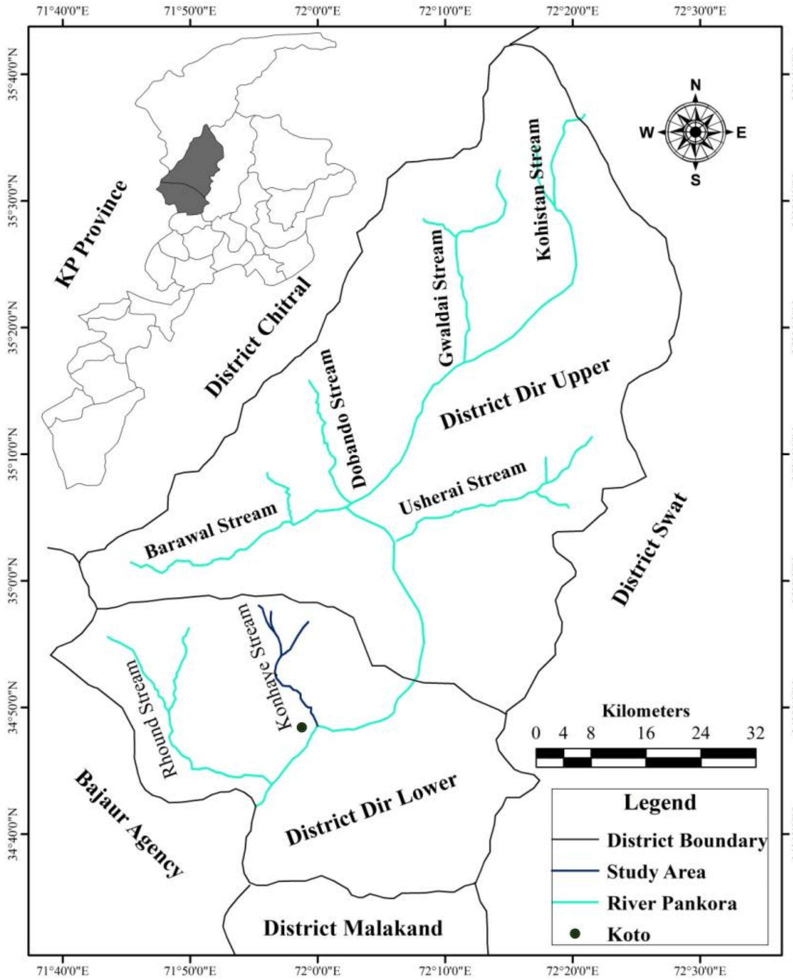

Figure 1: Map showing location of study area and river Panjkora at districts Dir Upper and Dir Lower.

Water was collected in polythene bottles (sterilized), two times a month (April through July, 2013). The bottles were initially washed and rinsed with deionized water. The pH and conductivity of the samples were observed on the spot using portable pH meter (Natner, UK) and portable conductivity meter (Jenway, England), while for the rest of parameters, the samples were carried to laboratory. The rest of the parameters were determined using standard suggested protocol. The nitrate contents were determined via Sulphonilic method through UV spectrophotometer (Hitachi-U-2000) while potassium and sodium contents were determined using flame photometer (Jenway-FPF-7).

The fish specimens were collected on every 15th and 30th, twice a month (April through September, 2013), by using different types (hand, cast, and patti) of nets having various mesh sizes and also by simple hooks. The collected specimens were fixed in 10% buffered commercial grade formalin directly, while the larger specimens (≥15cm) were injected with 10% formalin (intraperitoneal) before fixing them. The specimens were then transferred to alcohol (70%). The collected specimens were identified by following Ullah (2013), Hasan and Ullah (2013), Hasan *et al*. (2013, 2014, 2015a), Yousafzai *et al*. (2013) and Rauf *et al*. (2015).

Data analysis

The data regarding occurrence and abundance (of various fish species) were used for calculating Species richness (S), Simpson's diversity index (D), Simpson's Reciprocal Index (1/D), Simpson's evenness index ($E_{1/D}$), Shannon-Weiner's Index (H′), Menhinick's Index (D_{mn}), and Margalef's Index (D_{mg}) by following Ullah et al. (2014d), the formulae are given below. The cations and anions of the water parameters were studied through drafting a Piper tri-linear diagram (from Ullah *et al*., 2014e). Pearson correlation was calculated to check all possible correlations / association between the water quality parameters by following Ullah *et al*. (2014f). All the statistical analyses were carried out in Microsoft Excel (V. 2010) and Statistix (V. 8.1). GW_Chart (V. 1.23.2) was employed for drawing Piper tri-linear diagram while the map of the study area was prepared in ArcGIS (Version 9.3).

Month wise Percentage = fish caught in the month/ total fish caught

n = number of individual species

N=Total number of individuals

Relative Abundance (Pi) = n/N

Species Diversity=Pi (Log2 (Pi))

Simpson's Biodiversity Index (D)=1-(∑n(n-1)/N(N-1))

Simpson's Reciprocal Index=1/D

(Simpson's Evenness) $E_{1/D}$=(1/D)/S (S=Species Richness)

Margalef's Index (D_{mg})=S-1/lnN,

Menhinick's Index (D_{mn})=S/√N,

Shannon-Weiner's Index (H′) = ∑Pi (Log2 (Pi))

Results and Discussion

The biological diversity is an indication of ecosystem's pliability and flexibility (Sarkar *et al*., 2017). The ichthyofaunistic structure and composition are promoted by certain pivotal factors, including the physicochemical quality of the water body and inter-species interaction (Ullah, 2013). Keeping in view, the importance of physicochemical characterization of water for fish, all the important parameters that affect fish assemblages were studied (Ullah *et al*., 2014e).

The highest and lowest temperature was recorded in July (27.9°C) and April (19.9°C), pH in May and July (7.5) and June (7.1), DO in April (9.91 mg L^{-1}) and July (8.5 mg L^{-1}), EC in July (217.2 µs cm^{-1}) and April (190.2 µs cm^{-1}), TDS in July (135.04 mg L^{-1}) and April (111.1 mg L^{-1}), TSS in April (134.4 mg L^{-1}) and May (120.9 mg L^{-1}), total hardness in July (131 mg L^{-1}) and June (110 mg L^{-1}), free CO_2 in July (4.5 ppm) and May (4.1 ppm), turbidity in July (2.67 NTU) and April (1.11 NTU), salinity in July (0.11 ppm) and April and May (0.001 ppm), Ca hardness in July (81 mg L^{-1}) and May (67 mg L^{-1}), Mg hardness in July (48 mg L^{-1}) and May (35 mg L^{-1}), sodium in July (5.7 mg L^{-1}) and April (4.9 mg L^{-1}), Potassium in June (3.8 mg L^{-1}) and April (2.3 mg L^{-1}), total alkalinity in July (117 mg L^{-1}) and April (93 mg L^{-1}), chloride in July (19.7 mg L^{-1}) and April (11 mg L^{-1}), and the highest concentration of nitrate was recorded in April (0.045 mg L^{-1}) and lowest in May (0.001 mg L^{-1}), respectively. The water quality parameters are recorded in Table 1, as per Ullah *et al*. (2014e). The water quality parameters were observed to be within the permissible limits as suggested by WHO (2011). The results for water quality were observed to be in congruence with previous studies on different water bodies in the adjoining areas (Yousafzai *et al*., 2013; Hasan *et al*., 2015a).

Table 1: Physico-chemical parameters of the Konhaye Stream District Dir Lower.

Parameters	Minimum	Maximum	Mean	S.D	Standard Values for life *
Temp (^oC)	19.90	27.90	23.125	3.514	16-40 ^oC
pH	7.100	7.500	7.3330	0.201	6.5-9.0
DO (mg L^{-1})	8.500	9.910	9.0030	0.627	5.0 mg L^{-1}
EC(µs cm^{-1})	190.2	217.2	201.68	11.31	100 µs cm^{-1}
TDS (ppm)	111.1	135.1	126.10	9.477	<400ppm
TSS (ppm)	120.9	134.4	127.10	6.864	<80ppm
FreeCO_2 (ppm)	110.0	131.0	124.75	9.912	10-15 ppm
$Turbidity_{(NTU)}$	67.00	81.00	76.500	6.403	0.5-10 NTU
Salinity (ppt)	35.00	48.00	42.250	6.292	0.001-0.5 ppt
T.H (mg L^{-1})	4.900	5.700	5.2250	0.341	10-400 mg L^{-1}
Ca.H (mg L^{-1})	2.300	3.800	2.9750	0.670	4-160 mg L^{-1}
Mg.H (mg L^{-1})	93.00	117.0	105.00	9.954	<15 mg L^{-1}
Na (mg L^{-1})	11.00	19.70	16.550	3.861	>5 mg L^{-1}
K (mg L^{-1})	0.001	0.041	0.0145	0.001	<5 mg L^{-1}
T.A (mg L^{-1})	4.100	4.500	4.3250	0.171	10-400 mg L^{-1}
Cl (mg L^{-1})	1.110	2.670	1.8250	0.727	10-600 mg L^{-1}
NO_3 (mg L^{-1})	0.001	0.110	0.0530	0.006	0.1 mg L^{-1}

* Limits suggested by the United States Public Health standards for surface water.

The strongest (r>0.5; *p*=0.001) correlations/associations of temperature across all sampling sites were observed to be with EC (0.981), turbidity (0.966), and total alkalinity (0.951). pH showed significant correlation with total hardness (0.7516) followed by sodium (0.6727); DO with nitrate (0.913) and TSS (0.674); EC with sodium (0.9781), turbidity (0.9143), and total alkalinity (0.9091); TDS with chlorine (0.9609) and total alkalinity (0.9538); TSS with Nitrate (0.7941); calcium hardness with Free CO_2 (0.93) and magnesium hardness (0.815); magnesium hardness with Salinity (0.966), free CO_2 (0.954), and turbidity (0.902); sodium with turbidity (0.805); potassium with salinity (0.927); total alkalinity with turbidity (0.994) and salinity (0.962); chlorine with Turbidity (0.843); free CO_2 with salinity (0.859), and for turbidity highest correlation was shown by salinity (0.969). The Pearson's correlations between the water quality parameters are shown in Table 2.

Table 2: Pearson's Correlation coefficient matrix of the studied physico-chemical parameters of the water of Konhaye Stream.

	Temp.	pH	DO	EC	TDS	TSS	TH	Ca. H	Mg. H	Na	K	T.A	Cl	NO_3	F. CO_2	Turb.	Salinity
Temp.	1																
pH	0.341	1															
DO	-0.79	-0.329	1														
EC	**0.981**	**0.5069**	-0.829	1													
TDS	**0.831**	0.0682	-0.952	**0.806**	1												
TSS	-0.5	-0.903	**0.674**	-0.659	-0.429	1											
TH	0.011	**0.7516**	0.309	0.1171	-0.48	-0.397	1										
Ca. H	0.484	-0.435	0.019	0.3184	0.2438	0.4808	-0.139	1									
Mg. H	**0.809**	-0.27	-0.552	**0.6814**	**0.7602**	0.081	-0.4	**0.815**	1								
Na	**0.925**	**0.6727**	-0.771	**0.9781**	**0.6926**	-0.768	0.2989	0.191	0.525	1							
K	**0.672**	-0.351	-0.743	0.5723	**0.9072**	-0.01	-0.732	0.473	**0.865**	0.396	1						
T.A	**0.951**	0.1274	-0.88	**0.9091**	**0.9538**	-0.399	-0.295	0.456	**0.871**	**0.805**	**0.861**	1					
Cl	**0.806**	0.3093	-0.999	**0.8357**	**0.9609**	-0.655	-0.32	0.012	0.578	0.772	**0.761**	**0.894**	1				
NO_3	-0.51	-0.458	**0.913**	-0.611	-0.765	**0.7941**	0.2421	0.425	-0.17	-0.61	-0.49	-0.61	-0.9	1			
F. CO_2	**0.765**	-0.226	-0.343	**0.6305**	**0.5603**	0.1649	-0.172	**0.93**	**0.954**	0.502	0.677	**0.748**	0.372	0.0705	1		
Turb.	**0.966**	0.1167	-0.827	**0.9143**	**0.9172**	-0.354	-0.244	**0.538**	**0.902**	**0.81**	**0.839**	**0.994**	**0.843**	-0.527	**0.809**	1	
Salinity	**0.879**	-0.131	-0.749	**0.7865**	**0.9021**	-0.132	-0.435	**0.638**	**0.966**	0.641	**0.927**	**0.962**	**0.769**	-0.419	**0.859**	**0.969**	1

Bold r-Values >0.500 are significant at $p<0.05$.

Temp=Temperature, DO=Dissolved Oxygen, EC=Electric Conductivity, TDS=Total Dissolved Solids, TSS=Total Suspended Solids, TH=Total hardness, Ca. H= Calcium hardness, Mg. H=Magnesium hardness, Na=Sodium, K=Potassium, T.A=Total Alkalinity, Cl=Chloride, NO_3=Nitrate, F.CO_2=Free Carbon dioxide, Turb.=Turbidity

The major ionic characters, evaluated in the current study were plotted on Piper tri-linear-diagram and were compared with previous reports for classifying and designating the ionic nature of the collected water samples (Ravikumar and Somashekar, 2010; Ullah *et al.*, 2014e). Illustration through this diagram reveals the basic ions, responsible for controlling water chemistry. Using the scheme (shown in Fig. 2) of Ravikumar and Somashekar (2010), the diagram of the current study classified the water samples into "Mixed Ca^{2+}—Na^{+}—HCO_3^{-} Type" (from Ullah *et al.*, 2014e). The classification of water samples for the current study is shown in Fig. 3. In the current study, no temporal change was observed/recorded for the water samples, which suggests the ionic stability of the stream with respect to Ca^{2+}, Na^{+}, Mg^{2+}, K^{+}, Cl^{-}, SO_4^{2-}, and HCO_3^{-} (Manoj *et al.*, 2013; Ullah *et al.*, 2014e).

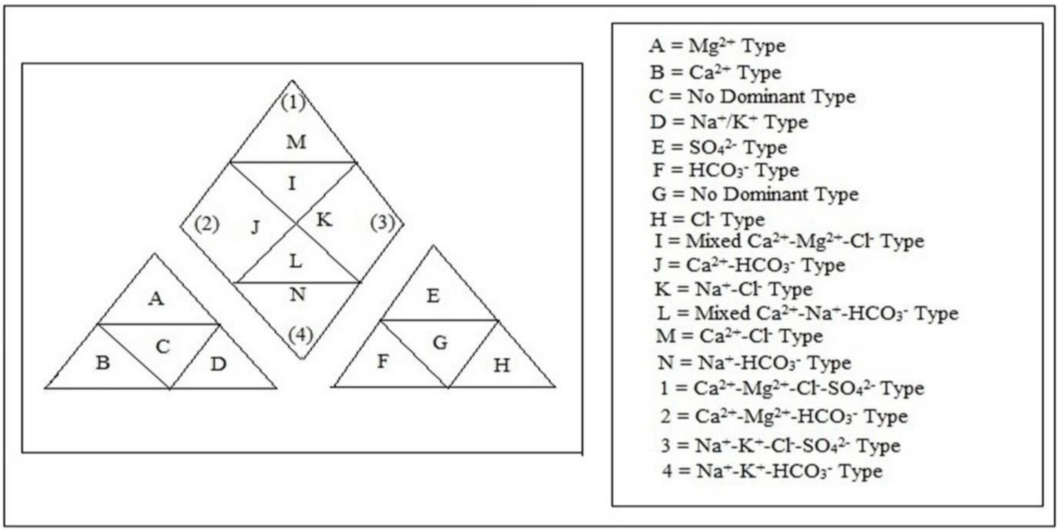

Figure 2: Reference Piper trilinear diagram; Left and right triangles designate cations and anions, respectively.

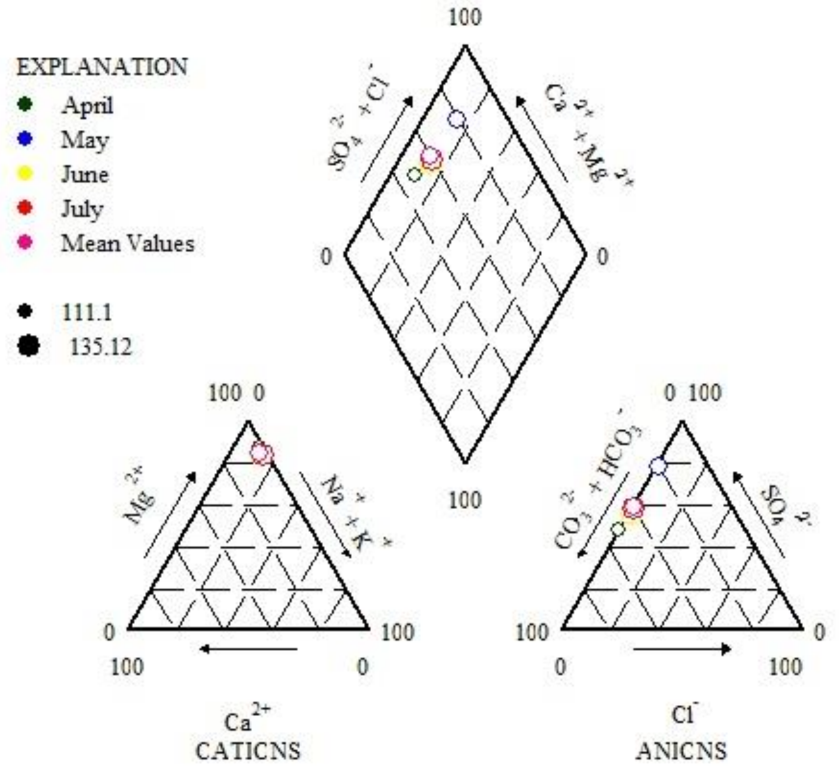

Figure 3: Piper-tri-linear-diagram illustrating hydrochemical regime across the study period.

The natural flow regimes such as change rate, duration, timing, frequency and magnitude of the water, and hydrologic condition control the assemblages of fish species and influence the ecological processes in aquatic ecosystems (Ullah, 2013). The aforementioned factors also bring about alterations and variations in the food resources for the abiding fish species.

This affects the fish diversity, structure, and composition by changing the food resources, and also provides an opportunity for other fish species to establish there from the nearby/ adjoined/ connected water bodies (Mirza *et al.*, 2011). The current study was having 14 species in common to that of Hasan and Ullah (2013), while 2 species viz *P. sophore* and *P. ticto* were missing from their study. These two species were the first report from the stream and the district, to the best of the available literature and our knowledge.

A total number of 16 fish species, belonging to 4 orders, 5 families and 12 genera were identified, shown in Table 3. The morphometric measurements and distinguishing characters (fin formulae) were noted as shown in Tables 4 and 5 respectively. The month-wise diversity, prevalence percentage, species richness (S), Margalef's (D_{mg}), Minhinick's (D_{mn}), and Shannon-Weiner's diversity indices are given in Table 6. Cypriniformes (75.253%; 298 Specimens) was found to be the richest order, followed by Channiformes (14.394%; 57 Specimens) and Mastacemeliformes (7.071%; 28 Specimens). Siluriformes (3.283%; 13

Specimens) was the least recorded order. Family-wise, Cyprinidae (71.465%; 283 Specimens) was found to be most abundant, followed by Channidae (14.394%; 57 Specimens). Mastcembelidae, Nemalcheilidae, and Sisoridae were found to be 7.07% (28 Specimens), 3.788% (15 Specimens) and 3.283% (13 Specimens) of the total catch. Taxonomically, Cyprinidae family was embodied to 8 genera and 11 species, Channidae family was represented by a genus and 2 species, while other familes Nemalcheilidae, Mastacembelidae, and Sisoridae consisted of a single genus as well as species.

Table 3: Recorded fish fauna of Konhaye Stream and their local names.

S. No	Order	Family	Genus and Species	Local names
1	Cypriniformes	Cyprinidae	*Schizopyge esocinus*	Ranth/ Aasala
2			*Racoma labiata*	Kanesatt
3			*Cyprinion watsoni*	Sabzug
4			*Cyprinus carpio*	China kub
5			*Barilius pakistanicus*	Pepal
6			*Barilius vagra*	Pepal
7			*Barilius modestus*	Pepal
8			*Crossocheilus diplocheilus*	Butten
9			*Garra gotyla*	Kanesatt
10			*Puntius ticto*	Paplait
11			*Puctius sophore*	Paplait
12		Nemacheilidae	*Schistura macrolepis*	Sowa
13	Channiformes	Channidae	*Channa punctatus*	Asle Katasarre
14			*Channa gachua*	Dessi Katasarre
15	Siluriformes	Sisoridae	*Glyptothorax punjabensis*	Sulamanne
16	Mastacembeliformes	Mastacembelidae	*Mastacemelus armatus*	Marmahay

Table 4: Morphometric measurements (cm) of the recorded fish specimens.

S. No	Fish Species	T.L	F.L	S.L	H.L	E.D	P.O.L	B.D
1	*Racoma labiata*	14.0	13.2	12	3.6	0.5	6.6	2.6
2	*Channa punctata*	16.5	13.5	5.0	3.0	0.6	15.1	3.0
3	*Channa gachua*	15.9	14.1	4.1	2.5	0.5	16	3.0
4	*Cyprinion watsoni*	13.7	11	12.8	2.5	0.8	1.5	4.0
5	*Cyprinius carpio*	16.0	13	12	3.0	0.6	1.9	4.3
6	*Barilius pakistanicus*	7.6	6.5	5.8	1.2	0.4	7.0	1.2
7	*Barilius vagra*	12.4	11.2	10.2	2.5	0.6	11.6	2.0
8	*Barilius modestus*	10.9	9.7	9.2	1.8	0.5	10.2	2.0
9	*Schistura macrolepis*	9.5	9.1	7.5	2	0.1	0.8	1.5
10	*Mastacembelus armatus*	23.5	21	3.9	2.4	0.2	22.6	2.0
11	*Glyptothorax punjabensis*	12.2	8.8	8.4	2.5	0.2	8.5	1.5
12	*Crossocheilus diplocheilus*	12	11	8.5	1.5	0.5	11	2.2
13	*Garra gotyla*	13.9	12.4	12.5	2.6	0.4	12.7	3.0
14	*Punctius ticto*	10.7	8.6	11.4	2.0	0.4	4.7	1.9
15	*Punctius sophore*	13.1	10.9	12.1	2.2	0.7	5.9	2.2
16	*Schizopyge esocinus*	23.6	22.8	19.5	4.0	0.8	0.3	4.0

T.L = Total Length, F.L= Fork Length, S.L = Standard Length, H.L = Head Length, E.D = Eye Diameter, P.O.L = Post Orbital Length and B.D = Body Depth.

Table 5: Diagnostic characters of ichthyofauna of Konhaye Stream District Dir Lower.

S. No	Species	D	P	V	A	C	L.L
1	*Schizopyge esocinus*	4/8	20	10	3/5	19	95-98
2	*Racoma labiata*	4/8	20	11	3/5	19	110
3	*Cyprinion watsoni*	3/9-10	15	8	2/7	19	33-36
4	*Cyprinus carpio*	3/17	15	9	3/5	19	36-38
5	*Barilius pakistanicus*	2/7	15	9	2/10	19	42-44
6	*Barilius vagra*	2/7	15-16	9	2/10	19	42-44
7	*Barilius modestus*	2/7	15-16	9	2/10	19	42-44
8	*Crossocheilus diplocheilus*	3/8	15	9	2/5	19	38
9	*Garra gotyla*	2/8	15	8	2/5	19	30
10	*Puntius ticto*	3/8-9	15	1/8	3/5	19	23-26
11	*Puctius sophore*	3/8-9	17	1/8	3/5	19	23-26
12	*Schistura macrolepis*	3/8	9	7	2/5	18	-
13	*Channa punctatus*	29-32	17	6	21-23	12	37-40
14	*Channa gachua*	32-37	15	6	21-23	12	39-47
15	*Glyptothorax punjabensis*	1/6	1/8	6	3/9	18	-
16	*Mastacemelus armatus*	32-39/74-90	23	-	3/75-88	-	-

D=Dorsal fins, P=Pelvic fins, V=Ventral fins, A=Anal fins, C=Caudal fins, L.L=Lateral Line Scales

Table 6: Month- and Species-wise numerical abundance and diversity indices.

S. No	Species	April	May	June	July	August	September	Total
1	*Mastacembelus armatus*	0	10	8	5	1	4	28
2	*Cyprinion watsoni*	7	5	5	1	0	6	24
3	*Garra gotyla*	8	13	10	10	9	8	58
4	*Crossocheilus diplocheilus*	7	6	5	4	7	8	37
5	*Schizopgye esocinus*	2	4	1	6	5	3	21
6	*Cyprinus carpio*	10	2	1	2	4	7	26
7	*Puntius sophore*	5	5	1	3	6	0	20
8	*Puntius ticto*	1	2	0	0	0	3	6
9	*Barrilius pakistanicus*	8	7	10	12	14	3	54
10	*Barrilius vagra*	5	0	0	2	6	0	13
11	*Barrilius modestus*	0	0	0	4	5	1	10
12	*Channa gachua*	3	4	7	9	10	0	33
13	*Channa punctata*	7	5	6	3	1	2	24
14	*Racoma labiata*	1	7	0	5	0	1	14
15	*Glyptothorax punjabensis*	3	2	0	0	0	8	13
16	*Schistura macrolepis*	1	6	2	0	6	0	15
	Total	68	78	56	66	74	54	396
	Month wise Percentage (%)	17.17	19.70	14.14	16.67	18.69	13.64	100%
	Margalef's Index (D_{mg})	3.081	2.984	2.484	2.864	2.556	2.758	2.510
	Menhinick's Index (D_{mn})	1.698	1.585	1.470	1.601	1.395	1.633	0.804
	Shannon's Weiner's Index (H′)	0.437	0.461	0.399	0.43	0.452	0.392	2.573

Month wise Percentage = fish caught in the month/ total fish caught; D_{mg} = S-1/lnN; D_{mn} = S/√N; H′ = ∑ Pi (Log2 (Pi))

The rank-abundance curve for all the collected species is shown in Fig. 4. The curve illustrates that the fish fauna is rich, but its relatively steep slope portrays low evenness of the fish species. The dominance of the fish species from family Cyprinidae is also reported by other researchers in different other water bodies across Pakistan as well as in India (Shahnawaz *et al*., 2010; Vass *et al*., 2011; Ullah, 2013; Hasan and Ullah, 2013; Hasan *et al*., 2013; Yousafzai *et al*., 2013; Ullah *et al*., 2014d; Hasan *et al*., 2015a; Hasan *et al*., 2015b; Rauf *et al*., 2015; Sharma *et al*., 2017). Wahab and Yousafzai (2017) studied the Cyprinid fauna of the river Panjkora in district Lower Dir and reported 7 genera and 10 species including *Cyprinus carpio, Carassius auratus, Schizothorax plagiostomous, S. esocinus, S. labiatus, G. gotyla, Crossocheilus diplocheilus, Tor putitora, Barilius vagra,* and *B. pakistanicus*. Hasan *et al*. (2014) also reported Cyprinidae family to be the richest family with 9 fish species (*S. plagiostomus, C. auratus, Salmophasia punjabensis, C. diplocheilus, B. vagra, B. pakistanicus, B. modestus, Puntius conchonius*, and *P. ticto*) from the three streams (Salarzai, Mamund, and Nawagai streams that flow into river Panjkora at district Lower Dir) of the nearby Bajaur Agency (to the west of district Lower Dir) from 2004 to 2010.

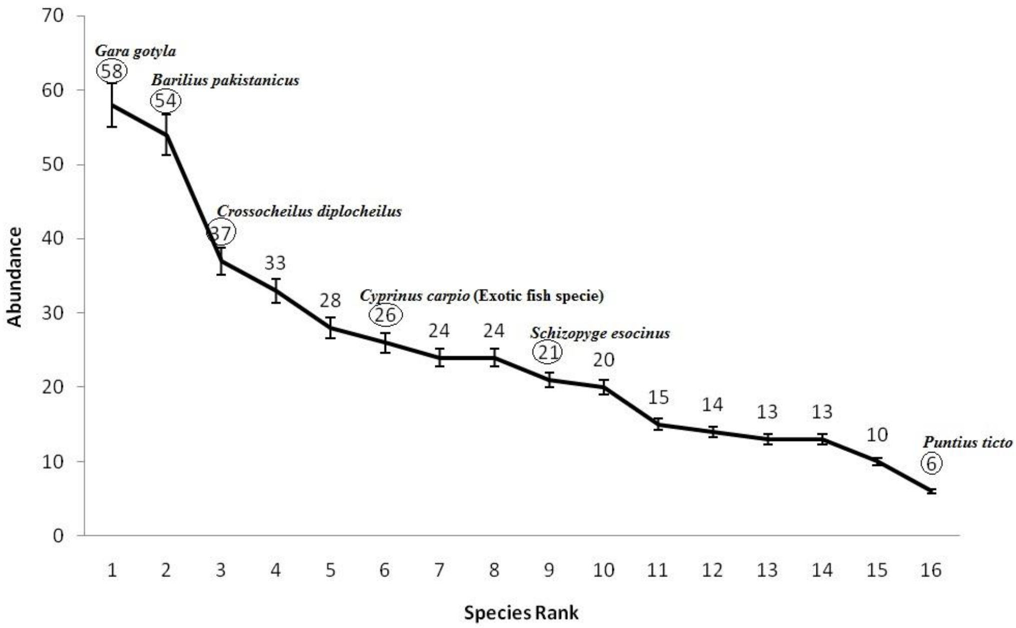

Figure 4: Rank abundance curve for Ichthyofauna of the stream.

Numerically, *G. gotyla* (14.65%), *B. pakistanicus* (13.64%), and *C. diplocheilus* (9.343%) were found to be the most abundant ones. The abundance of *Channa gachua, Mastacembelus armatus, Cyprinion watsoni, C. punctata, Schizopyge esocinus, P. sophore, Schistura macrolepis, Racoma labiata, Barilius vagra, Glyptothorax punjabensis, Barrilius modestus,* and *P. ticto* were found to be 8.333%, 7.071%, 6.061%, 6.061%, 5.303%, 5.051%, 3.788%, 3.535%, 3.283%, 3.283%, 2.525%, and 1.515% respectively. The atypical observation during the study was the abundance of an introduced/exotic fish species (*C. carpio*), which made 6.566% of the total catch. The species richness was calculated through Menhinick's index as well as Margalef's index, which was found to be 5.98 and 19.9 respectively. The calculated diversity indices such as relative abundance (Pi), species diversity, Shanon-Weiner's biodiversity index, Simpson's biodiversity index, Simpson's reciprocal index, and Simpson's evenness index are given in Table 7.

Table 7: Different ichthyo-diversity indices for Konhaye Stream district Dir Lower.

	Shannon-Weiner's Index			Simpson's Index	
Species	**Pi**	**Log_2(Pi)**	**Pi(Log_2(Pi))**	**n**	**n(n-1)**
Mastacembelus armatus	0.0707	-3.8224	-0.2703	28	756
Cyprinion watsoni	0.0606	-4.0448	-0.2451	24	552
Gara gotyla	0.1464	-2.7716	-0.4059	58	3306
Crossocheilus diplocheilus	0.0934	-3.4202	-0.3196	37	1332
Shizopgye esocinus	0.0530	-4.2375	-0.2247	21	420
Cyprinus carpio	0.0656	-3.9293	-0.2580	26	650
Puntius sophore	0.0505	-4.3079	-0.2176	20	380
Punctius ticto	0.0151	-6.0450	-0.0916	6	30
Barilius pakistanicus	0.1364	-2.8748	-0.3920	54	2862
Barrilius vagra	0.0328	-4.9294	-0.1618	13	156
Barrilius modestus	0.0252	-5.3080	-0.1340	10	90
Channa gachua	0.0833	-3.5853	-0.2988	33	1056
Channa punctata	0.0606	-4.0448	-0.2451	24	552
Racoma labiata	0.0353	-4.8225	-0.1705	14	182
Glyptothorax punjabensis	0.0328	-4.9294	-0.1618	13	156
Schistura macrolepis	0.0379	-4.7229	-0.1789	15	210
			H′ = 3.77579	N = 396	∑n(n-1) =12690
N (N-1) = 156420	D = 0.918872		1/D = 1.0883		$E_{1/D}$ = 0.068

Pi = Relative Abundance (n/N); Pi (Log2 (Pi)) = Species Diversity; H′ = Shannon-Weiner's Index; n = number of individual species; N=Total number of individuals; D=Simpson's Biodiversity Index, D = 1 - (∑ n(n-1)/N(N-1)); 1/D = Simpson's Reciprocal Index; (Simpson's Evenness) $E_{1/D}$ = (1/D)/S (S=Species Richness).

Shannon's index (3.775) revealed a rich diversity of the ichthyofauna in the stream, but Simpson's evenness index (0.068) demonstrated less evenness of the fish species distribution across the stream. As compared to the study of Hasan *et al*. (2014), Shannon's index of the current study was higher which means that the Konhaye Stream is richer in diversity as compared to all the three streams of the adjacent Bajaur Agency, however, the evenness values was higher for their study as compared to the current study. The uneven distribution of the fish species as compared to Hasan *et al*. (2014) might be attributed to the overexploitation of the fish fauna of the Konhaye Stream by having a comparatively higher population density as compared to the Nawagai, Mamund, and Salarzai streams of Bajaur Agency. The main factor for less evenness or uneven distribution of the fish fauna is also attributed to the hostile effects of anthropogenic over activities, no implementation of rules by the concerned governmental bodies/ organizations/ departments, and no regulatory rule on the use of mesh size such as the use of nets having smaller mesh size. Use of different types of chemicals and electric generators for fishing is quite common in the study area and there are no rules for fish catch per season/ indiscriminate catching/ juvenile fishing, which affect both evenness and diversity. The improper way of fishing and employing different ill-mannered and nasty fishing techniques lead to habitat loss, and also effects the movement/migratory behavior of the fish species. Rauf *et al*. (2015), Bhaumik (2017), and Sarkar *et al*. (2017) also reported anthropogenic activities to be the major reason, altering ichthyofaunal diversity in the riverine ecosystem as well as in their tributaries.

Comparing the diversity of the stream with previous studies, the stream was found to be less diverse than the Panjkora river at district Lower Dir, as Hasan *et al*., (2015a) reported 25 fish species from the Panjkora river at district Lower Dir. But the stream was found to be more diverse than the Panjkora river at district Upper Dir, as Muhammad *et al*. (2014) listed 11 fish species from the upper part of the river. Collectively, the Panjkora River was found to be more diverse than the stream, which might be due to the fact, that the river is a bigger and has longer water body, and having five tributaries at Upper Dir district, and two at Lower Dir district – the stream under current investigation is one of those tributaries. Ullah (2013) reported the Simpson's diversity index (D=0.921) for Panjkora river, which is slightly and probably negligibly higher than the present study (D=0.91), depicting that Konhaye Stream is a bit less diverse. Ullah *et al*. (2014d) reported a total of 14 fish species from the second tributary (Rhound stream) of the Panjkora river at district Lower Dir. The Simpson's diversity index (D=0.897) for Rhound stream was lesser than that of the current study (D=0.91), depicting that Konhaye Stream is more diverse, but the Simpson's evenness ($E_{1/D}$=0.068) was similar for both the streams, depicting the same level of anthropogenic stress on both the streams. These both streams are also under severe stress due to agricultural runoffs, as both are banked with huge agricultural lands and farming activities (Ullah *et al*., 2016a, 2016b).

The current study revealed the stream to be quite rich as for as diversity of fish fauna is concerned, but does not have an even distribution. Non-native fishes can spread out rapidly and can swiftly dominate the native ones, once they get established. On account of environmental favoring conditions, non-native species can establish to an extent, where they are sufficiently abundant and become invasive and can adversely impact the native species (Kernan, 2015). Invasive species can gradually establish as a breeding population and can replace other indigenous species (Sharma *et al*., 2017). An exotic fish species, common carp *Cyprinus carpio*, thrived well in the stream and was caught in a huge number, showing the harbouring potential of the stream, and depicting it to be the best option for mitigating the declining population of the other species in the main river system due to construction of hydropower projects (such as Koto Hydropower Project). The effluent from the project is adversely affecting the biodiversity of the river and is a matter of serious concerns due to the accumulation of higher concentration of heavy metals in the fish tissues, which is toxic to fish in over permissible limits. Toxicants not only lead to different hostile/ toxic effects on biochemistry, haematology, histopathalogy, DNA, behavior (feeding, reprodutive, migratory, etc.), and immune system of the fish (Ullah *et al*., 2015, 2016c, 2016d, 2016e, 2018a, 2018b) but also render them susceptible to different secondary fungal, viral, and bacterial infections.

Recently, mass mortality of different fish species has been observed in the Panjkora River. A decline in the population of *T. putitora*, *R. labiata*, and *S. plagiostomous* has been observed in the river downstream, associated with the effluents from the project leading to extreme pollution downstream. Discussion with the local fishermen and anglers revealed that the abundance of another highly prized game fish, *S. esocinus* (previously known as *Schizothorax. esocinus* (Ullah *et al*., 2014d)), reduced substantially (only 5.303% of the total catch in the current study), seeking proper attention and need an immediate action for alleviating the toxic effects on the fish species and over all fish population. The aforementioned issue might not only lead to biodiversity loss but also is a potential health risk for the local masses in case of fish intake/consumption from the affected areas/sites.

It was concluded that the physicochemical factors of the ambient water were within WHO recommended permissible limits. The stream is quite diverse, but the distribution is uneven. The fish diversity and composition is under stress due to anthropogenic activities. The flourished population of common carp revealed the culturing potential of the stream, and if properly stocked, it can mitigate the scenario of the threatened fish fauna of the main riverine bodies around the province. Moreover, this study added two fish species, *P. sophore* and *P. ticto*, to the ichthyofaunal record of the stream and the district. However, keeping in view the stress on the stream, it is recommended to design programs for abating pollution and assessing water quality, diversity, and community composition at regular intervals.

Acknowledgment

We are thankful to Mr. Ikram Khan, Qari Zia Ullah, Mr. Atta Ur Rehman, and Mr. Zakir Ullah for their help in fish collection, and Mr. Wali Jan Dalanwal (Assistant Director, KPK Fisheries Department, Former Research Officer at Carp Hatchery and Training Centre, Sher Abad) and Mr. Gul Hasan (Department of Environmental Sciences, University of Peshawar) for water quality assessment/analysis.

References

Bhattacharjya, B.K., Bhaumik U. and Sharma A.P., 2017. Fish habitat and fisheries of Brahmaputra River in Assam, India. *Aquatic Ecosystem Health & Management*, 20(**1-2**), 102-115.

Bhaumik, U., 2017. Fisheries of Indian Shad (*Tenualosa ilisha*) in the Hooghly–Bhagirathi stretch of the Ganga River system. *Aquatic Ecosystem Health and Management,* 20(**1-2**), 130-139

Costa, P., and Schulz, U., 2010. The fish community as an indicator of the biotic integrity of the streams in the Sinos River basin, Brazil. *Brazilian Journal of Biology*, 70, 1195-1205.

Dubey, A.K., Shukla, S.K. and Verma, H., 2012. Ichthyo-diversity of banisagar Dam at Chhatarpur Madhya Pradesh, India. *International Journal of Fisheries and Aquatic Sciences*, 2, 157-161.

Hasan, Z., and Ullah, S., 2013. The ichthyofaunal diversity, relative abundance, physico chemical analysis and the estimation of biodiversity index of River Panjkora District Dir (Lower), Khyber Pakhtunkhwa. 33rd Congress of Zoology (International), at Islamabad.

Hasan, Z., Ahmad, I., Yousuf, M., Rehman, L.U. and Khan, J., 2013. Fish biodiversity of River Swat.

Pakistan Journal of Zoology, 45(**1**), 283-289.

Hasan, Z., Khan, W., Khan, M.A., Rehman, L.U., Khan, J. and Ullah, S., 2014. Comparative abundance of fish fauna of different streams of Bajaur Agency, Khyber Pakhtunkhwa, Pakistan. *Biologia (Pakistan)*, 60(**1**), 159-163.

Hasan, Z., Ullah, S., Rasheed, S.B., Kakar, A. and Ali, N., 2015a. Ichthyofaunal diversity of River Panjkora, district Dir Lower, Khyber Pakhtunkhwa. *The Journal of Animal and Plant Sciences*, 25(**3 Supp. 2**), 550-563.

Hasan, Z., Ullah, N., Ullah, S. and Kakar, A., 2015b. Ichthyo-diversity of River Zhob, district Zhob, Balochistan. *The Journal of Animal and Plant Sciences*, 25(**3 Supp. 2**), 532-535.

Joshi, K.D., Alam, Md.A., Jha, D.N., Srivastava, K., Srivastava, S.K., Kumar, V., and Sharma, A.P., 2017. Studies on ecology, fish diversity and fisheries of Ken–Betwa Rivers (India): Proposed for inter-linking. *Aquatic Ecosystem Health and Management*, 20(**1-2**), 71-85.

Kernan, M., 2015. Climate change and the impact of invasive species on aquatic ecosystems, *Aquatic Ecosystem Health and Management*, 18(**3**), 321-333.

Khan, A.M., Shakir, H.A., Khan, M.N., Abid, M. and Mirza, M.R., 2008. Ichthyofaunal survey of some fresh water reservoirs in Punjab. *Journal of Animal and Plant Sciences,* 18, 151-154.

Khan, M.A., and Hasan, Z., 2011. A preliminary survey of the fish fauna of Changhoz Dam, Karak, K.P.K, Pakistan. *World Journal of Fish and Marine Sciences*, 3, 376-378.

Lakra, W.S., Kumar, U.S.S., Pandey, R., Dubey, A., Kumar, D.V. and Prakash, G.O., 2010. Fish diversity, habitat ecology and their conservation and management issues of a tropical river in Ganga basin, India. *The Environmentalist,* 30, 306-319.

Manoj, K., Ghosh, S. and Padhy, P.K., 2013. Characterization and classification of hydrochemistry using multivariate graphical and hydrostatical techniques. *Research Journal of Chemical Sciences*, 3(**5**), 32-42.

Mirza, Z.S., Mirza, M.R., Mirza, M.A. and Sulehria, A.Q.K., 2011. Icthyofaunal diversity of the River Jhelum, Pakistan. *Biologia (Pakistan),* 57, 23-32.

Muhammad, I., Hasan, Z., Ullah, S., Ullah, W. and Ullah, H., 2014. A preliminary survey of fish fauna of river Panjkora at District Upper Dir, Khyber Pakhtunkhwa Pakistan. *Journal of Biodiversity and Environmental Sciences*, 5(**1**), 362-368.

Nagabhushan, C.M. and Hosetti, B.B., 2010. Diversity of ichthyo-fauna in relation to physico-chemical characters of Tungabhadra Reservoir, Hospet. Wetlands, Biodiversity and Climate change. pp. 1-9.

Rauf, M., Din, N.U., Hasan, Z., Haseeb, A., Shah, H. and Ullah, S., 2015. Ichthyofaunistic study of River Kabul at Machini, Khyber Pakhtunkhwa, Pakistan. *Journal of Biodiversity and Environmental Sciences*, 7(**3**), 186-194.

Ravikumar, P. and Somashekar, R.K., 2010. Multivariate analysis to evaluate geochemistry of ground water in Varahi River Basin of Udupi in Karnataka, India. *Ecoscan*, 4(**2&3**), 153-162.

Sarkar, U., Gupta, B. and Lakra, W., 2010. Biodiversity, ecohydrology, threat status and conservation priority of the freshwater fishes of River Gomti, a tributary of River Ganga (India). *The Environmentalist*, 30, 3-17.

Sarkar, U.K., Dubey, V.K., Singh, S.P. and Singh, A.K., 2017. Employing indicators for prioritizaiton of fish assemblage with a view to manage freshwater fish diversity and ecosystem health in the tributaries of Ganges basin, India. *Aquatic Ecosystem Health and Management*, 20(**1-2**), 21-29.

Shahnawaz, A., Venkateshwarlu M., Somashekar D.S. and Santosh K., 2010. Fish diversity with relation to water quality of Bhadra River of Western Ghats (India). *Environmental Monitoring and Assessment*, 161, 83-91.

Shaikh, H.M., Kamble, S.M. and Renge, A.B., 2011. The study of ichthyofauna diversity in upper Dudha project water reservoir near Somthana in Jalna District (MS) India. *Journal of Fisheries and Aquaculture*, 2, 8-10.

Sharma, A.P., Das, M.K., Vass, K.K. and Tyagi, R.K., 2017. Patterns of fish diversity, community structure and ecological integrity of River Yamuna, India. *Aquatic Ecosystem Health and Management*, 20(**1-2**), 30-42.

Ullah, S., 2013. The ichthyofaunal diversity, relative abundance, physico chemical analysis and the estimation of biodiversity index of River Panjkora District Dir Lower, Khyber Pakhtunkhwa. M.Sc. Thesis, Department of Zoology, University of Peshawar, Pakistan.

Ullah, S., 2014. GIS Integrated Approach for Assessing Drinking Water Quality. VDM Publishing Heinrich-Böcking-Str. 6-8 D - 66121 Saarbrücken Germany. pp. 24-25.

Ullah, S., Hasan, Z., and Begum, M., 2014a. The edible ichthyofauna of Konhaye Stream District Dir Lower, Khyber Pakhtunkhwa. *Pakhtunkhwa Journal of Life Sciences*, 2(**3/4**), 87-95.

Ullah, S., Akmal, M., Aziz, F., Ullah, S. and Khan, K.J., 2014b. Hand pumps' water quality analysis for drinking and iIrrigation purposes at District Dir Lower, Khyber Pakhtunkhwa Pakistan. *European Academic Research*, 2(**1**), 1560-1572.

Ullah, S., Javed, M.W., Rasheed, S.B., Jamal, Q., Aziz, F., and Ullah, S., 2014c. Assessment of groundwater quality of district Dir Lower Pakistan. *International Journal of Biosciences*, 4(**8**), 248-255.

Ullah, S., Hasan, Z., Ahmad, S., Rauf, M., and Khan, B., 2014d. Ichthyofaunal diversity of Rhound stream at district Lower Dir, Khyber Pakhtunkhwa Pakistan. *International Journal of Biosciences*, 4(**8**), 241-247.

Ullah, S., Ullah, N., Rahman, K., Khan, T.M., Jadoon, M.A. and Ahmad, T., 2014e. Study on physicochemical characterization of Konhaye Stream district Dir Lower, Khyber Pakhtunkhwa Pakistan. *World Journal of Fish and Marine Sciences*, 6(**5**), 461-470.

Ullah, S., Javed, M.W., Shafique, M. and Khan, S.F., 2014f. An integrated approach for quality assessment of drinking water using GIS: A case study of Lower Dir. *Journal of Himalayan Earth Sciences*, 47(**2**), 163-174.

Ullah, S., 2015. Protective role of vitamin C against cypermethrin induced toxicity in *Labeo Rohita* (Ham.): biochemical aspects. M.Phil. Thesis. Department of Animal Sciences, Quaid-i-Azam University Islamabad, Pakistan.

Ullah, S. and Zorriehzahra, M.J., 2015. Ecotoxicology: a review of pesticides induced toxicity in fish. *Advances in Animal and Veterinary Sciences*, 3(**1**), 40-57.

Ullah, R., Zuberi, A., Naeem, M. and Ullah, S., 2015. Toxicity to hematology and morphology of liver, brain and gills during acute exposure of Mahseer (*Tor putitora*) to cypermethrin. *International Journal of Agriculture and Biology*, 17(**1**), 199–204.

Ullah, S., Hussain, Z., Mahboob, S. and Al-Ghanim, K., 2016a. Heavy metals in *Garra gotyla*, *Cyprinus carpio* and *Cyprinion watsoni* from the River Panjkora, District, Lower Dir, Khyber Pakhtunkhwa, Pakistan. *Brazilian Archives of Biology and Technology*, 59, e16160321.

Ullah, S., Hasan, Z. and Zuberi, A., 2016b. Heavy metals in three commercially valuable cyprinids in the river Panjkora, district Lower Dir, Khyber Pakhtunkhwa, Pakistan, *Toxicological and Environmental Chemistry*, 98(**1**), 64-76.

Ullah, S., Begum, M., Ahmad, S. and Dhama, K., 2016c. Genotoxic effect of endosulfan at sublethal concentrations in mori (*Cirrhinus mrigala*) fish using single cell gel electrophoresis (comet) assay. *International Journal of Pharmacology*, 12, 169-176.

Ullah, S., Begum, M., Dhama, K., Ahmad, S., Hassan, S. and Alam, I., 2016d. Malathion induced DNA damage in freshwater fish, *Labeo rohita* (Hamilton, 1822) using alkaline single cell gel electrophoresis. *Asian Journal of Animal and Veterinary Advances*, 11, 98-105.

Ullah, S., Hasan, Z. and Dhama, K., 2016e. Toxic effects of endosulfan on behaviour, protein contents and antioxidant enzyme system in gills, brain, liver and muscle tissues of rohu, *Labeo rohita*. *International Journal of Pharmacology*, 12, 1-10.

Ullah, S., Hasan, Z., Zorriehzahra, M.J. and Ahmad, S., 2017. Diagnosis of endosulfan induced DNA damage in rohu (*Labeo rohita*, Hamilton) using comet assay. *Iranian Journal of Fisheries Sciences*, 16(**1**), 138-149.

Ullah, S., Zuberi, A., Alagawany, M., Farag, M.R., Dadar, M., Karthik, K., Tiwari, R., Dhama, K. and Iqbal, H.M.N., 2018a. Cypermethrin induced toxicities in fish and adverse health outcomes: its prevention and control measure adaptation. *Journal of Environmental Management*, 206, 863–871.

Ullah, S., Li, Z., Hasan, Z., Khan, S.U. and Fahad, S., 2018b. Malathion induced oxidative stress leads to histopathological and biochemical toxicity in the liver of rohu (*Labeo rohita*, Hamilton) at acute concentration. *Ecotoxicology and Environmental Safety*, 161, 270-280.

Vass, K.K., Das, M.K., Tyagi, R.K., Katiha, P.K., Samanta, S.,

Srivastava, N.P., Bhattacharjya, B.K., Suresh, V.R., Pathak, V., Chandra, G., Debnath, D. and Gopal, B., 2011. Strategies for sustainable fisheries in the Indian part of the Ganga Brahmaputra River basins. *International Journal of Ecology and Environmental Sciences*, 37(**4**), 157-218.

Wahab, A. and Yousafzai, A.M., 2017. Cyprinid fauna (Cypriniformes) of River Panjkora, District Lower Dir, Khyber Pakhtunkhwa, Pakistan. *Pure and Applied Biology*, 6(**4**), 1354-1365.

WHO., 2011. World health organization, standard water quality parameters for aquatic life. Geneva, Switzerland.

Yousafzai, A.M., Khan, W. and Hasan, Z., 2013. Fresh records on water quality and ichthyodiversity of River Swat at Charsadda, Khyber Pakhtunkhwa. *Pakistan Journal of Zoology*, 45(**6**), 1727-1734.