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Diversity of freshwater fish in the lower reach of Indus River, Sindh province section, Pakistan

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ABSTRACT

According to reports, the last comprehensive fish records from the Indus River were published in 1977. Although few recent studies have been conducted, they are limited to some confined localities, and hence there was a gap of comprehensive fish diversity analysis of the Indus River in Sindh province section. Therefore, the present investigation was performed to describe the fish fauna of the Indus River from its northern to its southern extremities. In order to establish fish diversity and distribution, the study was accomplished from June 2016 to May 2017 covering 8 sampling locations across the river. A total of 44 fish species, belonging to 35 genera, included in 18 families, and 9 orders were recorded. Family Cyprinidae was the most specious with 13 species followed by Bagridae and Cichlidae with 4 species each, and Siluridae with3 species. Alpha Diversity Indices study showed that the ichthyofauna diversity of the River was not high in comparison with previous studies. Shannon's index for the whole Indus River locations was 0.95 and the evenness index was 0.77. Sustained populations of exotic fish species were shown to have established in the Indus River.

INTRODUCTION

The Indus River is one of the main rivers in Pakistan starting from the Tibetan Plateau, in the district of Lake Manasarovar, flows through the Ladakh region of Jammu and Kashmir, towards Gilgit-Baltistan and the Hindukush ranges. In its southern part, the Indus River passes through nearly the whole area of Pakistan before it meets the Arabian Sea at the port city of Karachi in Sindh. The Indus River has a length of 3,200 km, its total drainage area is about 1,165,000 square kilometres, 453,000 of which lie in the

ranges and foothills of the Himalayas, the Hindu Kush, and the Karakoram Range; the rest is in the semiarid plains of Pakistan. The river's annual flow is about 243 cubic kilometres, twice that of the Nile River and three times that of the Tigris and Euphrates rivers combined **Yu *et al.* (2013).**

The history of the fish diversity of the Indus River has started with publications of **(Günther, 1868; Day, 1871-1872, 1878-1889 and Alcock, 1898)** on fishes of the Indian sub-continent and prior to the creation of the state of Pakistan. More specifically, **(Ahmad, 1943)** reported on the fish diversity of the Lahore district. To the best of our knowledge **Ahmad (1943)** mentioned for the first time the fish fauna of the Pakistani part of the Indus River. In the 3rd quarter of the 20th century, **Hussain (1973)** studied the ichthyofauna of the lower reaches of the Indus River; **Ahmad *et al*. (1976)** provided a check-list of the Indus River plain, while Sheri and Saied revised the list of the freshwater fishes of Pakistan. Since then, no ichthyofaunal survey on the whole basin of the Indus River was made. **Urooj *et al.* (2011)** reviewed the literature on the fish fauna of the basin of the Indus River and showed that the studies were restricted to certain areas, rivers, streams or lakes. From 1960s until the end of the 20th century, there were 12 studies, three of which are on the lakes of the Indus River valley. With the turn of the 21st century, 9 studies have been performed on the fish fauna of parts of the Indus River in Pakistan (**Urooj *et al*., 2011; Mirza *et al*., 2011; Rafique & Khan 2012; Saeed *et al*., 2013; Mahar *et al*., 2014; Muhammad *et al*., 2017; Navid *et al*., 2017; Sheikh *et al*., 2017; Perraiz *et al*., 2018**).

The total number of freshwater fish species of Pakistan varies according to the different authors, from a minimum of 160 species, as reported by **(Mirza, 1994),** to the maximum of 193, as mentioned in the studies of (**Rafique, 2007; Rafique and Mian, 2012; Navid *et al*., 2017; Sheikh *et al*., 2017).** In other studies, intermediate numbers, such as 171 species **(Peter 1999; Mirza, 2004)** or 186 species **(Khan *et al*., 2008; Urooj *et al*., 2011),** were given. With such variation in the total number of the freshwater fish species, the actual need for an up-to-date list of the freshwater fish fauna of Pakistan is clear; in particular, the study of the fish species in the Indus River which is the main freshwater resource in this country is a reasonable starting point.

The aims of the present investigation are: (1) to study and compare the ichthyofauna along the Pakistani stretch of the Indus River; (2) to assess the variation in time of fish biodiversity of the Indus River by comparing the present results with those previously recorded; (3) to compare the freshwater fish biodiversity of the Pakistani stretch of the Indus River with the similar data available from the neighbouring countries.

MATERIALS AND METHODS

Study site and sampling

The present investigation was conducted in the vicinity of the Indus River of the Pakistani side during June 2016 to May 2017. In order to compare the fish diversity, the

terrain of the Indus River valley was divided into 3 sections. Live specimens were collected from 8 sampling sites within the 3 sections aforementioned. In section I, the following 3 stations were grouped: Gudu Barrage (Station 1), Shikarpur (station 2) and Sukkur Barrage and its tributaries (Station 3). In section II, the following 3 stations were included: Manchar Lake (station 4). Manjhand (station 5) and Kotri Barrage and its tributaries (Station 6). Section III contained the following 2 localities Keenjhar Lake (station 7) and Kharo Chan (station 8). (Figure 1). Different types of nets with different mesh size gillnets, cast net, seine net, pot net, permanently set trap nets and hook and lines **Hassan *et al.* (2020a).** Some of this fishing gear were set before dusk and raised at the dawn of the day were used to collect live fish specimens from the localities. Fish were kept immediately in ice until taken to the laboratory, then were preserved in 10% formalin for taxonomic and morphometric studies. At each location, basic field data, including latitude and longitude were recorded. The identifications of fishes were completed using morphological features and morphometric analysis. Measurements were taken by slide calipers in millimetres and measuring tapes in centimetres. Methods of (**Talwar and Jhingran, 1991)** and **Ali (1999)** were used to obtain the body morphometric of fish and their identification. Genera and respective species are presented alphabetically. The families were listed in phylogenetic order based on **(Eschmyer, 2018a)** and the proper spelling of scientific names and common names follow Fish Base **(Froese and Pauly, 2018).** All listed species are represented by a voucher specimen deposited at the fish collection repository of the Fresh Water Biology & Fisheries Department, University Of Sindh Jamshoro, Pakistan.

The ratio of number of species/ number of genera, number of species/number of families, and number of genera/ number of families were calculated for the fish fauna of the Indus River following the method of **Goren (1993).**In order to quantify the dispersal of the species among the families, certain indices are used by quantitative ecologists have been adopted and modified. The first index expresses the degree of complexity of the fish fauna. For this purpose, the ecological terms "species diversity" has been altered to "family diversity" **(Goren, 1993).** This index provides the degree of dispersal of the species among the families. Where the species are equally dispersed the index will be high, while when most of the species are concentrated within a few families, the value of the index is low. The Shanon-Weaver formula is used **(Pielou, 1969).**

Families Diversity: $H' = \sum_{i=1}^{f} (P_i / n P_i)$

Where H' = species diversity (changed here to families diversity), P*i* = proportion of the *i*th family; f = number of families in the region. The evenness rate (J) which can range from 0 to 1 was calculated as:

$J = H'/ H max$

The similarities at the species, genus and family levels were calculated for the ichthyofauna of the Indus River and rivers in the other regions for comparison. Jaccard's dichotomy coefficient **(Magurran, 1991)** is calculated from presence/absence

data and is directly interpretable as the proportion of unshared species, excluding joint absences, as follows:

C_{ij}= a /a + b + c

Where a is the number of species that samples i and j have in common, b is the number of species in sample i not shared with sample j and c is the number of species in sample j not shared with sample i.

A Family rank-number of species curve is plotted, in which each family is represented by a point proportional to the number of species it contains.

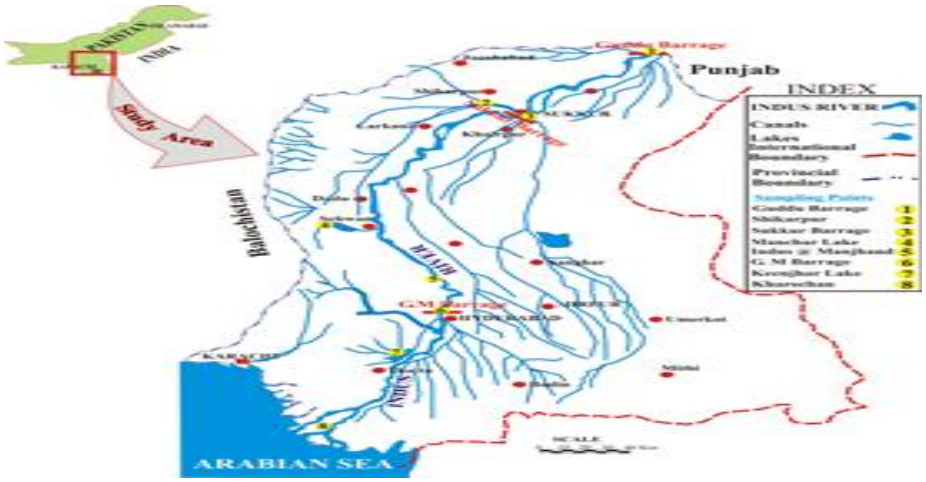

Fig. 1. Sampling sites in the Indus river Sindh Pakistan.

RESULTS

The results showed that the Indus River is inhabited with 44 species belonging to 35 genera contained in 18 families of 9 orders. The largest order is Perciformes with 7 families followed by Siluriformes with 4 families then Cypriniformes with 3 families and finally, Clupeiformes, Osteoglossiformes and Synbranchiformes with one family each (Figure 2).

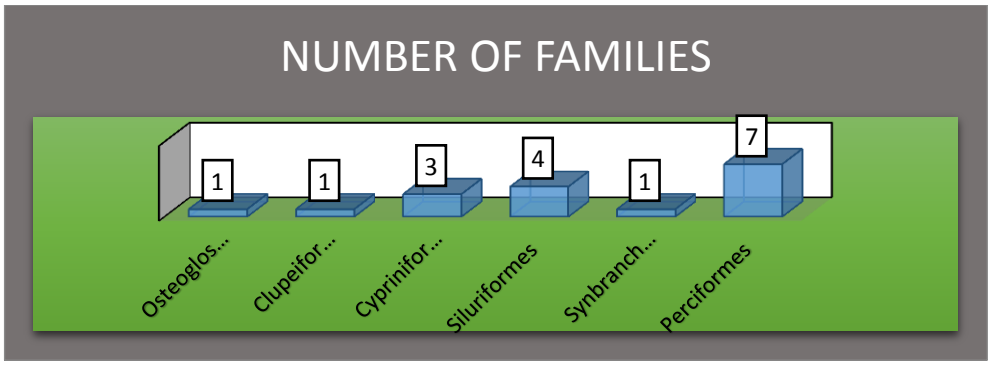

Figure 2. Fish orders examined and number of families they contained

Species wise, the richest family is Cyprinidae with 13 species (0.30%) followed by Bagridae with 4 (0.1%), Clupeidae and Cichlidae with 3 (0.07%), Notopteridae, Channidae, Xenocyprididae, Siluridae, Ailiidae and Mastacembelidae with 2 (0.05%) and finally Ambassidae, Belonidae, Danionidae, Gobiidae, Heteropneustidae, Latidae, Mugilidae and Sisoridae with only one species (0.02%) **(Table 1, Figure 3).**

Table .1. Presence/ absence of family and species obtained from 8 sampling localities. 1, Gudu Barrage; 2, Shikarpur; 3, Sukkur Barrage; 4, Manchar Lake; 5, Manjhand; 6, Kotri Barrage; 7, Keenjhar Lake; 8, Kharo Chan; S, station.

Family Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Section I S1, 2, 3**	**Section II S4, 5, 6**	**Section III S7, 8**
Notopteridae											
Chitala chitala	+	+	+	-	-	-	+	-	+	-	-
Notopterus notopterus	-	-	-	-	-	-	+	-	-	-	+
Clupeidae											
Gudusia chapra	-	-	-	-	+	+	-	+	-	+	+
Tenualosa ilisha	-	-	-	+	+	+	-	+	-	+	+
Tenualosa toli	-	-	-	-	+	+	-	+	-	+	+
Channidae											
Channa marulius	+	+	+	+	+	+	+	-	+	+	+
Channa punctata	-	-	-	-	-	-	+	-	-	-	+
Cyprinidae											
Cirrhinus mrigala	+	+	+	+	+	-	+	-	+	+	+
Cyprinus carpio	-	-	-	+	-	-	-	-	-	+	-
Gymnostomus ariza	-	-	+	+	-	-	+	-	+	+	+
Labeo bata	-	-	-	-	+	-	+	-	-	+	+
Labeo calbasu	+	+	+	+	-	+	+	-	+	+	+
Labeo catla	+	+	+	+		+	+	-	+	+	+
Labeo gonius	-	-	-	-	+	-	-	-	-	+	-
Labeo rohita	+	+	+	+	-	+	-	-	+	+	-
Osteobrama cotio	-	-	-	-	+	+	-	-	-	+	-
Pethia ticto	-	-	-	-	+	-	-	-	-	+	-

Puntius chola	-	-	-	-	-	+	-	-	-	+	-
Puntius sophore	-	-	-	+	+	+	-	-	-	+	-
Systomus sarana	-	-	-	+	-	-	-	-	-	+	-
Xenocyprididae											
Ctenopharyngodon idella	-	-	-	+	-	-	+	-	-	+	+
Hypophthalmichthys molitrix	-	-	-	+	-	-	+	-	-	+	+
Danionidae											
Salmostoma bacaila	-	-	-	-	+	-	-	-	-	+	-
Bagridae											
Mystus cavasius	+	+	+	+	-	+	+	-	+	+	+
Rita rita	+	+	+	+	-	-	+	-	+	+	+
Sperata aor	-	-	-	-	+	-	-	-	-	+	-
Sperata seenghala	+	+	+	+	-	+	+	-	+	+	+
Siluridae											
Ompok bimaculatus	-	-	+	-	-	-	+	-	+	-	+
Wallago attu	+	+	+	-	-	-	+	-	+	-	+
Sisoridae											
Bagarius bagarius	-	-	-	+	-	+	-	-	-	+	-
Heteropneustidae											
Heteropneustes fossilis	-	-	-	-	-	-	+	-	-	-	+
Ailiidae											
Clupisoma garua	-	-	-	-	+	+	-	-	-	+	-
Eutropiichthys vacha	-	-	-	-	+	-	-	-	-	+	-
Belonidae											
Xenentodon cancila	-	-	-	+	-	-	+	-	-	+	+
Mastacembelidae											
Mastacembelus armatus	-	-	+	-	-	+	-	-	+	+	-
Macrognathus pancalus	-	-	-	-	-	+	-	-	-	+	-
Ambassidae											
Chanda nama	-	-	-	-	+	-	-	+	-	+	+

Latidae											
Lates calcarifer	-	-	-	-	-	-	-	+	-	-	+
Cichlidae											
Coptodon zillii	-	-	-	-	-	-	+	-	-	-	+
Oreochromis niloticus	-	-	-	+	-	-	+	-	-	+	+
Oreochromis mosambicus	-	+	+	+	-	-	-	+	+	+	+
Sarotherodon galilaeus	-	-	-	+	-	-	+	-	-	+	+
Mugilidae											
Valmugil speighleri	-	-	-	-	-	-	-	+	-	-	+
Gobiidae											
Glossogobius giuris	-	-	-	-	+	-	-	-	-	+	-
Number of species	10	11	14	21	16	16	21	7	14	35	28
Number of genera	8	9	12	18	14	11	18	6	12	29	23
Number of families	3	6	7	9	8	7	9	5	7	14	13
Number of species/Number of families	3.3	1.8	2.0	2.3	2.0	2.3	2.3	1.4	2	2.5	2.2
Number of species/Number of genera	1.3	1.2	1.2	1.2	1.2	1.5	1.2	1.2	1.2	1.2	1.2
Number of genera/Number of families	2.7	1.5	1.7	2.0	1.8	1.6	2.0	1.2	1.7	2.1	1.8

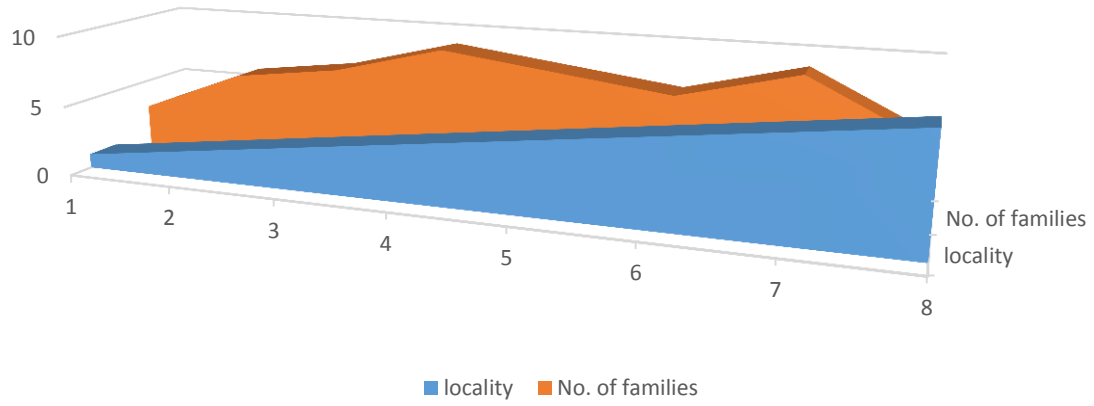

Figure .3. Sampling localities with their respective number of families studied

There were 5 marine species belonging to 3 families (Clupeidae, Gobiidae, and Mugilidae) and there were 5 species of mixed freshwater and marine environments (Belonidae, Cichlidae, and Latidae) (Table 2).

Table. 2. Family rank of the freshwater fish fauna of Indus River, Sindh Province section as shown according to the localities studies.

Stations	**Number and % of families based on species**														**Total**	
	With 1 species		**With 2 species**		**With 3 species**		**With 4 species**		**With 5 species**		**With 6 species**		**With 8 species**			
	No. of families	**%**	**No. of families**	**%**	**No. of families**	**%**	**No. of families**	**%**	**No. of families**	**%**	**No. of families**	**%**	**No. of families**	**%**	**No. of families**	**%**
Guddu Barrage	3	60	-	-	1	20	1	20	-	-	-	-	-	-	5	100
Shikarpur	4	66.6	-	-	1	16.7	1	16.7	-	-	-	-	-	-	6	100
Sukkur Barrage	4	57.1	1	14.3	1	14.3	-	-	1	14.3	-	-	-	-	7	100
Manchar Lake	4	50	1	12.5	2	25	-	-	-	-	-	-	1	12.5	8	100
Manjhand	5	62.5	1	12.5	1	12.5	-	-	-	-	1	12.5	-	-	8	100
Kotri Barrage	4	57	1	14.3	1	14.3	-	-	-	-	1	14.3	-	-	7	100
Keenjhar Lake	2	22.2	4	44.4	2	22.2	-	-	1	11.2	-	-	-	-	9	100
Kharo Chan	3	75	-	-	1	25	-	-	-	-	-	-	-	-	4	100
Total	29		8		10		2		1		2		1		54	

All eight localities studied have shown to contain mono-specific families and one family with 3 species. The localities Gudu Barrage and Shikarpur have one family each with 4 species. Families with 5 species were reported in the localities Sukkur Barrage and Keenjhar, while families comprising 6 species were noted in the localities Manjhand and Kotri Barrage. Finally, Manchar Lake is the only locality that has shown to contain family with 8 species (Table 2, Figure 4)

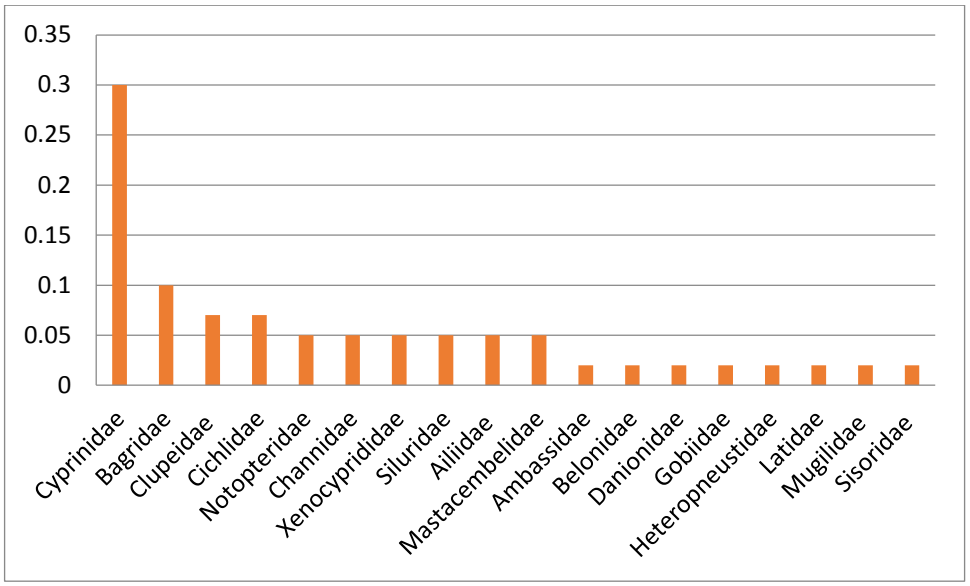

Figure 4. Percentage of the families reported and examine

The ratio of the number of species/number of families was at its highest value 3.3 in Gudu Barrage and the lowest value 1.4 at Kharo Chan, while the highest value of the ratio of the number of species/number of genera reaches 1.5 at Kotri Barrage and the lowest value 1.2 was observed in all localities except for Gudu and Kotri Barrages. The highest and lowest values of the ration of the number of genera/number of families shown were 2.7 and 1.2 at Gudu Barrage and Kharo Chan respectively (Table 1).

Result of the comparison of the three sections I, II and III for the 3 ratios mentioned above that section II has the highest value 2.5 and section I has the lowest value 2 for the ratio number of species/number of families respectively. The 3 sections were having the same value 1.2 of number of species/number of genera, while section II and section I have the highest 2.1 and lowest value 1.7 for the number of genera and number ration respectively (Table 1).

The family diversity (H̓) and evenness rate (J) were calculated for all eight localities studied. For the family diversity (H̓), the highest and the lowest values were 1.0060 and 0.3962 observed in localities Kharo Chan and Shikarpur respectively. For the evenness rate (J), the highest and the lowest values were 0.5092 and 0.9713 noted in the localities Shikarpur and Keenjhar Lake respectively (Table 3).

Table 3. Comparison of the family diversity (H') and evenness rate (J) between all eightn localities studied and 3 sections of the river proposed. S= station.

Locality	Family diversity (H')	Evenness Rate (J)
Gudu Barrage Station no. 1	0.6159	0.8813
Shikarpur Station no. 2	0.3962	0.5092
Station no. 3	0.6424	0.7601
Manchar Lake Station no. 4	0.6923	0.7255
Manjhand Station no. 5	0.8362	0.8763
Kotri Barrage Station no. 6	0.6359	0.7525
Keenjhar Lake Station no. 7	0.9268	0.9713
Kharo Chan Station no. 8	1.0060	0.9031
All eight localities	0.9493	0.7562
Section I (S1, 2,3)	0.7512	0.8889
Section II (S1, 2,3)	0.8804	0.7682
Section III (S1, 2,3)	0.944	0.8475

The Jaccard's dichotomy coefficient was calculated to check the similarities between 8 localities studied. The two localities Gudu Barrage and Shikarpur have shown the highest similarity 0.96, while the Keenjhar Lake and Kharo Chan localities were having similarity value of 0.5 (Table 4)

Table 4. Jaccard's dichotomy coefficient matrix for fish species obtained from the 8 localities studied.

	Gudu Barrage	Shikarpur	Sukkur Barrage	Manchar Lake	Manjhand	Kotri Barrage	Keenjhar Lake	Kharo Chan
Gudu Barrage	-	0.96	0.86	0.71	0.54	0.65	0.67	0.70
Shikarpur	-	-	0.89	0.70	0.55	0.70	0.70	0.70
Sukkur Barrage	-	-	-	0.70	0.59	0.70	0.74	0.73
Manchar Lake	-	-	-	-	0.57	0.67	0.70	0.81
Manjhand	-	-	-	-	-	0.64	0.54	0.54
Kotri Barrage	-	-	-	-	-	-	0.54	0.59
Keenjhar Lake	-	-	-	-	-	-	-	0.5

The result of calculation the similarity between the 3 sections that contained the 8 localities using Jaccard's dichotomy coefficient has shown highest similarity value of 0.75 between section I and III, while the lowest similarity value was 0.61 between section I and II (Table 5).

Table 5. Jaccard's dichotomy coefficient matrix for fish species obtained from

	Section I (Station no. 1, 2, 3)	**Section II (Station no. 4, 5, 6)**	**Section III (Station no. 7, 8)**
Section I (Station no. 1, 2, 3)	-	0.71	0.75
Section II (Station no. 4, 5, 6)	-	-	0.71

sections I, II and III studied

Comparison of the values of family diversity (H̀) and evenness of section I(Gudu Barrage, Shikarpur, Sukkur Barrage), section II(Manchar Lake, Manjhand, Kotri Barrage) and section III(Keenjhar Lake, Kharo Chan) with results obtained from comparable regions in Sindh Province Section, Pakistan. (Table 6).

Table 6. Comparison of the values of family diversity (H̀) and evenness of section I (Gudu Barrage, Shikarpur, Sukkur Barrage), section II(Manchar Lake, Manjhand, Kotri Barrage) and section III (Keenjhar Lake, Kharo Chan) with results obtained from comparable regions in Sindh Province Section, Pakistan.

	Section I (S1, 2, 3)	**Mirza et al. 2011**	**Altaf et al. 2015**	**Usman et al. 2017**	**Pervaize et al. 2018**
Family diversity (H̀)	0.75	2.91	2.83	0.55	0.67
Evenness	0.89	0.19	0.50	0.70	0.71
	Section II (S4, 5, 6)	Khan et al. 2008	Urooj et al. 2011	Hussain et al. 2016	Muhammad et al. 2017
Family diversity (H̀)	0.88	3.63	0.93	2.34	3.66
Evenness	0.77	0.74	0.81	0.94	0.55
	Section III (S7, 8)	Mahar et al. 2014	Sheikh et al. 2017	-	-
Family diversity (H̀)	0.94	0.76	1.02	-	-
Evenness	0.85	0.84	0.75	-	-

DISCUSSION

It has been documented that the freshwater ichthyofauna of Pakistan is mainly constitutes of South Asian elements and mixed slightly with North and West Asian species **(Mirza, 1994).** With such scenario, it has been expected that some genera such as Schizothorax, Ptychobarbus, Glyptothorax, Cyprinion and Garra are present in some localities of the Indus River drainage **(Mirza, 1975, 1994).** The results obtained in the present study confirmed the South Asian elements through the fish samples collected

from localities along the Indus River from its north to its southern extremes. On the other hand, the results exhibited the disappearance of certain fish taxa that they are usually live and reported in the Indus River. Among these are the two cyprinid genera Schizothorax and Tor, the members of the family Nemacheilidae, the sisorid genus Glyptosternum, and the bagrid genus Mystus. Also, members of the families, Schilbeidae, Amblycipitidae, Clariidae, Aphaniidae and Cuchiidae. Among the missing marine species are the gobiid genus Boleophthalmus and the cartilagenous family Pristidae.

In all 8 localities studied, the number of mono-specific families is higher than number of families with multi species. Differences in the number of species among related taxa have been an area of interest in the framework of adaptive radiation, where some lineages seem to diversify greatly in phenotypes and, often, in number of species.

At this stage and on the basis of the present study, it is too early to decide that the rapid diversification process in progress in the Indus River area. This is because more comprehensive sampling programme needs to be implemented so that more localities should be included that can represent the whole regions of the Indus River. Also, time frame for sampling should cover the four seasons of the year. For the Indus River estuary in particular, several localities need to be chosen in order to cover the mouth of the river at the entrance and the outlet of the estuary in order to report any primary freshwater fish species that might found in the estuarine area and marine species ascending the river.

The present results showed that the families Cyprinidae and Bagridae are the dominant families in the Indus River. This finding is an agreement with the previous studies on the Indus River in particular and on the Pakistan freshwater fish fauna **(Mirza 1975; Mirza 1994; Khan *et al*., 2008; Urooj *et al*., 2011; Muhammad *et al*., 2017).** For Cyprinidae, the important freshwater family, such dominance can be associated with the origin and evolution of this family in South-East Asia and the spreading of its members westwards in the Tertiary **(Mirza, 1975).** There are three cradles of the family Cyprinidae in Pakistan, these are: the South-East Asiatic, Central Asia and West Asia **(Mirza, 1975).** It is not surprizing the dominance of the speciose family Cyprinidae in Indus River if known that represented by 3122 species encompasses in 376 genera **(Eschmeyer, 2018)**. It has been designated as the most speciose of Indus drainage system containing 70 species **(Rafique, 2000).** The present study also confirms this conclusion with 13 species belonging to Cyprinidae out of 44 species recorded and therefore being the most species.

Among the most represented genera of the family Cyprinidae in the present study is the members of the genus *Labeo*, where 5 species of this genus were recorded. Members of the genus Labeo are mainly distributed in Asia and Africa, with Pakistan having 15 species out of which, 3 species (*Labeo caeruleus, L. gedrosicus,* and *L. macmahoniare* endemic to the south-western Pakistan.

Bagridae is the other dominant family noticed in the present study. It is belong to the order Siluriformes that initiated in the ancient southern continent in the Mesozoic Era before its fragmentation **(Mirza, 1994)** and distinguished and evolved into

diverse groups in South America, Africa and South Asia **(Greenwood *et al.*, 1966).** Bagridae, the most primitive of most silurid species, is one of the 3 families (Schilbeidae and Clariidae) common to Africa and South Asia **(Regan, 1922)** member of which have better tolerance harsh environment, which in turn enable them to find routes for their dispersal **(Myers, 1967).**

The family Bagridae is exemplified in three genera, Rita, Mystus and Sperata. The former is endemic to the Oriental Region and contains one species *Rita rita*, which is distributed in the Indus plain and the adjoining hilly areas. The genus Mystus, is widely distributed in the Oriental Region but is also represented in West Asia as far as Iraq **(Menon, 1960).** The genus Sperata contained 4 species in Pakistan, *Sperata acicularis, Sperata aor, Sperata aorella*, and *Sperata seenghala*. There are 8 species of the genus Mystus in Pakistan, with one species, *Mystus gulio* of partly preferring marine habitats.

The nature of the terrain of the 8 sampling localities chosen is different. It ranges from the mountainous area in the north and down to the Indus River valley plain in the south. With such variation in the environment, fish species content and richness will vary accordingly between these localities.

The subsequent species were appeared to be common among most of the 8 localities studied that extended on the whole length of the Indus River from the north to the south, these are: *Channa marulius, Labeo calbasu, L. catla, Mystus cavasius* and *Sperata seenghala*. These species were found in 7 out of 8 localities studied. They have been documented from different localities in Pakistan **Khan *et al*. (2008); Mahmood and Salam, (1997); Mirza and Ahmed, (1987); Rafique, (2000); Rafique and Khan, (2012).** This proposes a varied range of dispersal of the overhead mentioned species in Pakistan and therefore, the ability to comply with the different habitats.

Less common species among the sampling localities are: *Cirrhinus mrigala*, *Labeo rohita* and *Rita rita* as they appear in 6 or 5 out of 8 of the sampling localities investigated. These species are commercially vital Indian major carps of South East Asian region **(Talwar and Jhingran, 1991).** The least common species that found in one sampling locality are: from north to south, *Cyprinus carpio* and *Systomus sarana* from Manchar Lake, *Labeo gonius, Pethia ticto, Salmostoma bacaila, Sperata aor*, and *Systomus sarana* from Manjhand, *Macrognathus pancalus* and *Puntius chola* from Kotri Barrage, *Channa punctata, Coptodon zillii* and *Heteropneustes fossilis* from Keenjhar Lake. Finally, Kharo Chan is characterised in having the species *Lates calcarifer* and *Valmugil speighleri*. However, The common carp *Cyprinus carpio*, the commercially important, *Sperata aor, Wallago attu* and *Rita rita* are the important cat fishes of this area with considerable fishery value **(Talwar and Jhingran, 1991),** and *Rita rita* has been reported to be common in Indus River **(Rafique, 2000)** were recorded occasionally and found to have little contribution in overall relative abundance (Table I). Their population could be deteriorated due to rigorous fishing. *Oreochromis mossambicus*, a cichlid,

capable of bearing brackish waters **(Rafique, 2000)** was found quite available during study period.

According to **Mirza (1975)**, Manchar Lake is situated in the North-western Montagne region that encompasses the north-eastern part of Baluchistan. This region is characterised in having high elevation, mild summer and cold winter. The presence of the common carp, *Cyprinus carpio* only in this locality can be explained on the basis of aquaculture escape from the nearby ponds to the Manchar Lake**. Mahar *et al.* (2016)** noted that the common carp is generally cultured in lakes in Pakistan including Manchar Lake. **Mirza and Mirza (2014)** reported the presence of the cyprinid species *Systomus sarana* in the upper Indus region, which concurs the Manchar Lake locality. Therefore, the presence of this species in Manchar Lake is not unusual.

The locality Manjhand is located within the Indus River plain and the fish species of this locality are already reported by other investigators **(Mahar *et al.*, 2016; Muhammad *et al.*, 2017)** and partially by **Khan *et al* (2008); Bibi *et al* (2013).**Therefore, it is not unexpected to have the species reported from this locality in this study.

Kotri Barrage locality is found within the Indus River plain that characterised in having mild winter and hot summer. The climatic settings are marine type and the fish faun is mainly dominated by South Asian fish elements **(Mirza, 1995).** The two species, *Macrognathus pancalus* and *Puntius cholathat* have been reported only from this locality are also reported from this region by **Muhammad *et al.* (2017).**

Both localities, Keenjhar Lake and Kharo Chan are situated within the Indus River Plain. The fish elements are belong mainly to South Asian fish group. The species that have been reported from these localities were also reported by **Urooj *et al.* (2011).** The appearance of the marine element such as *Valmugil speighleri* is reported from Kharo Chan locality near the estuary of the river Indus. The presence of the two species *Coptodon zillii* and *Heteropneustes fossilis* from Keenjhar Lake could be explained on the basis that these species favouring the hot and dry weather in the lower reaches of the Indus River plain. Those two species were noted to thrive in regions similar to that of lower Indus River plain **(Al-Hassan and Muhsin, 1986; Tarkan *et al.*, 2015).**

In general, the number of species, genera and families showed to have a trend of increase from north to south of the Indus River extremes (Table 1, Figure 2). This general trend of increase is depicted in the value of the species diversity ($\dot{H}$). This finding is in agreement with the suggestion of **(Mirza, 1975)** and **(Mirza, 2014)** that biodiversity of freshwater fishes of Pakistan increasing from north south.

The evenness value calculated for the 8 sampling localities appeared to be moderate to high and upheld in all localities (0.7255 – 0.9713), except it is rather low at Shikarpur locality (0.5092). The species richness is not all of what we called diversity. The designation of diversity expresses that it is the mixture between richness and

evenness that creates diversity **(Tuomitso, 2012).** The difference in the distribution between the different species in a community is called evenness. The high value of evenness obtained for most of the sampling localities in the present study can be explained that the fish assemblages in these localities have the same distribution resulting in highest possible evenness value. On the other hand, for Shikarpur locality with low evenness value, most of the individuals belong to only little number of species **Hillebrand *et al.* (2008).**

The changes in the value of evenness have a significant bearing on the performance of the ecosystem **(Chapin *et al.*, 2000)** through the effects on the distribution and functions of the species **(Hillebrand *et al.*, 2008).** It will help in envisaging how the ecosystem functions will react to the nonstop shifts in the abundance of the species under anthropogenic pressures. With changes that lead to loss of abundance of a species in the ecosystem, evenness starts to change much earlier than species richness unless this debility is uniform. Therefore, pursuing population evenness will supply early warning indications about the status of the population. The low value of evenness obtained for the Shikarpur locality could be due to the small number of species reported from this locality and at the same time 4 out of 11 species are belong to same family.

The value of Jaccard's dichotomy similarity coefficient between the 8 sampling localities can be grouped in 5 classes, these are: 0.5-0.59, 0.6-0.69, 0.7-0.79, 0.8-0.89 and 0.9-0.99 (Table 4). The two localities, Gudu Barrage and Shikarpur showed the highest value of similarity (0.96). Such similarity reflects the closeness in the number of species and the similarity in the families contains them. These two localities are located in the northern Montana region of Pakistan **(Mirza, 1975),** with similarities in both the environment and the climate. It is clear from the present results that the similarity values obtained between Manjhand and the remaining localities, the similarity values between Kotri Barrage and both Keenjhar Lake and Kharo Chan and between Keenjhar Lake and Kharo Chan are falling within the lower value class 0.5-0.59. It seems that the distribution of the sampling localities has affected this sort of similarities between the localities chosen in the present study.

The 8 sampling stations were grouped into 3 sections, I, II, and III representing northern, middle and southern region of Pakistan in order to reduce the discrepancies between localities for the different biodiversity traits (Table 1, 5). Section II that contains the localities Manchar Lake, Manjhand and Kotri Barrage, showed to have higher number of species, genera and families than the other two sections. This result is represented in the ratios species/families, species/genera and genera/ families (table 1) and in the family diversity value ($\dot{H}$). This variation in fish taxa is in agreement with longitudinal distribution of taxa in Pakistan and gradual changes in the fish faun suggested by **Mirza (2014).** This suggestion is reflected in the high value of evenness, which indicates that fish species are evenly distributed (Table 1).

The value of Jaccard's dichotomy similarity coefficient between the 3 sections showed to be close between the sections representing regularity in the distribution of the fish taxa in the Indus River.

The result of comparison of the values of the family diversity and evenness obtained for section I showed that these two values of section I falling in the range obtained for studies performed in relatively similar localities to those of section I (Table 6). However, the family diversity obtained for section I is smaller than the studies compared with except for those obtained by **Usman *et al.* (2016)**. On the other hand, the value of evenness attained for localities of section I is higher than that gotten from other studied. Values of family diversity and evenness of section II and section III compared with those acquired by studies performed in similar areas in Pakistan have also shown to be positioned within the ranges of these two values attained from the other studies (Table 6). The lower value of the family diversity obtained for sections I, II and III than the comparable studies is due to these factors. First, the present study has performed only one collection at each locality, while other studies have accomplished seasonal sampling from each locality. The second, type of fishing gear used in the sampling technique and the third, variation in the topographic nature of each locality. These factors could bring changes in species content, which lead to differences in family diversity. As to the value of evenness acquired for the 3 sections showed to be higher than that presented by other studies compared. This suggests that the distribution of the species in the sampling localities studied in the present investigation is even. This results in support of the suggestion provided by **Chapin *et al* (2000); Hillebrand *et al* (2008)**.

The present study showed that Ichthyofauna of the Indus River is deprived related to other chief rivers of the Asia viz., Ganges, Brahmaputra, Salween, Mekong, Yangtze and Hawang Ho. There are 400, 350 and 300 species in Mekong, Ganges and Yangtze drainages respectively (Wellcome 1985). Studies also showed that other freshwater bodies in India have higher value of species diversity than the Indus River **(Kaur *et al* (2017); Singh and Johal, (2009)**. The possible explanation for this east-west changes of species diversity is the centre of fish diversity is centred in east Asia and deceased westward **(Mirza, 1975)**.

With such an impact on inland fisheries is distinct improvement projects need to be introduced for supportable use of fisheries assets. One of these heightening projects is the supplying of natural water bodies with the fish seed produced in fish hatcheries. Consequently, fishery invention can be upheld not by natural stocking but by the discharge of hatchery-raised individuals. Likewise, introducing more native species in aquaculture net will enhance the fish production in the country. The potential candidates being the *Tenualosa ilisha*, *Chitala chitala*, *Labeo calbasu*, *Labeo dyocheilus*, *Wallago attu*, *Sperata seenghala*, *Rita rita*, *Clupisoma garua*, *Clarias batrachus*, *Channa marulius* and the cold water schizothoracid snow carps.

The alien species are the chief source of diminution in fish species in many water bodies. The non-native fishes like *Ctenopharyngodon idella*, *Hypopthalmichthys molitrix*, *Cyprinus carpio*, *Oreochromis niloticus* and *Oreochromis mossumbicus* could also have their part in diversity failure of the native ichthyofauna owing to their hostile living act **(Pallewatta *et al.*, 2003).**

In the present study *Oreochromis aureus* and *Oreochromis mossambicus* were the most abundant and most evenly dispersed species, whereas richness and evenness of *Ctenopharynodon idella*, and *Hypopthalmichthys molitrix* are also analogous to the native fishes. From the results of the present study it is seemingly clear that these species are possibly creating sustainable populations. Similar results were obtained by **Ortega *et al.* (2007)** from Peru for the above mentioned introduced fishes. Nevertheless, a wide-ranging study is obligatory for valuation of the complete fish fauna of Pakistan and to examine the role of the invasive fishes if there is any near the declining native fish diversity.

In our research, the maximum length of *H. fossilis* was 24.10 cm in TL which is smaller than 31.0 cm in TL in the Ganga River, India **(Khan *et al.*, 2012)** and 26.80 cm in TL from an earlier study in the Gajner *Beel*, Bangladesh **(Rahman *et al.*, 2019a)**. Knowledge about maximum length is vital to estimate the growth parameters, which is important for development of fisheries resource and their management **(Khatun *et al.*, 2018, 2019; Parvin *et al.*, 2018; Rahman *et al.*, 2019b, Nima *et al.*, 2020).**

Based on **Froese (2006)** *b* values should keep in the range of 2.5–3.5. In our study, all the *b* values are within the predictable range. According to **Tesch (1971)**, *b* values near to 3.0, indicating that fish grow isometric, larger than 3.0 indicate positive allometric and smaller than 3.0 revealed negative allometric. In the current study, over all *b* value was 3.07 that indicate isometric growth of *H. fossilis* in the Gajner *Beel*, wetland ecosystem, NW Bangladesh. Positive growth pattern was observed by **Khan *et al.* (2012)** (*b*=3.14) from the Ganga River, India and **Rahman *et al.* (2019a)** (*b*=3.08) from the Gajner *Beel*, Bangladesh. However, **Hossain *et al.* (2017)**, in an earlier study in the Gajner *Beel* during which period, reported isometric growth (*b*= 3.01), which is in similar with our study.

However, the fluctuation in growth pattern occur because of some factors such as sex, habitat availability, gonad ripeness, level of stomach fullness, seasonal effect, well-being of fish health, preservation method and deviations in the length class **(Hossain *et al.*, 2013, 2018)**, which are not accounted in this study.

Growth of *H. fossilis* was showed significant relation with temperature, DO and pH. Fish is a poikilothermic animal. Habitat temperature controls the fish body growth rate, temperature, food consumption, and various body functions because of fish is poikilothermic animal **(Houlihan *et al.*, 1993; Azevedo *et al.*, 1998; Sigurd *et al.*, 2008)**. Throughout the study, the maximum water temperature was recorded in May (31.0^{o}C) and the minimum was in January (19.0^{o}C). Freshwater fish have an optimum growing

temperature in the range of 25- 30°C **(El-Shebly *et al*., 2007; Shah *et al*., 2008; Hossain *et al*., 2013)**. The *b* value showed a positive correlation with temperature. The highest rainfall was observed in June and no precipitation was occurred in the month of December. Rainfall doesn't show any relation with growth. DO is considered the most vital parameter due to its necessity for aerobic metabolism **(**Timmons *et al*., 2001**)**. DO and pH also revealed correlation with growth. According to Biswas and Panigrahi (2015) desired level of DO is 5.0 to 15.0 mg/l. At least 3.0-5.0 mg/l DO is needed of for survive. Similarly, pH is also considered crucial for any aquatic ecosystem. If the pH value of any aquatic ecosystem is more acidic (pH < 4.5) or more alkaline (pH > 9.5) for long time, growth and reproduction will be diminished **(Ndubuisi *et al*., 2015)**. In our study, the monthly DO level ranged from 4.82 to 8.30 mg/l and pH ranged from 5.58 to 7.65 indicating a suitable habitat for fresh water fisheries resources in the Gajner *Beel*, (NW) Bangladesh.

CONCLUSION

It is concluded that the disappearance of certain fish taxa that they are usually live and reported in the Indus River but, the absence of these taxa from the present result can be contributed to the factors of, time of collection, type of fishing gear and the locality. Each type of fishing gear has its own level of selectivity, which is important to catch fish samples. The nature of the terrain of the 8 sampling localities chosen is different. It ranges from the mountainous area in the north and down to the Indus River valley plain in the south. With such variation in the environment, fish species content and richness will vary accordingly between these localities. Sustained populations of exotic fish species were shown to have established in the Indus River. Conservation measures and suggestions were discussed to save the fish fauna in the Indus River.

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