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Decreased fish diversity found near marble industry effluents in River Barandu, Pakistan

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Abstract In a recently published study we observed that effluents from marble industry affected physicochemical characteristics of River Barandu in District Buner, Pakistan. These changes in water quality due to marble effluents may affect fish community. The present study was therefore conducted to evaluate the impacts of marble industry effluents on fish communities in River Barandu using abundance, richness, diversity and evenness of fish species as end point criteria. The fish samples were collected by local fishermen on monthly basis from three selected sites (upstream, effluents/industrial, and downstream sites). During the study period, a total of 18 fish species were found belonging to 4 orders, 5 families and 11 genera. The Cyprinidae was observed to be the dominant family at all the three selected sites. Lower abundance and species diversity was observed at the industrial (22 %) and downstream sites (33 %) as compared to the upstream site (45 %). Effluents of marble industry were associated with lower abundance of species in River Barandu. It is recommended that industries should be shifted away from the vicinity of river and their effluents must be treated before discharging to prevent further loss of fish abundance and diversity in the River.

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Introduction

Freshwater resources across the world are facing serious pollution problems due to various anthropogenic activities, mainly the indiscriminate disposal of waste effluents. These activities, particularly in developing countries, have caused the degradation of aquatic environments which change the physiology and ecology of aquatic biota (Khanna and Ishaq 2013). Contamination makes the water inappropriate for drinking, agriculture, recreation and industry as well as reduces its aesthetic quality. Water contamination with heavy metals is a severe threat in terms of their toxicity, biomagnifications and bioaccumulation in the food chain (Alturiqi and Albedair 2012). In the last century, the environmental degradation and habitat loss, mainly in water where substantial demand on freshwater occurs, has endangered several aquatic species (Galib et al. 2013).

Due to the increasing surface water pollution and overfishing, fish richness and diversity are rapidly declining and many species have become extinct (Pompeu and Alves 2003; Pompeu and Alves 2005; Shukla and Singh 2013; Mohite and Samant 2013; Joshi 2014). Migratory fish are also declining because of factors like hydropower advancement, invasive species, pollution and climate change (Bower et al. 2014).

The fish fauna of Pakistan is characterized by at least 193 freshwater fish species belonging to 13 orders, 30 families and 86 genera (Rafique 2007). Among them, 86 species (8 exotic and 78 indigenous) have been documented as "species of special importance", in which a minimum of 31 species are important economically

(Rafique and Khan 2012). The increasing pollution of water is rapidly affecting the habitat use by many fish communities in Pakistan (Rafique and Khan 2012). Assessment of water samples from the river Indus in Pakistan showed that effluents from Dera Ismail Khan influenced the physicochemical and ecological characteristics of the River Indus (Azizullah et al. 2014). Recently, Ahmad et al. (2014) concluded that effluents discharges caused an increase in metal accumulation in water and in different tissues of fish in River Panjkora in Pakistan.

In Pakistan, 1228 out of 6634 registered industries are considered to be extremely contaminating (Sial et al. 2006; Azizullah et al. 2014). Due to a release of various organic and inorganic toxic effluents, these industries are a main source of water contamination in Pakistan (Nasrullah et al. 2006; Yousafzai et al. 2008; Yasar et al. 2015). The most important industries contributing to water pollution in Pakistan are pharmaceuticals, petrochemicals, textile, leather tanning, ceramics, steel, oil mills, food industries, sugar industries, fertilizer factories, and marble industries (Sial et al. 2006; Tariq et al. 2006; WWF 2007; Yousafzai et al. 2008). Most of the industries in Pakistan dispose their waste effluents directly into the nearby drains, agricultural land, ponds, streams and most importantly in the adjoining rivers (Ullah et al. 2009; Mulk et al. 2015). For instance, the Kabul River in Khyber Pakhtunkhwa receives round about 80,000 m^3 industrial effluents every day (MOE-PAK 2005). Likewise in the capital Islamabad, the Sawan River receives waste effluents from its two industrial estates without any proper treatment (Mian et al. 1998). In Pakistan, it has been calculated that only about 1 % of industrial wastewaters are treated before being released (MOE-PAK 2005). The industries are producing large amounts of wastewater containing enormous number of organic and inorganic pollutants for example toxic metals including chromium, copper, arsenic, cadmium, mercury, cobalt, zinc, nickel and lead. Additionally, the effluents also causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), and salinity (Azizullah et al. 2014; Mulk et al. 2015).

It has been estimated that Pakistan has over 297 billion tons of marble resources with over 100 varieties and colors (SBI 2010). It is a significant constructive material and plays an important role in the economic and aesthetic development of the country (Mulk et al. 2015). But at the same time it is one of the major sources of water pollution as 70 % of marble resources get wasted in the mining, polishing and cutting processes which ultimately cause pollution of the surrounding environment (Aukour and Al-Qinna 2008). Shakir and Qazi (2013) concluded that industrial pollution adversely affects fish growth in Pakistan. Another study reported that fish assemblage was severely affected at polluted area of Nullah Palkhu and Nullah Aik in Sialkot, Pakistan (Qadir et al. 2009). Fish habitats are being polluted with various aquatic pollutants which are hazardous to fish populations (Shaheen and Jabeen 2015) and ultimately cause the shortage of aquatic animal protein (Lu et al. 2015). The industrial effluents have large amount of toxic metals posing hazardous impacts to fish fauna which also leads to serious human health concern (Ambreen et al. 2015). In a recent study Majeed et al. (2015) concluded that the water of selected ponds in four districts of Baluchestan province of Pakistan was safe for the reproduction and growth of fish fauna because there is no any industry located nearby. But on the other hand fish species communities and other aquatic biota is adversely affected by rapid industrial pollution in Pakistan (Yasar et al. 2015). In a recently published study we observed that waste effluents from the marble industry affected physicochemical characteristics of water and cause an increased heavy metal contamination in River Barandu (Mulk et al. 2015). It is possible that changes in the quality of river water due to discharging of marble effluents affect fish communities in River Barandu. Therefore, the present study was conducted to evaluate the impacts of the marble industry effluents on fish communities in River Barandu, Pakistan by measuring species diversity, evenness, and abundance of fish species.

Materials and methods

Study area

Buner is a district in Malakand division of Khyber Pakhtunkhwa province in Pakistan. It geographically lies between 34°9′ and 34°43′N latitude and 72°10′ and 72°47′E longitude. On the North it is bounded by Swat, on the East by Hazara division and River Indus, on the South by district Mardan and on the West by Malakand Agency (Fig. 1). River Barandu is the main water source of the district. It provides habitat to a number of important aquatic organisms (Said 2000) and is the major source of water for drinking, irrigation and industries (Said 2000; Mulk et al. 2015).

Sample collection

Fish samples were collected from three different sites (1 km upstream, industrial, and 1 km downstream sites) of the River Barandu from April to November 2012. A distance of one km was kept from industrial site towards each site. The local fishermen were guided for use of scientific ways to sample the specimens. A majority of the collected fish were identified at the point of capture and were

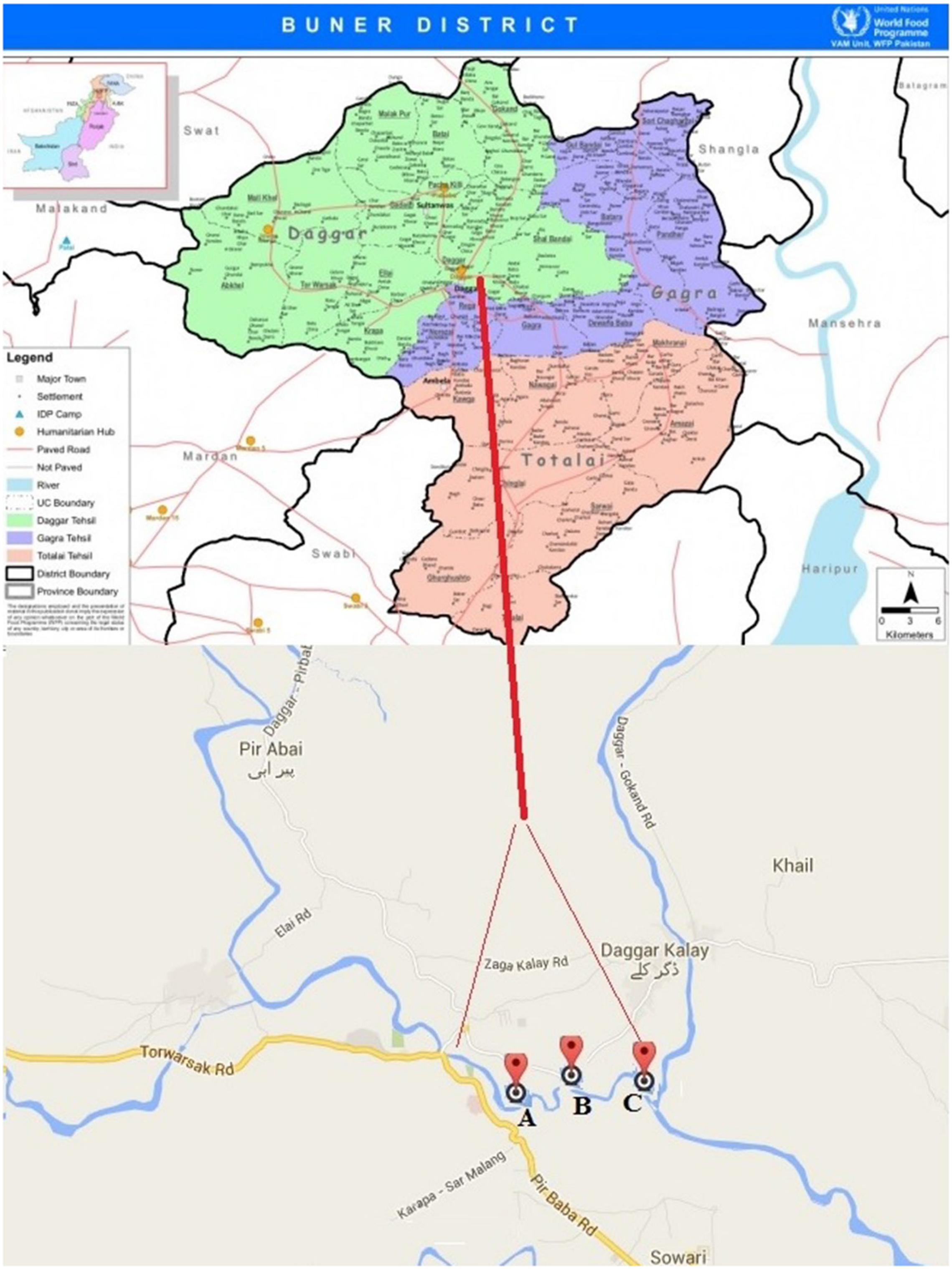

Fig. 1 Map of District Buner (WFP 2009): sampling sites *a* upstream, *b* industrial, *c* downstream site

released back into the river. The unidentified specimens were transported to the laboratory for identification according to Talwar and Jhingra (1991) and/or Mirza and Sadhu (2007).

Data analysis

The mean, standard deviation and percentage were calculated. One-way ANOVA using SPSS software was used to determine significance of differences among different data sets. The species abundance was calculated simply by taking the sum of all the individuals and species richness by counting the number of all the species caught during the study period. Indices were calculated adopting the method used by Vijaylaxmi et al. (2010) and Kamaruddin et al. (2011). Three community indices including species diversity, species evenness, and species richness were applied to determine fish community. Species diversity was determined using Shannon–Weaver diversity index (Shannon and Weaver 1963) and Simpson's index of diversity (Simpson 1949). Species evenness was determined according to Pielou (1969).

Results

Fish classification

During the whole study period, 18 species of fish were identified which belonged to four orders, five families and 11 genera (Table 1).

Monthly variations

Monthly variations were observed in all fish species. At all the three sites a general trend was observed where more species were collected in August/September, and less species were collected in April (Fig. 2).

Percentage and diversity indices of fish communities

During the present study period (April–November 2012), a total of 1726 fish specimen were collected from River Barandu. The number of collected specimen at upstream was 771 (45 %) whereas the number of specimens at the industrial site was 381 (22 %), and the number at the downstream site was 574 (33 %) (Table 2). Among the collected species, *Puntius sophore* was found to be the most dominant fish species with 198 (11 %) specimen of the total collected specimen. It was further observed that some species (*Ctenopharyngodon idella*, *Glyptothorax punjabensis*, *Glyptothorax cavia*) were totally absent at the industrial site. All other collected species had a lower abundance at the industrial site as compared to the other two sites and a lower abundance at the downstream site as compared to the upstream site (Fig. 3). The abundance of *Barilius pakistanicus*, *Barilius vagra*, *Tor putitora, P. sophore*, *Puntius ticto*, *Puntius conchonius, Schistura punjabensis, S. pakistanicus, G. punjabensis* and *Mastacembelus armatus* were found to be significantly lower at the industrial site as compared to the upstream site. Furthermore, the population of *P. sophore* was also significantly higher at the upstream site than the industrial and downstream sites, while *S. punjabensis* was significantly lower at the industrial site as compared to the other two sites of River Barandu (Fig. 3).

Different indices calculated for the three sites showed variations. The Shannon diversity index (H) at the upstream site was 2.62, at the industrial site was 2.53 and

Table 1 Classification of fish species caught at River Barandu during April–November 2012

S. No	Order	Family	Genus	Species
1	Cypriniformes	Cyprinidae	*Tor*	*putitora*
2				*macrolepis*
3			*Schizothorax*	*esocinus*
4				*plagiostomus*
5			*Barilius*	*pakistanicus*
6				*vagra*
7			*Puntius*	*sophore*
8				*ticto*
9				*conchonius*
10			*Garra*	*gotyla*
11			*Chrossochielus*	*diplochielus*
12			*Ctenopharyngodon*	*idella*
13		Balitoridae	*Schistura*	*punjabensis*
14				*pakistanicus*
15	Siluriformes	Sisoridae	*Glyptothorax*	*Punjabensis*
16				*cavia*
17	Mastacembeliformes	Mastacembelidae	*Mastacembelus*	*armatus*
18	Channiformes	Channidae	*Channa*	*gachua*

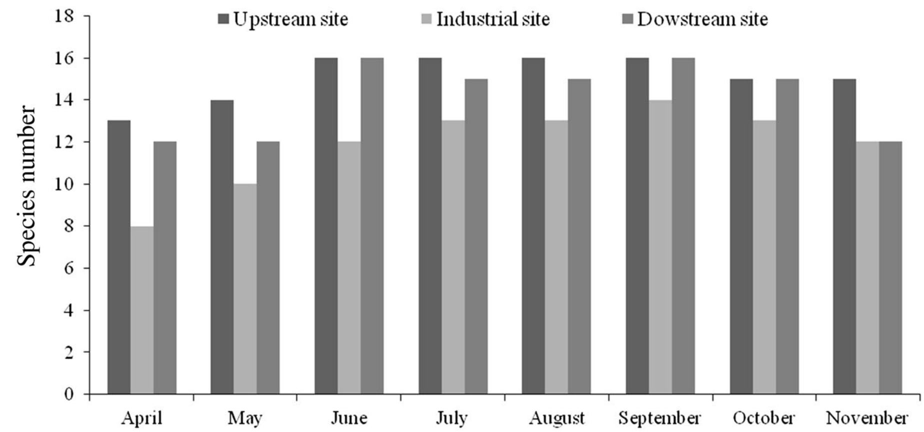

Fig. 2 Monthly variations in fish diversity in River Barandu

Table 2 Percentage and diversity indices of fish species at the three sampling sites of Barandu River from April to November 2012

	Upstream *n* (%)	Industrial site *n* (%)	Downstream *n* (%)	Total
Number and %	771 (45)	381 (22)	574 (33)	1726 (100)
Species abundance	18 (100)	15 (83)	18 (100)	
Shannon H	2.62[a]	2.53	2.62[b]	0.69
Simpson 1-D	0.92	0.91	0.92	0.64
Pielou's Evenness J	0.39[c]	0.43	0.41	0.09

Significant difference ($P < 0.05$)

[a] Upstream site is higher than industrial site

[b] Downstream site is higher than industrial site

[d] Industrial site is higher than upstream site

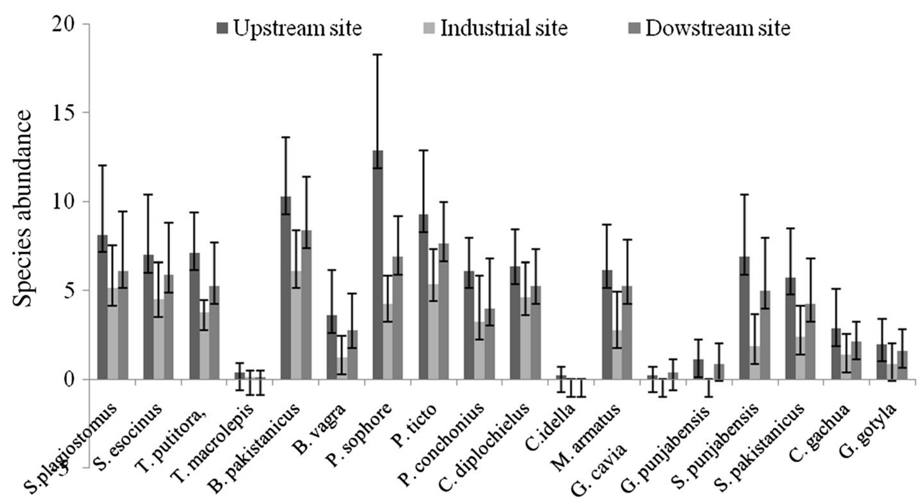

Fig. 3 Means ± SD of variation of all the species at three sites (upstream, industrial, and downstream site)

at the downstream site was 2.62. In Shannon diversity index (H), the upstream and downstream sites were higher than industrial site. The Simpson diversity index (1-D) at the upstream and downstream sites was 0.92 while at the industrial site it was 0.91. The Pielou's Evenness (E′) at the upstream, industrial and downstream sites was 0.39, 0.43 and 0.41, respectively. In species evenness, the industrial site was found higher as compared to the upstream site. For the total population of fish at all the three sites, Shannon diversity index was 0.69, the Simpson diversity index was 0.64 and the Pielou's Evenness was 0.09 (Table 2).

Discussion

Although River Barandu is the most important water source of the District Buner, studies on the impact of anthropogenic activities on its biota are lacking. The present study will provide a base line for future research while exploring the fish fauna and impact of pollution on fish populations in River Barandu.

During the present study period (April–November, 2012), a total of 1726 fish specimens were collected and were identified to 18 species. In a previous study, Saeed et al. (2013) identified 11 species in River Barandu. Recently Khattak et al. (2015) identified 24 fish species from River Kabul. Mirza (2007), Yousafzai et al. (2013) and Hasan et al. (2013) reported 39, 38 and 35 fish species, respectively in river Swat, a River in the nearby district of Buner. The comparatively higher number of fish species in River Swat is because it is a relatively larger river and passes through a variety of ecological zones from Kalam (Swat) to River Kabul (Charsadda). Mirza et al. (2011) also reported a higher number of fish species (51 species) in River Jhelum. This is also a comparatively larger and lengthy river in Pakistan passing through diverse environmental conditions.

In the present study, family Cyprinidae was found to be the dominant family in River Barandu represented by 12 species. These findings are strongly supported by previous studies in the area. For example, Cyprinidae was reported to be the richest family in the river Swat of Pakistan (Yousafzai et al. 2013; Hasan et al. 2013). In River Jhelum of Pakistan also the most abundant family was Cyprinidae which represented 67 % of the total fish population (Mirza et al. 2011). The family was also dominant in the recent study on River Kabul (Khattak et al. 2015). The present study showed that the fish fauna of the River Barandu is composed of taxa that are common to those in many Southeast Asian riverine ecosystems. The river systems of Southeast Asia including the Indian subcontinent are dominated by Cyprinidae (Bhat 2003).

Variations in species richness and diversity were observed among different months and study sites. The monthly variation can be attributed to temperature and seasonal changes. Fish assemblage was greater at all sites during the warm season of May to October as compared to the cooler months from November to April. This may reflect a tendency of several species to occur in higher densities during summer spawning or a greater availability of prey items leading to higher feeding densities (Idelberger and Greenwood 2005). The monthly variations in the present study were in agreement with many previous studies in different parts of the world (Comp and Seaman 1985; Maes et al. 1998; Tsou and Matheson 2002; Idelberger and Greenwood 2005). Water temperature, dissolved oxygen and rainfall were regarded as major influential factors in fish species distribution (Hossain et al. 2012; Sohail et al. 2014). In a recent study on River Kabul a similar monthly variation in fish species was reported (Khattak et al. 2015). This similarity is probably due a similar fish fauna at both the river and due to similar monthly variation in temperature at both the river (Khattak et al. 2015; Mulk et al. 2015).

The highest species diversity in the present study was found at the upstream site and the lowest was at the industrial site. Total 18 species were collected at the upstream site, 15 at the industrial site and 17 at the downstream site. Three fish species (*C. idella*, *G. cavia* and *G. punjabensis*) were not observed at the industrial site and only a single specimen of *T. macrolepis* was found at the downstream site. Similarly, *C. idella* was missing at the downstream site during the present study period. This may be attributed to industrial effluents discharging to the river which affect its water quality. At the downstream site before the fish collection site the majority of the marble effluents settle down to the bottom of the river, this may be the reason that fish assemblage was recovered up to some extent over there. In a recent study we reported that marble industry effluents caused significant alteration in different water quality parameters including TSS and several metals in River Barandu (Mulk et al. 2015). High TSS due to industrial effluents reduces the visibility of fish in water and affects the ability to hunt for food which ultimately affects the growth and feeding behavior. TSS has also been shown to retard development of unhatched embryos and larval fish as well as disrupt normal respiration by occluding gill filaments (Mitchell and Stapp 1992). Streams usually exhibit variations in population distribution from upstream to downstream, which is more remarkable in the case of streams receiving untreated industrial and municipal effluents (Postel and Richter 2003).

Economically important fishes of the study area are *S. esocinus, S. plagiostomus, T. putitora, T. mecrolepisand C. idella*. According to IUCN, *T. putitora* is declared endangered, *S. plagiostomus* is vulnerable and *M. armatus* is of least concern (IUCN 2011). Other species identified in the present study were not evaluated by IUCN (Rafique and Khan 2012). The presence of some species (*T. mecrolepis, C. idella, G. cavia, G. panjabensis*) in fewer number in River Barandu leads us to speculate that the species are rare or nearly extirpated in this specific water distribution. Literature survey reveal that wherever the research on fish faunas has been conducted, more species than suspected figures pointed out to be threatened or cannot be re-collected at all (IUCN 1996; Stiassny 1996; Emmanuel and Modupe 2010).

The fish assemblages have been used as environmental indicators to measure and evaluate the extent of habitat degradation in rivers or streams (Zampella et al. 2006). For a better description of fish diversity, a measurement of species richness and evenness of their distribution at the three selected sites was made. At upstream site species richness (18) and abundance (771) were higher as compared to the other two sites. The Shannon diversity index (H) and Simpson diversity index (1-D) at the upstream site were slightly higher than at the industrial site. Shannon–Weiner index (H) reflects both number of species and evenness of their population, i.e., diversity increases as both increases. Diversity will be the maximum when all species that made up the community have similar population sizes (equally abundant). The diversity is relatively a function of the variety of habitats; the more diverse habitats have a tendency to be populated by a huge number of species than the less variable one (Emmanuel and Modupe 2010). The Simpson's index of diversity (1-D) represents the probability that two individual fish randomly selected from a sample will belong to different species. Simpson's index of Diversity (1-D) value ranges between 0 and 1, the greater the value, the greater will be the sample diversity (Vijaylaxmi et al. 2010). In our study the Simpson's index of Diversity (1-D) were the same (0.92) with a slight decrease at the industrial site (0.91). The Pielou's Evenness (E′) was the lowest at the upstream and the highest at the industrial site but the difference was not significant. Pielou's Evenness (E′) value also ranges from 0 and 1, the lowest the value the highest will be the evenness in species and vice versa. The diversity index (1-D) indicated that the population at the three studied sites was almost similar. This was because all the species declined at the industrial site but still this site was also divers and with the exception of three species all others species were found there. Pielou's Evenness represented that the evenness in species was low. This is because some species were found in higher number while the others were less in number. The reason for the highest evenness at the industrial site can be that some fish species were totally absent at this site. The ecological indices in the present study are supported by the report of Vijaylaxmi et al. (2010) for Bheema River of Gulbarga district, Karnataka. All the indices were slightly affected by industrial effluents. Similar to the present study, Khanna and Ishaq (2013) attributed the low species diversity of fishes in River Asan (India) to the discharges from industries, high rate of sedimentation and pollution due to domestic and commercial wastewater. This study is also supported by a recent study which reported that fish diversity and abundance in River Kabul were significantly lower at polluted site (Nowshera) due to the acidic pH and high TSS (Khattak et al. 2015). Bunn and Arthington (2002) reported that various types of riverine ecosystems have been gone and populations of several species have become highly uneven due to human interference. It is estimated that population of the fish species has already declined by more than 50 % in the past and if the current trends continue, the population may decline even up to 80 % in the future (IUCN 2011; Rafique and Khan 2012).

In 1992 legislation of National Conservation Strategy (NCS) of Pakistan was approved, while in 1997 for the control of pollution and environment protection, Pakistan environmental protection act (PEPA) was implemented. In PEPA minimum limits of effluents discharge were identified according to national environment quality standards (NEQS). Legislation implementation was the most difficult task in environmental protection of the country. For implementing NEQS, self monitoring and reporting (SMART) program was begun in consultation with representatives of industry, government, NGOs and research development institutions. This system influences industries to observe their environmental performance and report to provincial environment protection agencies (EPAs). Industries are made legally and socially bound to take preemptive measures (Ali et al. 2015). But due to lake of awareness and education in the area marble industries are constantly discharging their effluents without treatment. In this regard there is also lacking of any published data that EPA took action against it.

Due to the lack of previous data on fish abundance and diversity in this river, it is difficult to measure the rate of decline in diversity in the present study but this article would be helpful as a reference for assessment in future. This research could serve as a baseline data to high authority in the management and conservation of habitat for the fish and other aquatic fauna of River Barandu in district Buner of Pakistan.

Conclusions

It can be concluded from the present study that River Barandu provides habitat to a variety of fish fauna. But the marble factories located in its vicinity discharge huge quantity of untreated effluents into it, which badly affects its biota. There was low species diversity and abundance of fish at the industrial site as compared to the other two sites. Three species were completely missing at the industrial site. This study provide clue for the association between the marble industry effluents and the decrease in fish abundance in River Barandu. It is recommended that the marble industry should be shifted away from the river and their wastewater must be treated before discharging. Government must take instant action for awareness and education of the locals and to regulate fishing and industry in the area. Regular studies should be conducted to monitor fish diversity and impact of pollution on fish fauna in River Barandu.

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Compliance with ethical standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Statement All applicable guidelines for the care and use of animals were followed.

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