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continued on the back inside cover

Caption: Stripe-backed Weasel *Mustela strigidorsa*. Medium—digital, Software—procreate, Device—iPad + Apple pencil © Dhanush Shetty.

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COMMUNICATION

Evaluation of fish diversity and abundance in the Kabul River with comparisons between reaches above and below Kabul City, Afghanistan

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Abstract: The fish fauna of the Kabul River downstream of the City of Kabul face threats from increasing human population such as pollution, overfishing, and increased development. Despite the rapid increase of these activities leading to threats to fishes in the Kabul River, no studies have examined the changes in diversity, distribution, and abundance of fish fauna in the Kabul River surrounding of Kabul City. In this study, the Kabul River was divided into two zones (upstream and downstream) consisting of six sampling sites (3 sites per zone). Of the total of 1,190 fishes collected, Cypriniformes was the dominant order with one family, six genera, and eight species. Cyprinidae was the dominant family of that order with 81.4% (*n*= 969) of total individuals. Species abundance was higher in the upstream reaches in almost all analyses. Upstream sites recorded 11 species, while seven species were recorded from downstream sites. Fish species richness was significantly higher upstream versus downstream reaches (9.67 ± 1.53 vs. 6.33 ± .58; U= .00, z= -1.99, p= .04, r= .81). Species diversity upstream was significantly higher than downstream (H'= 1.90 ± 0.15, D_1= 0.81 ± 0.02). Similarly, species evenness was also higher upstream than downstream (J'= 0.84 ± 0.01). Low diversity, abundance, and evenness in downstream reaches are likely due to anthropogenic activities affecting the river in and around Kabul City.

Keywords: Anthropogenic, diversity indices, native species, pollution, species composition.

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Author contributions: UK performed a compilation of data, analysis, interpretation, and wrote the first draft of the manuscript. AFH did all fieldwork like field sampling and field data collection. RJT reviewed and edited the first draft of the manuscript. All authors reviewed and incorporated all the comments received from the reviewers and incorporated them in the manuscript. Before submitting, all authors read and approved the final version of the manuscript.

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INTRODUCTION

Fishes are the most diverse and abundant group of vertebrates in the world (Powers 1989; Ravi & Venkatesh 2008), making up nearly 50 % of all vertebrate diversity. Further, fishes are important keystone species in many ecosystems and exhibit diverse behaviours and ecologies (Spencer & King 1984; Allan 2004; Dudgeon et al. 2006; Wu et al. 2014). They play important roles managing balanced trophic dynamics within a system. Additionally, fishes contribute to food security throughout most of the world, making up as much as 17 % of the world population's protein intake (Bennett et al. 2018) and fishing is one of the most common livelihoods globally (FAO 2014).

An assessment done by the International Union for Conservation of Nature (Reid et al. 2013), on more than 5,000 species, reported that freshwater fishes are the most threatened group of vertebrates in the world. The Himalayan region holds a variety of both warm and cold-water fishes (Jayaram 2010). Coad (2015) reported that there are 85 species of fishes belonging to 10 families in the landlocked country of Afghanistan, however, FishBase.org (2020) reports 125 species (all freshwater species) known to occur in Afghanistan – a gulf that reflects the paucity of reliable data on fish diversity in Afghanistan. Though, several studies on the fishes have been conducted throughout different regions of the Himalaya (Vishwanath et al. 1998; Shrestha 1999; Goswami et al. 2007; Jayaram 2010; Gurung et al. 2013; Thoni & Gurung 2014; Gurung & Thoni 2015; Prasad et al. 2020), in Afghanistan, such studies are very limited in scope and number, despite the fact that several fishes found in the country are endemic and likely threatened (UNEP 2003). In order to preserve biodiversity in a given area, we must understand what the diversity is and how it is impacted by different resource uses, development processes, and management strategies.

The Kabul River is home to a diverse fish community including the globally endangered Golden Mahseer *Tor putitora* (UNEP 2008). The Kabul River is mainly used for irrigation, waste disposal, watering livestock, and fishing. The river runs through the most densely populated areas of the city. In the Kabul River, water pollution is a significant threat to the freshwater ecosystem (Weir 2018). The United Nations Environment Protection (UNEP 2003) reported pollution of the Kabul River in the city of Kabul mainly by the release of industrial effluents, domestic waste, and development activities. To date no biodiversity indices-based research efforts on fish fauna have been carried out in Afghanistan. Hence, this study aims to assess the diversity, distribution, and abundance of fish fauna in the Kabul River downstream of Kabul City compared to upstream.

MATERIAL AND METHODS

Study area

This study was conducted along reaches of the Kabul River above and below Kabul City, located at 34.542°N 68.803°E, at an elevation of 1,791 m (Figure 1). The study area was divided into two different zones: upstream, and downstream. Three sampling sites each from each zone were selected to sample fish (Figure 1; Table 1). Four sampling replicates were taken in each sampling sites, keeping 400 m distance between sampling replicates. Sites were selected to ensure that similar habitat types were represented in upstream and downstream reaches. Fish sampling was carried out between December 2019 to June 2020 by using nets (mesh sizes ranging from ½ inch to 2.5 inch) both in upstream and downstream reaches. We used different mesh sizes of nets so as to minimize the bias in sampling fishes of numerous sizes due to specific gears.

The area receives 312 mm of precipitation on an average annually, with rarer precipitation in the summer months (NEPA 2007). Average annual temperature of the area ranges from 4.3 °C to 19.6 °C, with approximately 12.4 °C to 32.1 °C during summer months and -7.1 °C to 8.3 °C in winter months (Broshears et al. 2005). The area is densely populated (Mack et al. 2009), with much of the non-wood forest product industry (mainly fruits and tree nut farming and industry) dependent upon the Kabul River and its tributaries for the disposal of effluents (dyes, metals, and minerals). A population of roughly 3–5 million people live in the greater Kabul area (Barbè 2013).

Fish sampling

Using the expertise of the local fishermen, ichthyofaunal sampling was done in the selected sampling sites. Fishes were collected using gill nets and fish traps for two days in each sampling site. Fishes were counted, photographed, and identified up to the species level when possible, before being released back into the river. Species that were not readily identified by the project team on site were photographed and all diagnostic data required for identification were taken for further identification and referred to available literature. Taxonomic studies of the fish fauna collected from this study were performed following Mishra (1959), Talwar &

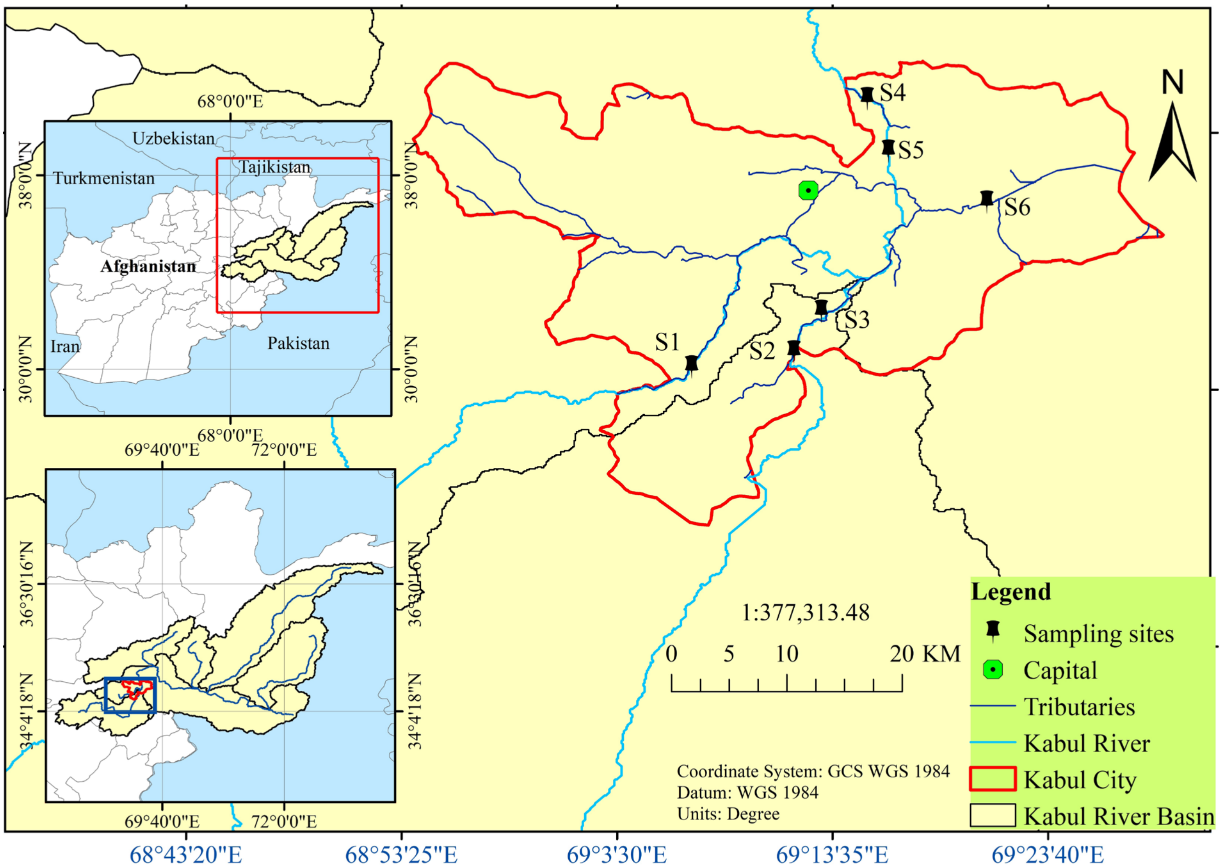

Figure 1. Map of the study area showing sampling sites, Kabul River and its tributaries, and Kabul City, Afghanistan.

Jhingran (1991), Jayaram (1981, 2010), and Coad (2014, 2015).

Analysis of data

A Mann-Whitney test, comparing species diversity and abundance was performed using IBM SPSS Statistics 23.0 to examine differences in species abundance and diversity between upstream and downstream locations. Dendrogram of Bray-Curtis coefficients of similarity (Bray & Curtis 1957) and rank abundance plots of sites were generated using BioDiversity Professional version 2.0 (McAleece 1999). As there seems to be no single diversity index more appropriate than another (Morris et al. 2014), several common diversity indices were tested. Shannon diversity index (Shannon & Wiener 1949), Simpson's diversity (Pielou 1969), Pielou evenness index (Pielou 1975), Margalef's richness index (Margalef 1958), Menhinick's index (Menhinick 1964), and Sorensen's similarity coefficient (Dice 1945; Sørensen 1948) were calculated using the following formulae:

(a) Shannon diversity index: $H' = -\sum_{i=1}^{n} p_i \ln p_i$

where p_i = the proportion of individuals belonging to the i^{th} species.

(b) Simpson's diversity: $D_1 = 1 - \sum_{i=1}^{n} {p_i}^2$

where p_i = the proportion of individuals belonging to the i^{th} species.

(c) Pielou evenness index: $J' = \frac{H'}{LnS}$

where H' = Shannon diversity index; S= species richness.

(d) Margalef's richness index: $D_{Mg} = \frac{S-1}{Ln(N)}$

where S= species richness; N= total number of individuals.

(e) Menhinick's index: $D_{Mn} = \frac{S}{\sqrt{N}}$

where S= species richness; N= total number of individuals.

(f) Sorensen's similarity coefficient: $CC = \frac{2C}{S1+S2}$

where C= number of species the two communities

Figure 1. Map of the study area showing sampling sites, Kabul River and its tributaries, and Kabul City, Afghanistan.

Sampling zones	Sampling sites	Geographic coordinates		Elevation (m)
		Latitude (D.M.S)	Longitude (D.M.S)	
Upstream	S1	34.41746°N	69.11657°E	1,919
	S2	34.42923°N	69.19619°E	1,814
	S3	34.4609°N	69.21761°E	1,797
Downstream	S4	34.62652°N	69.25344°E	1,761
	S5	34.58567°N	69.27003°E	1,782
	S6	34.54591°N	69.34672°E	1,776

have in common; *S1*= number of species in community one; *S2*= number of species in community two.

The initial data entering, data cleaning, data coding, calculation of some descriptive analyses, and generation of charts were conducted using Microsoft Excel 2016. The map of the study area was produced using ArcMap version 10.5.

RESULTS AND DISCUSSION

Fish composition

A total of 1,190 fishes were collected (Table 2) from the study area. Out of the total of all fishes across both zones, 81.4 % (n= 969) of belong to the order Cypriniformes, 18.2 % (n= 216) to Salmoniformes, and 0.4 % (n= 5) to Cichliformes (Figure 2). This is in line with the research carried out by Saund et al. (2012) in the Mahakali River, Nepal, where they have reported Cypriniformes as the most dominant order. Studies conducted by Shendge (2007), Aryani (2015), and Akhi et al. (2020) have reported similar community structures. However, the aquatic habitats of Afghanistan are less conducive to and are geographically isolated from many of the more diverse groups of Asian Siluriformes, resulting in our relatively low diversity of catfishes. Cyprinids can live in cold waters, tolerate very low oxygen levels, and exhibit a broad range of trophic guilds (Royce 1996). Hence, combined with historical processes, they are typically found to be more dominant in freshwater habitats throughout most of the Asian continent.

The order of Cypriniformes was represented by one family, six genera, and eight species. The second most abundant order, Salmoniformes, was represented by one family, two genera, and two species. Cichliformes was only represented by a single species. Among families, Cyprinidae was the most dominant within the study area, and Salmonidae was second most dominant family. Similarly, Dau & Parkash (2009), Cunico et al. (2011), Choubey & Qureshi (2013), Mohsin et al. (2013), Hu et al. (2019), and Herawati et al. (2020) reported Cyprinidae as the dominant family in regional censuses throughout much of Asia.

Among the predominant fish families, Cyprinidae is one of the most diverse (Boschung & Mayden 2004; Shen et al. 2016) and pollution-disturbance-tolerant families, with more than 2,000 species and 210 genera (Barbour et al. 1999; Grabarkiewicz & Davis 2008). Their ability to survive in unclean habitats validates their dominance in the most polluted part of the Kabul River (Kabul city and downstream reaches).

Species abundance

Within the upstream sites, *Schizothorax sp.* was highly abundant at sites S2 (n= 76) and S3 (n= 117) followed by *Schizothorax esocinus*. At S1, *Oncorhynchus*

Table 2. Overall fish species composition in Kabul River under Kabul City.

Family	Species	N	%
Cyprinidae	*Alburnoides holciki*	90	7.6
	Ctenopharyngodon idella	54	4.5
	Cyprinus carpio	36	3.0
	Hypophthalmichthys molitrix	81	6.8
	Schizothorax esocinus	228	19.2
	Schizothorax sp.	420	35.3
	Tariqilabeo diplochilus	48	4.0
	Tariqilabeo sp.	12	1.0
Salmonidae	*Oncorhynchus mykiss*	198	16.6
	Salmo trutta	18	1.5
Cichlidae	*Coptodon zillii*	5	0.4

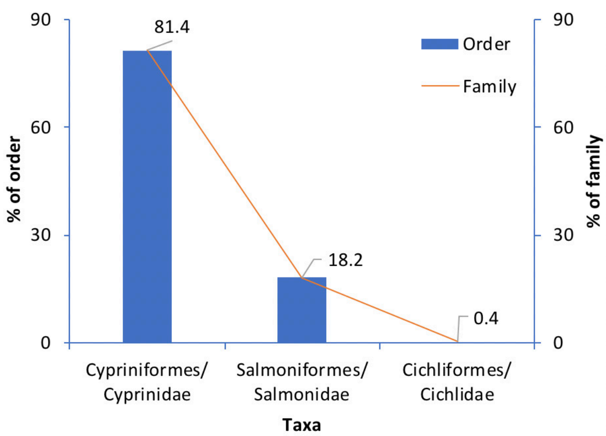

Figure 2. Composition of fishes based on order and family.

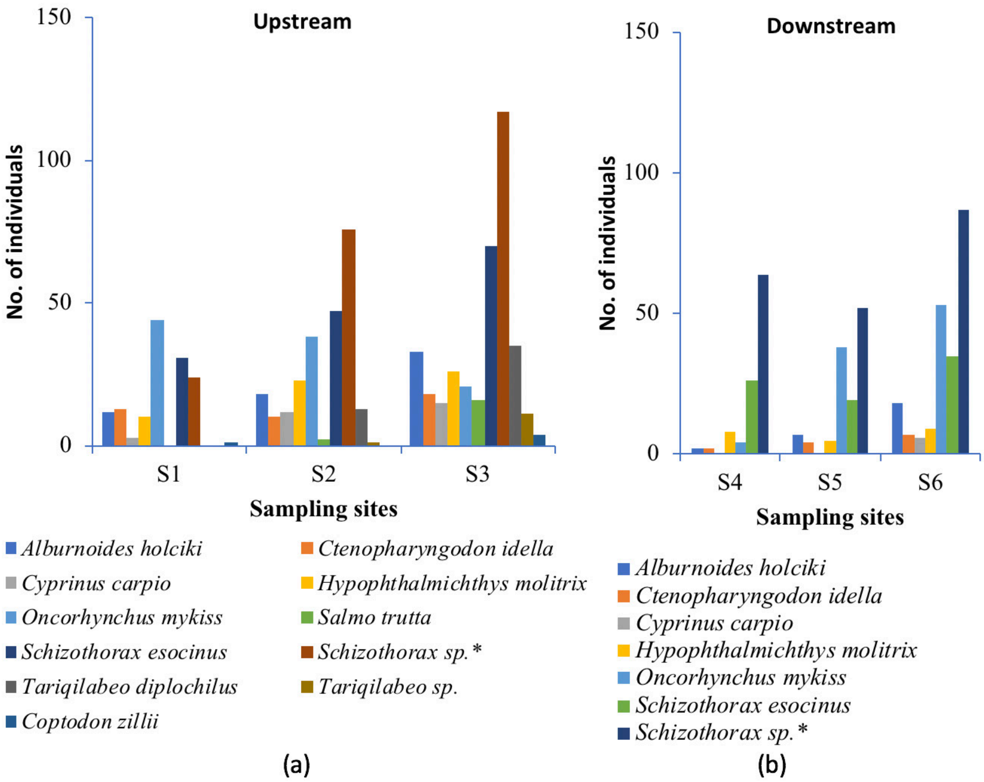

Figure 3. Species abundance in different sampling sites of (a) upstream and (b) downstream (Note: * indicates highest no. of individuals).

mykiss (n= 44) was the most abundant species, followed by *S. esocinus* (n= 31) (Figure 3a). *Schizothorax* sp. was the most abundant species at all three of the downstream sites (S4 n= 64, S5 n= 52, S6 n= 87; Figure 3b). Species abundance significantly differs among the 6 different sampling sites. *Alburnoides holciki* (n= 33), *Ctenopharyngodon idella* (n= 18), *Cyprinus carpio* (n= 15), *Hypophthalmichthys molitrix* (n= 26), *Salmo trutta* (n= 16), *Schizothorax esocinus* (n= 70), *Schizothorax* sp. (n= 117), *Tariqilabeo diplochilus* (n= 35), *Tariqilabeo* sp. (n= 11), and *Coptodon zillii* (n= 4) were recorded more in S3 than in other sites.

Overall, in upstream sites, *Schizothorax* sp. was abundant (n= 217, 72.33 ± 46.61), followed by *Schizothorax esocinus* (n= 148, 49.33 ± 19.60) and *Oncorhynchus mykiss* (n= 103, 34.33 ± 11.93). *Coptodon zillii* (n= 5, 1.67 ± 2.08) was least abundant fish species in the upstream zone (Table 3). Likewise, in the downstream, *Schizothorax* sp. (n= 203, 67.67 ± 17.79) was most abundant and *Cyprinus carpio* (n= 6, 2 ± 3.46) was least abundant.

Pandey et al. (2018) also found abundance and dominance of *Schizothorax* spp. in rivers in Uttarakhand, India. Similar reports on the abundance of schizothoracines were also made in the Tibetan Plateau (Zhang et al. 2017; Ma et al. 2020). Moreover, Kabul is a cold place located at 1,791 m and Aljazeera (2012) reported -17°C at night in February. Schizothoracines are cold-water species, also living at elevations of up to 3,323 m (Petr et al. 2002). Thus, the abundance of schizothoracines in the Kabul River is in consistence with the other rivers of the Himalaya.

While comparing overall fish abundance between upstream and downstream reaches, upstream (n= 744) was found to be higher than downstream (n= 446). This result is contrary to normal patterns of fish diversity along a river continuum (Edds 1993; Tiemann et al. 2004). In addition, the dendrogram of Bray-Curtis coefficients of similarity in the abundance of fish was produced. As per the cluster analysis, S2 and S6 had a parallel Bray-Curtis similarity in their species abundance of about 83 %. Though these sites are from different locations (upstream and downstream), the high similarity explained between these sites is mainly due to similar level of anthropogenic activities and pollution level. S1, S5, S3, and S2–S6 combined had a common similarity of about 74 %, indicating similarity in species abundance (Figure 4).

Species present at the upstream sites like *Salmo trutta, Tariqilabeo diplochilus, Tariqilabeo* sp., and

Table 3. Mean species abundance with standard deviation at upstream and downstream sites.

Species	Upstream		Downstream	
	No. of individuals	Mean ± Standard Deviation	No. of individuals	Mean ± Standard Deviation
Alburnoides holciki	63	21.00 ± 10.82	27	9.00 ± 8.19
Ctenopharyngodon idella	41	13.67 ± 4.04	13	4.33±2.52
Cyprinus carpio	30	10.00 ± 6.24	6	2.00 ± 3.46
Hypophthalmichthys molitrix	59	19.67 ± 8.50	22	7.33 ± 2.08
Oncorhynchus mykiss	103	34.33 ± 11.93	95	31.67 ± 25.11
Salmo trutta	18	6.00 ± 8.72	-	-
Schizothorax esocinus	148	49.33 ± 19.60	80	26.67 ± 8.02
Schizothorax sp.	217	72.33 ± 46.61	203	67.67 ± 17.79
Tariqilabeo diplochilus	48	16.00 ± 17.69	-	-
Tariqilabeo sp.	12	4.00 ± 6.08	-	-
Coptodon zillii	5	1.67 ± 2.08	-	-

- indicates absence.

Table 4. Native and non-native fish species recorded in different sites.

Species	Occurrence	Sampling sites					
		S1	S2	S3	S4	S5	S6
Alburnoides holciki	Native	√	√	√	√	√	√
Salmo trutta	Native	x	√	√	x	x	x
Schizothorax esocinus	Native	√	√	√	√	√	√
Tariqilabeo diplochilus	Native	x	√	√	x	x	x
Coptodon zillii	Native	√	x	√	x	x	x
Ctenopharyngodon idella	Non-native	√	√	√	√	√	√
Cyprinus carpio	Non-native	√	√	√	x	x	√
Hypophthalmichthys molitrix	Non-native	√	√	√	√	√	√
Oncorhynchus mykiss	Non-native	√	√	√	√	√	√

Coptodon zillii were not recorded from the downstream sites. This is likely because of the high intensity of ongoing habitat degradation caused by the discharge of industrial waste and sewage directly into the river system, construction activities, and the high density of human population and their associated anthropogenic effects on the downstream reaches.

Native and non-native species in sampling sites

From the total of nine species recorded from the area (lumping *Schizothorax* sp. with *Schizothorax esocinus* and *Tariqilabeo* sp. with *Tariqilabeo diplochilus*), five species were found to be native and four non-native species (Table 4).

We recorded the highest number of native species from S3 (*n*= 286), followed by S2 (*n*= 157), and S6 (*n*= 140). Similarly, as shown in Table 5, non-native fish species were recorded more in S3 (*n*= 84) followed by S2 (*n*= 83) and S6 (*n*= 75. The lowest number of non-native fish were found in S4 (*n*= 14). It was found that almost all non-native fish species were used for aquaculture in the area. The decrease in native species richness while moving from upstream to downstream was also reported by Loures & Pompeu (2019). They stated that the main reason behind such occurrence is mainly due to increase in non-native species in downstream areas.

Diversity and richness of fish species

The high species richness in S3 and S2 were indicated by Margalef's diversity index (D_{Mg}) (1.69 and 1.64, respectively), as their values were higher than other sampling sites. To examine the similarity of species

Table 5. Sorenson's similarity coefficient (whose value ranges from 0 to 1) showing degree of similarity among sampling sites.

	S1	S2	S3	S4	S5	S6
S1	1.00	0.78	0.84	0.86	0.86	0.93
S2		1.00	0.95	0.75	0.75	0.82
S3			1.00	0.71	0.71	0.78
S4				1.00	1.00	0.92
S5					1.00	0.92
S6						1.00

Table 6. Mean ± standard deviation of biodiversity indices for upstream and downstream sites in Kabul city.

Diversity Indices/ Sites	Upstream Mean ± SD	Downstream Mean ± SD
Menhinick's index (D_{Mn})	0.63 ± 0.05	0.53 ± 0.05
Margalef's diversity index (D_{Mg})	1.59 ± 0.15	1.07 ± 0.04
Shannon diversity index (H')	1.90 ± 0.15	1.36 ± 0.22
Pielou evenness index (J')	0.84 ± 0.01	0.74 ± 0.10
Simpson's diversity D_1)	0.81 ± 0.02	0.67 ± 0.09

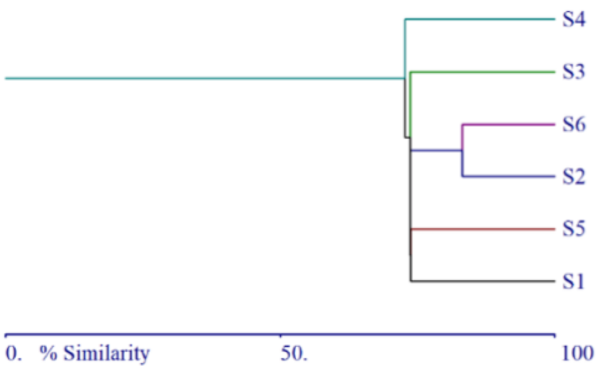

Figure 4. Bray-Curtis similarity dendrogram; cluster analysis (single linkage) based on the Bray-Curtis index of similarity applied to the fish abundance.

richness between the sampling sites, Sorenson's similarity coefficient (CC) was appraised (Table 5). Sampling sites S2 & S3, S1 & S6, S4 & S6, and S5 & S6 indicated having similarity of 95 %, 93 %, 92 %, and 92 % between them, respectively. Sorenson's similarity coefficient value between S3, S4, and S5 (CC= 0.71) was the lowest, which also shows 71 % of similarity between them.

Altogether, upstream sites recorded 11 species while downstream sites recorded seven species. High richness upstream (D_{Mn}= 0.63 ± 0.05, D_{Mg}= 1.59 ± 0.15) was supported by Menhinick's Index (D_{Mn}) and Margalef's diversity index (D_{Mg}). For downstream, Menhinick's index and Margalef's diversity index were 0.53 ± 0.05 and 1.07 ± 0.04 correspondingly, which was considerably less than upstream (Table 6). This was supported by Mann-Whitney test which revealed that fish richness upstream (9.67 ± 1.53) and downstream (6.33 ± .58) was significantly different (U= 0.00, z= -1.99, p= 0.04, r= 0.81) (Table 7).

Fish species diversity was evaluated using various diversity indices. The most diverse site among all was S3 with Shannon diversity index (H') of 2.04 and Simpson's diversity (D_1) of 0.83. S4 was the site with least diversity (H'= 1.12, D_1= 0.57). Similarly, species evenness was highest in S3 with Pielou evenness index (J') of 0.85 and lowest in S4 (J'= 0.62).

Overall, diversity of fishes was higher in reaches of the Kabul River upstream (H'= 1.90 ± 0.15, D_1= 0.81 ± 0.02) of Kabul City when compared to downstream reaches (H'= 1.36 ± 0.22, D_1= 0.67 ± 0.09) which was indicated both by the Shannon diversity index and Simpson's diversity. Likewise, species evenness was higher in reaches upstream of Kabul City (J'= 0.84 ± 0.01) compared to downstream reaches (J'= 0.74 ± 0.10). Previous studies have shown a similar pattern in which reaches of rivers upstream of densely populated areas harbour higher diversity of freshwater fishes compared to downstream (Tawari-Fufeyin & Ekaye 2007).

The higher species richness and diversity in upstream reaches in the study area may be due to the constant flow of the river, less modification of land use, less pollution and fewer developmental activities. Urban activities like urban and industrial construction leads to land use change, adding pollution and nutrients to the river system, varying hydro-morphology and hydrologic flow regimes, and creating unstable flow (as the valley remains dry in most of the winter months) which negatively effects fish diversity and richness (Grimm et al. 2000; Wang et al. 2001; Booth 2005; Walsh et al. 2005; Gebrekiros 2016).

Freshwater ichthyofauna conservation

Afghanistan is an arid and landlocked country (Breckle 2007; Wily 2015), but is abundant in water resources (Qureshi 2002). However, as much as 80 % of Afghanistan's freshwater is contaminated and water pollution is a serious threat to the conservation of aquatic biodiversity and human survival (Weir 2018). In Kabul City, solid waste, waste water (both domestic and industrial), and open sewers directly drain into the Kabul River (UNEP 2003), exacerbated by population growth (Mack et al. 2009), modifying the aquatic habitat. Habitat quality plays a great role in the fish composition,

Table 7. Mann-Whitney U test result of species richness between upstream and downstream.

	Group	N	Mean rank	Mean Sum	*U*	*z*	*p*	*r*
Species richness	Upstream	3	5.00	15.00	.00	-1.99	.04	.81
	Downstream	3	2.00	6.00				

U—Mann-Whitney U test | *z*—z statistics | *p*—significance value | *r*—effect size.

Table 8. Fish species recorded from the Kabul River in Kabul City, Afghanistan with global conservation status.

Species	Conservation status	Regional status
Alburnoides holciki	Not Evaluated	Native
Ctenopharyngodon idella		Non-Native
Cyprinus carpio		Non-Native
Hypophthalmichthys molitrix		Non-Native
Oncorhynchus mykiss		Non-Native
Salmo trutta	Least concern	Native
Schizothorax esocinus	Not Evaluated	Native
Schizothorax sp.		Native
Tariqilabeo diplochilus	Not Evaluated	Native
Tariqilabeo sp.		Native
Coptodon zillii	Least Concern	Native

diversity, and distribution in any stream or river system (McClendon & Rabeni 1987; Agarwal et al. 2018). Use of agriculture pesticides, and overfishing (Saeed 2018) are other threats to the conservation of the freshwater ecosystem in Kabul City. This study has documented 11 fish species from the area. One species of them is listed under the IUCN Red List of Threatened Species (Table 8). To conserve these species and other associated species in the area, adoption of scientific fishing or sustainable fishing methods, timely monitoring of water quality, and proper management of solid waste and waste water are urgently recommended.

CONCLUSIONS

The Kabul River downstream of Kabul City is threatened by numerous anthropogenic activities. The majority of fishes recorded from the area were from the upstream sites where the aquatic habitat was least disturbed compared to downstream sites. Intensive agriculture, infrastructural development, and ineffective management of waste in the downstream area increases sedimentation, contamination, and changes the overall aquatic habitats and their function. Our study shows that species diversity, richness, and abundance tend to decrease as we move from sites upstream of Kabul City to sites downstream of Kabul City. Thus, implementation of sustainable development practice is deemed essential, so as to manage the water resources and conserve its biodiversity. Moreover, studies on physiochemical parameters of the river, aquatic macroinvertebrates and fishes, and their association needs to be carried out to generate additional baseline information on the aquatic biodiversity of the area and to monitor water quality.

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